Environmental Research Laboratories

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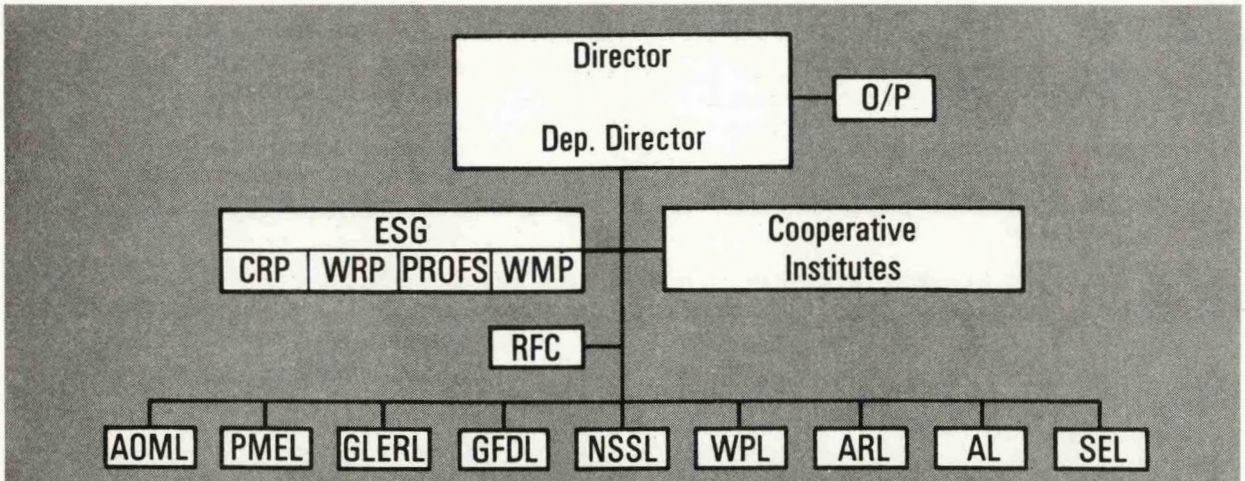
ENVIRONMENTAL RESEARCH LABORATORIES



The mission of the Environmental Research Laboratories (ERL) is to conduct an integrated program of fundamental research, related technology development, and services to improve understanding and prediction of the geophysical environment comprising the oceans and inland waters, the lower and upper atmosphere, the space environment, and the Earth.

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These are highlights of Laboratory accomplishments and abbreviated summaries of immediate objectives. More comprehensive and detailed descriptions of activities and plans may be found in the Laboratories' annual reports (and other documents), which may be obtained directly from the Laboratories.

Environmental Research Laboratories

The National Oceanic and Atmospheric Administration (NOAA) was formed in 1970 by bringing together environmentally oriented agencies from the Departments of Commerce, Interior, and Transportation, the Navy, the Army, and the National Science Foundation. NOAA's goal is to improve understanding and use of the physical environment. The Environmental Research Laboratories (ERL), under NOAA's Research and Development arm, are headquartered in Boulder, Colo. Other facilities are located at various sites throughout the country. The major Laboratories in ERL are Aeronomy (AL), Atlantic Oceanographic and Meteorological (AOML), Air Resources (ARL), Geophysical Fluid Dynamics (GFDL), Great Lakes Environmental Research (GLERL), National Severe Storms (NSSL), Pacific Marine Environmental (PMEL), Space Environment (SEL), and Wave Propagation (WPL). The Environmental Sciences Group (ESG) is a new structure composed of the Climate Research Project (CRP), the Weather Research Program (WRP), the Program for Regional Observing and Forecasting Services (PROFS), and the Weather Modification Program (WMP). In addition to these laboratories and ESG, joint institutes in various universities undertake research for ERL, and the Research Facilities Center (RFC) provides aircraft support to a variety of research programs. (RFC will be a part of the Office of Aircraft Operations in the National Environmental Satellite Data and Information Service effective FY 1984.) ERL conducts an integrated program of research, fundamental technology development, and services. The program includes the oceans and Great Lakes, the lower and upper atmosphere, and the solar-terrestrial environment.

The output of the Laboratories includes public services such as solar forecasts and warnings, development of technology such as Doppler radar to improve tornado detection and warnings, mathematical models such as regional and global models to predict climatic variations, and applied research such as improved ocean current forecasts for minimizing ship operation costs and ocean upwelling observations for maximizing fish catches. The users of ERL output include the atmospheric and marine research communities; NOAA service components; Federal, State, and local governments; and the private sector.

The Laboratories supplement their in-house research through contracts and grants sponsored by the individual Laboratories or by the Office of the Director. The contracts and grants involve nearly all aspects of the Laboratories' research programs, and are used by universities, State and Federal agencies, and private companies to conduct research related to the NOAA mission.

ERL activities are concentrated in eight major programs:

- Weather observation and prediction
- Cloud physics/weather modification research and development
- Air quality research and development
- Climate research
- Solar-terrestrial research and services
- Marine observation and prediction
- Marine assessment research and services
- Marine resources research and services

WEATHER OBSERVATION AND PREDICTION

Weather Observation and Prediction includes programs of AL, AOML, GFDL, NSSL, WRP, PROFS, RFC, WPL, and the joint institutes. This set of programs interacts directly with Weather Modification R&D, with Ocean and Lake Services R&D and Solar-Terrestrial Research and Services on the lower and upper physical boundaries, with Air Quality in the short-term time period, and with Climate in the long-term time frame. This program area can be further divided into eight program elements: research on observational systems, modeling and prediction, severe storms, hurricanes, sea-air interaction, cloud and precipitation processes, mesoscale research, and technology transfer.

The most versatile and successful observational tools are radar and lidar. Techniques being developed using radar remote sensing include optical and infrared scintillation for measurement of path-averaged values of wind, refractivity fluctuations, heat and moisture flux, rainfall rate, and dropsize distribution. Doppler radar research on flow and precipitation fields within severe thunderstorms has led to the interagency NEXRAD Program, whose goal is to design a new national Doppler radar network during the 1980's. In development are optical and infrared lidar techniques for the remote measurement of winds, temperature, humidity, and aerosols; passive microwave techniques for the measurement of temperature and humidity profiles and cloud liquid; active radar techniques for the measurement of winds, clouds, precipitation, turbulence, and refractivity fluctuations; and passive and active acoustic techniques for the study of the boundary layer. As techniques are developed, they are transferred to operational programs. A high-power, large antenna VHF Doppler radar technique for measuring winds, turbulence, and gravity waves is being used at Poker Flat, Alaska, to measure these parameters continuously throughout the lowest 100 km of the atmosphere. A second radar system at Platteville, Colo., is being phased into PROFS for real-time windspeed and wind direction data. The sounder system, a microwave device for vertical sensing of water vapor and liquid water, has been integrated into the National Weather Service (NWS) regional facility in Denver. Remote techniques are also being developed to map electrical discharges in three-dimensional space, for correlation with storm dynamics and precipitation, and with changes in electric fields.

Programs of the modeling and prediction element have several goals. In the large scale, goals include the following: to develop or improve atmospheric prediction models suitable for the 5- to 30-day time frame (for application in NWS), to identify external forcing mechanisms that are required by models to simulate the evolution of macroscale atmospheric disturbances over the range of several weeks to 4 months, and to search for a physically based, probabilistic approach for long-range simulation of atmospheric variations. In the mesoscale, goals include understanding of hurricane dynamics, including the genesis, development, and decay of tropical depressions and the study of small-scale features within hurricane systems; production of accurate numerical simulations of mesoscale processes, to understand what role synoptic-scale parameters play in their generation and evolution; understanding of internal gravity waves including their generation, interaction, and breakdown; and development of three-dimensional numerical models.

The severe-storms research element includes the use of specially developed instruments to acquire severe-storm data and to analyze these and conventionally acquired data to obtain a more comprehensive understanding and improved prediction of severe storms, to develop models of convective storms, and to compare models with observations.

The specially developed instrumentation includes a 50-station surface network, an instrumented television tower, two large 10-cm Doppler radars, an atmospheric electricity measurement system, two 3-cm transportable Doppler radars to measure three-dimensional velocity fields in convective storms, and pressure sensor arrays to detect and monitor gust fronts in the vicinity of airports.

The hurricane research element involves three projects. (1) The Hurricane Strike Project for improving short-term forecasts of hurricane landfall includes experimental, theoretical, and statistical studies and makes use of radar, aircraft, and satellite observations. Flights are made for approximately 200 hours per year on the Hurricane Strike and Stormfury projects, using the uniquely well-equipped NOAA RFC aircraft. Investigations include boundary layer processes, evolution of convection and associated wind fields, cloud microphysics, and flow characteristics in and near the eyewall and spiral rainbands. (2) The hurricane modeling project simulates convective and mesoscale processes in hurricanes. (3) The hurricane research project involves a combination of efforts on pre-hurricane disturbances, hurricane genesis, hurricane climatology, general tropical meteorology, radar precipitation measurement, analysis of Seasat satellite data, and hurricane sea-air exchange processes.

The sea-air interaction element involves the experimental study and numerical modeling of sea-air interactions, especially under extreme weather conditions such as hurricanes. The experimental studies are conducted using a series of aircraft observations of sea- (or lake-) air interactions, such as surface wind and wave fields under a wide range of meteorological and coastal conditions. Specific projects include the Pacific Near Shore and Inshore Wind Study, and the Lake Erie Surface Wave Study. Models are used to predict storm surges within bays, estuaries, and lakes. Experimental observations are then compared with the wave and storm surge models in order to validate or improve the models.

The cloud and precipitation processes element involves the numerical modeling of clouds over complex terrain to predict precipitation, and experimental projects to verify the models. In support of the experimental programs, optical, infrared, and microwave radar and lidar systems systems are utilized, permitting the measurement of cloud-echo intensities at three optical and three radio frequencies as a function of three-dimensional space and time. These echo-intensity fields can be measured as a function of both wavelength and polarization. The Doppler effect is used at radio frequencies to determine velocity fields and fields of turbulent kinetic energy dissipation rates. The multifrequency approach provides information on droplet size, and the dual polarization capabilities permit identification of the cloud or precipitation particles as spherical water droplets or nonspherical ice crystals. Microwave radiometric techniques are used to measure line integrals of cloud liquid water and water vapor.

The mesoscale research includes basic and applied research on mesoscale processes of the atmosphere, with particular emphasis on large meso-alpha scale convective complexes. The research includes development of mesoscale numerical models, conduct of theoretical and diagnostic studies, analyses of mesoscale weather systems, participation in meteorological field experiments, and studies of the microstructure and turbulence of the atmospheric boundary layer using mainly airborne techniques.

One of the research facilities used in this program element is the Boulder Atmospheric Observatory, which includes a 300-m-high meteorological tower and associated remote sensors. The atmospheric research conducted at this facility includes micrometeorological and boundary layer studies, and meso-beta scale (i.e., scales up to 200 km) research. The latter research includes downslope wind situations and studies of clouds and precipitation under upslope conditions.

The technology transfer element includes development and testing of operational sensing systems that are transferred to service components of NOAA such as NWS, and other Federal agencies such as the Federal Aviation Administration (FAA). Doppler radar for identifying and warning of severe thunderstorms and tornadoes has been tested for the Air Force and the FAA. These tests indicate that Doppler radar reliably detects the greatest majority of destructive tornadoes tens of minutes before they produce damage. Work done through the WRP group improves the understanding of excessive convective rainfall and develops techniques for forecasting flash-flood-producing storms. It is conducted in close cooperation with NWS.

PROFS Phase I is a joint NWS-NESS-ERL program to design local weather service systems for NWS. The system design will incorporate many of the advances made in the past decade in satellite- and ground-based remote sensing, in automated and surface weather stations, in data processing and display, in mesoscale analysis and forecasting, and in dissemination.

A major real-time field exercise is planned during 1983 to examine the forecasts and warnings of severe thunderstorms in the Denver/Boulder, Colo., region.

CLOUD PHYSICS/WEATHER MODIFICATION RESEARCH AND DEVELOPMENT

Weather modification research and development included research at AOML, OWRM, RFC, WMPO, WPL, and joint institutes through FY 1982. All of NOAA's weather modification programs with the exception of the Federal-State Cooperative Program were eliminated by Congress in its FY-1983 Continuing Resolution. This program area interacted directly with the weather observation and prediction activities and air quality studies related to inadvertent modification. The goals of the weather modification R&D program were to develop technologies to assist with water management and disaster mitigation through, respectively, enhancement of precipitation (rain and snow) and amelioration of severe storms. The development of both types of technologies involves alteration of cloud systems (primarily convective clouds). The principal research problems involve basic understanding of microphysical, convective-scale, mesoscale, synoptic-scale, and boundary layer processes, as well as their mutual interaction and prediction. The weather modification research projects were mainly in a convective (summertime) precipitation enhancement program known as FACE (Florida Area Cumulus Experiment) and a project to beneficially modify hurricanes (Project Stormfury). FACE was a randomized statistical program aimed at determining our ability to increase areal rainfall over South Florida from tropical cumulus clouds through dynamic seeding. A FACE confirmatory program was carried out during the summers of 1978-1980, and a number of papers summarizing scientific results were submitted for publication during 1982. Although the central approach of FACE was statistical, peripheral studies were aimed at understanding some of the basic physical linkages in the dynamic seeding hypothesis (that seeding of convective clouds with freezing nuclei [silver iodide] can increase rainfall on an area-wide basis). The microphysical structure of the clouds and their convective and mesoscale organization also were under investigation. These studies used surface mesoscale networks, instrumented aircraft, a variety of radars, and rain gage networks. Numerical modeling studies have partially explained the relationship between the synoptic flow and the organization of the sea breeze convergence zones.

The only remaining cloud physics research is focused on hurricanes and related convective cloud systems, and the acidity of precipitation. Although the last actual seeding of a hurricane was in 1969, annual investigative field programs are conducted in which the research aircraft penetrate hurricane circulations to gather data on the structural characteristics of hurricanes, including cloud microphysical data and digital radar data. The observational efforts are complemented by a strong effort to model hurricanes numerically.

Other projects carried on in this program area are a small research effort concerned with basic studies on upslope and cumulus clouds, theoretical studies of the interaction of electromagnetic waves with cloud precipitation, and a Federal-State Cooperative Program. The upslope and cumulus study seeks to define the precipitation efficiency of upslope snowstorms and the relationships of droplet size distribution to cloud updrafts and ice content. The electromagnetic wave interaction studies support the development and utilization of multiwavelength (10-cm, 3-cm, and 8-cm), dual

polarization, multistation Doppler radars for the study of cloud and precipitation processes. The Federal-State Cooperative Program is developing criteria for the effective evaluation of operational cloud seeding. The research and development needed to establish these criteria are carried out through contracts under a Congressional mandate. Current activities are concerned with summertime rain enhancement and wintertime snowpack augmentation for North Dakota, Utah, and Nevada through ongoing, State-sponsored operational projects.

AIR QUALITY RESEARCH AND DEVELOPMENT

The air quality research and development program is accomplished in four Laboratories (ARL, AL, GFDL, and WPL). It interacts with the programs on weather and marine observation and prediction and on solar-terrestrial research and services. The air quality program provides the basic knowledge to protect health and environment, particularly in understanding and predicting human influence on the atmosphere. It monitors the global concentrations of atmospheric gases such as carbon dioxide and ozone, and of anthropogenic pollutants; predicts trajectories of contaminated air masses, including radioactive debris from nuclear detonations; studies possible climatic effects of atmospheric pollution, including atmospheric chemical cycles, atmospheric effects of volcanic eruptions, and atmospheric processes involved in producing acid rain; and studies solar irradiance received in various regions of the United States for alternative energy production applications. The program is subdivided into four elements: geophysical monitoring for climatic change, atmospheric transport model development, meteorology of air pollution, and theoretical analyses of atmospheric constituents.

In the geophysical monitoring element, the programmatic focus is on sampling to obtain baseline atmospheric data. These baseline data are used in analysis and modeling of sources, transport, and fate of natural and human-induced atmospheric constituents and pollutants. Four baseline observatories located in remote, relatively clean-air sites (Barrow, Alaska; Mauna Loa, Hawaii; American Samoa; and South Pole, Antarctica) are operated to measure background levels of carbon dioxide, aerosol concentrations, total atmospheric ozone, chlorofluorocarbons, and other atmospheric constituents, as well as solar radiation. These data are collected using flask samples or real-time data acquisition and analysis. The goal of these monitoring programs is the long-term surveillance of the atmosphere, and the determination of the extent to which gases and particulates put into the atmosphere by human activities and natural causes affect climate.

In addition to the four remote sites, other observational sites located in various parts of the world measure trace constituents of the stratosphere and troposphere. The work is carried out by a variety of methods including measurements from balloon-borne instruments and direct grab sampling, followed by chemical analysis in the laboratory. More recently, an increasing emphasis has been placed on the use of sophisticated optical techniques for in-situ measurements. For example, laser Raman spectroscopy is being used to determine aerosol components. Instrument development will continue in an attempt to utilize new technology to increase the sensitivity and accuracy of in-situ sampling. Improvements in measurement technology, e.g., better standards for trace measurements, are continually implemented. Examples of trace constituents include chlorofluorocarbons, nitrous oxide, and methane.

Analyses of the data include determination of the sources and potential sinks and the effect of meteorological and oceanographic parameters on atmospheric levels, determination or correlation of regional short-term variations, and documentation of long-term changes in the atmospheric levels. These data are supplied to a variety of NOAA and other users for further analysis and for modeling purposes.

The atmospheric transport modeling element includes the development and verification of computer models to simulate and/or predict local, regional, and global transport and diffusion of pollutants injected into the atmosphere. The models are used to evaluate the environmental effects of various kinds of energy production (e.g., nuclear fuels or fossil fuels) and of volcanic eruptions, and predicting the path of radioactive debris from various foreign atmospheric nuclear tests.

The goal of this element is to model the transport and chemistry of atmospheric materials to provide guidance for minimizing or ameliorating their adverse impacts. Models being developed include simulation of local, regional, and global transport and diffusion of pollutants injected into the atmosphere. Specific models provide forecasts of long-range trajectories of debris clouds from foreign nuclear tests, of releases of radioactive effluent from nuclear reactors, and of flow over rugged terrain or over a forest canopy. Models are tested and verified by sampling and other experimental programs both within ERL and by other Federal agencies. Other more structured model evaluations, such as special workshops to provide statistical verification of accuracy, are also utilized. Models are used in operational programs in the Department of Energy, the Environmental Protection Agency, and other Federal and State agencies. One area of major emphasis in the short term is the development and evaluation of numerical modeling studies of flow over rugged terrain. This type of information will increasingly impact assessment of the causes and solutions to the acid rain problem, and development of energy resources and power plant siting in the western United States.

The meteorology of air pollution element includes theoretical and experimental studies of the physical processes affecting the transport, diffusion, transformation, and deposition of air pollutants; development, evaluation, modification, and application of air quality simulation models for inert and reactive pollutants; and the effects of air pollutants on weather and climate, with much current emphasis on precipitation acidity. New techniques such as the perfluorocarbon and sulfur hexafluoride tracer systems are developed, evaluated, and used in operational programs at specific sites. Other techniques such as constant-level balloons tracked by mobile radars are utilized to determine regional circulation patterns, and plume observations are used to detect downstream flows and valley drainage systems.

These observational techniques are applied to studies of such phenomena as the transport of airborne material in and above a forest canopy or the flow over rugged terrain, and to the evaluation of atmospheric diffusion parameters. The results of these studies are used to verify mathematical models, evaluate environmental impact, and acquire understanding of the effects of local terrain on meteorological parameters.

The research element for theoretical analysis of atmospheric constituents studies the trends in air quality and significant atmospheric constituents; conducts monitoring and research leading to better understanding of the effects of changes in the atmosphere due to human-induced emission of ozone-destroying chemicals, and of carbon dioxide and sulfates from energy generation; and conducts monitoring and research on the sources, dispersion, and environmental effects of acidic chemicals that cause acid rain, which is deleterious to human structures and to the rivers and lakes of eastern North America and Europe. This element includes experimental studies, chemistry research, and development of new instrumentation such as automatic and continuous precipitation collectors, chemical analyzers, and dry deposition sensor systems to evaluate the amount and effects of acid precipitation and deposition due to increased use of sulfur coal for energy production. Improved measurement techniques, such as use of the CFC-13 to CFC-12 ratio to separate natural and human sources of carbon dioxide, are implemented.

Experimental studies are in progress to improve understanding of the mechanisms that produce pollution aerosols through adsorption of stack gases and gas-to-particle

conversions, and to determine the spatial distribution of natural and anthropogenic atmospheric nuclei. Other studies to measure the effect of smoke plumes from large power plants on local and regional visibility and insolation and to measure the evolution of acidity in cloud water downwind of pollution sources are used for input to various models to determine environmental effects of present and proposed power plants. Natural events such as the volcanic activity of Mount St. Helens are used to evaluate large-scale transport models and to estimate the effect of natural versus human-induced changes on air quality and climate.

Chemistry research includes the measurement of cross sections and branching ratios of specific chemical reactions relevant to ozone depletion and atmospheric pollutant interactions, and the measurement of line centers and line widths in order to determine the correct diode lasers to use for atmospheric measurement of trace constituents to validate specific pollutant reactions.

CLIMATE RESEARCH

Climate research includes programs of eight Laboratories, a program office, RFC, and four joint institutes. The climate programs interact directly with the air quality, solar-terrestrial, and ocean and lake services, and with weather observation and prediction R&D on the short-term time scale. The climate programs can be divided into three elements: ocean-atmosphere studies; observation and analysis of solar, atmospheric, and stratospheric variability; and climate modeling.

The EPOCS (Equatorial Pacific Ocean Climate Studies) program is investigating the physics and dynamics of the coupled ocean-atmosphere system in the equatorial Pacific. Understanding this system is vital to comprehending global fluctuations of climate on interannual time scales. A broad spectrum of oceanographic and atmospheric parameters is being monitored by a variety of sensors to create an integrated data base. Satellites are continuously monitoring winds and sea surface temperatures. Research vessels are using XBT's and current profilers to determine vertical thermal and dynamic cross sections. Moored arrays at the Equator are used to determine the major time scales of variability of ocean parameters such as current, temperature, and salinity. Drifting buoys are used in the Pacific Equatorial Current system to determine the larger scale current patterns as well as other spatially distributed parameters. Other projects are using aircraft to measure vertical fluxes of heat, moisture, and momentum over the tropical Pacific. The STACS (Subtropical Atlantic Ocean Climate Studies) program seeks to identify the processes that contribute most to the poleward transport of heat in the North Atlantic Ocean and to develop the technology to monitor these processes operationally. Initial emphasis of STACS is on the development of techniques to monitor the mass transport and heat content of the Florida Current. Several techniques are being tested to determine the most efficient approach for long-term monitoring of the Florida Current. Among these are electromagnetic induction measurements from communications cables, use of coastal tidal stations, Doppler radar observations of surface flow, and acoustic measurements. In addition to EPOCS and STACS, a broad range of research is conducted on the temporal and spatial variability of water mass structure, sea level, currents, and general circulation of deep ocean and coastal waters. Vertical mixing processes in the upper ocean, wind-generated response of middle-latitude upper ocean currents and temperature fields, and methods of inferring surface wind stress fields from satellite data are all projects within the climate program. In the area of technology development, the potential of using low-frequency sound sources and detectors (acoustic tomography) to measure the structure of the ocean is being investigated.

Projects in studies of climate variability include airborne measurement of solar radiation over the equatorial Pacific; determination of the intensity and time scales of variations in the solar UV radiation as a function of wavelength in the 110- to

400-nm range; and determination of its significance in molecular dissociation atmospheric chemistry, upper atmosphere heating, and measurements of atmospheric constituents. Global levels of atmospheric trace constituents that have significant effect on the Earth's radiation budget, including carbon dioxide, ozone, aerosols, and water vapor, are monitored and analyzed. Four monitoring stations (Alaska, Hawaii, Samoa, and South Pole)--one tropical and one high-latitude in each hemisphere--provide baseline observations for monitoring global air quality. These stations are supplemented by several specialized monitoring networks operated by groups from the United States and other nations. These monitoring stations, which perform measurements for research related to climate change, are supported by instrument calibration and development in ERL. Analysis and interpretation of the data from the stations emphasize air quality changes, with special emphasis on carbon dioxide, that might affect climate. ERL undertakes additional reimbursable work involving the measurements of solar radiation, temperature, and other parameters above a forest canopy in order to enlarge the understanding of the biosphere as a component of the climate system. (Atmospheric chemistry and stratospheric sampling programs also have impact on climate research; these programs are described in the Air Quality section.)

The modeling element is focused on constructing mathematical models of the atmosphere, the oceans, and the coupled fluid system that simulate the large-scale features of climate variability. Emphasis in atmospheric studies is on dynamical interaction between large-scale wave disturbances and the general circulation of the atmosphere, identification of the physical and dynamical mechanisms that maintain climate and cause its variation, and evaluation of the impacts of human activities on climate. The ocean circulation studies are also central to climate research. They focus on the large-scale response of the ocean to atmospheric forcing over a range of time scales from weeks to decades, ocean observational studies of the density structure and fields of various tracers, development of models of the world's oceans, interpretation of results in terms of a coherent hydrodynamical framework, and development of a capability to predict the large-scale behavior of the world's oceans in response to changing atmospheric conditions. The aim of observational studies is to identify and evaluate the physical processes by which atmospheric and oceanic circulations are maintained and to compare observational results with diagnostic studies of atmospheric and oceanic models.

SOLAR-TERRESTRIAL RESEARCH AND SERVICES

The solar-terrestrial program is accomplished in SEL. The program is unique in ERL because it contains both research and service components, and the majority user of the research program is the service program. The solar-terrestrial program interacts strongly with other government agencies such as DOD and NASA. The goal of the program is to promote efficient, safe, and economic utilization of extraterrestrial space for civilian and military activities, vehicular operations, and communications; to promote effective operation of essential public services without disruption by magnetic storms or solar events; to promote the discovery and development of natural resources and new energy sources while minimizing any adverse environmental impact; and to promote a better understanding of the physical processes in the near-Earth space environment and their relation to human activities.

The program is designed to maintain near-continuous operation of the Space Environment Services Center (SESC) for monitoring and predicting solar activity and events in the upper atmosphere and their effects on communications, electric power systems, and safety of air and marine navigation; and to maintain continuous acquisition and processing of data from the Geostationary Operational Environmental Satellites (GOES), and the polar-orbiting TIROS-N and NOAA satellites. SESC at Boulder, Colo., jointly operated with the United States Air Force Air Weather Service, is both the national and international focal point for operational space and upper atmosphere information.

SESC maintains a real-time data base from which government agencies, industries, universities, foreign governments, and other foreign and domestic users may obtain current information on the state of the Sun, the interplanetary medium, and the near-Earth space environment. SESC also provides forecasts and warnings of solar disturbances and their effects. These forecasts and warnings help to prevent failure of some aircraft and marine navigation and communications systems at high latitudes, and to improve the efficiency of all telecommunications systems, the effectiveness of military operations and solar-disturbance-sensitive research programs, and the reliability of electric power networks. Real-time observations of the Sun and the space environment are the basis for forecasts and warnings.

Research is undertaken to understand and model the fundamental physical processes responsible for the observed energy release, in the form of electromagnetic radiation and charged particles, from the solar surface during solar disturbances; the propagation and modification of this energy through interplanetary space to the near-Earth environment; the transfer of this energy into the Earth's magnetic field; and the behavior and subsequent effects of this energy within the magnetosphere, the ionosphere, and the upper atmosphere. The ultimate goal of this research is to develop a numerical model that can be used by the SESC to predict more accurately the timing and geographic distribution of the effects of solar disturbances on the Earth's environment, and on human activities. These studies use data from satellites, rocket-launched instruments, and ground stations.

MARINE OBSERVATION AND PREDICTION

The ocean and lake observation and prediction program is accomplished at AOML, GFDL, GLERL, PMEL, RFC, WPL, and joint institutes. The program interacts strongly with the climate, air quality, and other marine program areas. This research improves the capability for providing services to the marine community through increased understanding and improved observations of the behavior of the atmospheric boundary layer over the ocean, the wave and current motions in surface layers, and the physical properties of the surface and subsurface waters of the ocean. The program is composed of six elements: winds, waves, storm surges, ocean properties, tsunamis, and ice.

The marine winds element conducts research to improve the observation and forecasting of hazardous coastal winds that affect coastal populations including homeowners, fishermen, recreational boaters, the oil and gas industry, and commercial transportation. The most common methods of estimating winds over water use statistical relations between winds observed by ships of opportunity or the output of numerical weather prediction models. The former method is useful in hindcasting or climatological studies, but requires a long time series for statistical reliability. The numerical prediction method uses operational models to forecast wind over water. The major weakness of numerical weather prediction models is the large grid (from 90 to 180 km), which cannot resolve the data for the coastal zones and Great Lakes on a small-enough scale. Greater resolution in these models and in observational networks is required because at land-water boundaries, strong contrasts in heating, friction by coastal boundaries, and channeling of winds by mountains can induce local and regional wind patterns, such as the reported nearshore winds in excess of 100 miles per hour along the Alaskan coast.

Surface winds provide the driving force for the generation of other phenomena such as waves, currents, upwelling, and storm surges. Until the wind stress, which provides the major driving force, can be measured directly, it must be computed from the wind field in the boundary layer immediately above the water surface. The atmospheric boundary layer over water is significantly modified by the air and water temperature and the roughness of the water surface, resulting in large variations in the boundary layer stability. Air-sea temperature variations of 15°C are common along the

east coast and are even larger along sections of the Alaska coast. These variations can change the geostrophic-surface wind ratio by 30% and the angle between the surface and geostrophic wind by as much as 25°.

The marine waves element conducts research to improve forecasts and warnings of hazardous coastal wave conditions. Waves are generated by the action of the wind stress on the surface of the water. These waves grow and then propagate away from the area in which they are generated. The highest priority research is in the prediction of wave fields for coastal and continental shelf regions. This prediction capability requires knowledge of the characteristics of the wave field moving from the deep oceans, and of modification of the deepwater wave field as it moves into shallow waters and onto beaches. Improved prediction of deep-water waves requires an increased understanding of the processes affecting the generation and growth of these waves. Present prediction capability is being significantly improved by the development and application of both discrete spectral and parametric models. In addition to improving the models used for wave predictions and improving the understanding of wave dynamics, this program element develops and applies new techniques such as ground-based radar, airborne imaging radar, airborne laser wave profilometry, and satellite observations to observe the sea state or parameters for predicting sea state.

The storm surge element develops models that predict water impacts on coastal regions due to storms, and can be used for the protection of coastal populations. This type of information is needed for both coastal planning and for real-time forecast and warning. The planning activities include both the establishment of criteria to guide coastal development and the preparation of plans for evacuating coastal communities. Hurricanes and other violent wind storms cause surges of water that are often 15-20 ft above the normal water level and are especially dangerous when combined with a high tide or high-wave conditions. Present techniques for forecasting the timing, extent of coastline affected, and magnitude of the inundation are inadequate to ensure the safety of coastal populations. Research to address these deficiencies will include complex topographic areas like bays and inlets and complicating factors such as inhomogeneities in the wind field, variations in offshore bathymetry, and the effects of waves and currents.

The ocean observation program element contains research on currents, upwelling, and thermal properties. Improved understanding of ocean currents and their forecasts are an important focus of research. Ocean currents play key roles in shipping, fishing, pollutant transport, search and rescue operations, and climatic variability. For example, forecasts of the short-term location and movement of the Gulf Stream would provide for increased operational efficiency of ships and oil tankers. Increased efficiency in fishing operations and management of fisheries stocks is dependent on improved knowledge and forecasting of shelf currents and upwelling conditions. Knowledge of currents is essential in forecasting the movement of pollutants such as oil and chemicals released into marine waters. Knowledge of upwelling conditions is necessary to forecast coastal fog. Research on improving the accuracy of measuring and forecasting sea surface parameters is also undertaken in this program element. More accurate and higher resolution measurement of sea surface temperature fields would allow more accurate location of boundaries of different water masses and upwelling regions, and establishment of air-sea temperature differences. Air-sea temperature differences affect the stability of the atmospheric boundary layer over the water and, in turn, the surface wind field that generates waves and currents. Sea surface temperature analyses are prepared from thermal infrared images obtained by satellite sensors. Interpreters of these data have not yet determined how the radiation skin temperature measured by the satellite relates to the bulk temperature of the water measured by various in-situ methods. Improved ability to specify the surface temperature of the ocean would lead to improved results from atmospheric circulation models.

The tsunami program element includes improved prediction and monitoring of earthquake-induced ocean waves. These waves can travel great distances at high speeds

and can cause extensive damage to coastal communities. Improved forecasts and warnings require the capability to determine in real time the expected tsunami height and runup at various coastal locations. Qualitative forecasts based on historical data are now possible but quantitative forecasts are not. Key areas of research include tsunami generation, numerical tsunami modeling, and instrument development to monitor micro-tsunamis for analytical and numerical models and to detect tsunamis before landfall for operational warnings. The successful areas of research will be incorporated into an operational warning system to provide reliable (low false-alarm rate) and accurate warnings.

The ice element includes research to improve monitoring and prediction of growth, movement, and breakup of ice in the Bering Sea, along the Alaskan Arctic Coast, and in the Great Lakes. In the Great Lakes, forecasts of ice thickness and extent in nearshore areas and connecting channels would allow extension of the commercial navigation season and improved design of nuclear reactor coolant intakes and shore property. Ice formation and growth occur by in-place thermal growth or movement of ice from other areas by wind and waves. Thermodynamic models of ice cover indicate that optical properties of ice are extremely critical to accurate forecasts of ice cover. Hence, a knowledge of light transmission, absorption, and reflection characteristics of the various ice types common to the Great Lakes is essential for modeling, remote sensing, and energy budget studies. Regional algorithms for ice forecasts are being developed. These algorithms incorporate ice and wind dynamics and ice thermodynamics as well as local coastal geometries and site-specific user requirements. For example, in the arctic regions, ice forecasts involve a variety of time and space scales, and forecasts must be tailored to arctic logistical operations, to ship convoys, and to local operations. Arctic operations and logistics require an early season forecast, e.g., a 6-mo estimate given in the fall for the following summer. On this time scale the detailed dynamics are nondeterministic, so empirical models drawing heavily on statistical parameters could be utilized. Ship convoys require forecasts 1-2 weeks in advance. A mixed empirical-dynamic approach could be effective. For local operations, ~1-day regional dynamic ice forecasts should be adequate.

MARINE ASSESSMENT RESEARCH AND SERVICES

The marine assessment program includes contributions from AOML, GFDL, GLERL, PMEL, and joint institutes. ERL conducts process-oriented research to improve our understanding of natural oceanic and Great Lakes systems and the ecological impacts of human-induced stresses on these systems, and conducts problem-oriented research to develop improved assessment capabilities, including environmental prediction models, atlases, and advisory services. This research develops scientific information to support decisions pertinent to marine resources, water utilization, marine pollution, and marine activities having ecosystem sensitivities. Much of the work supports programs managed by NOAA's National Ocean Service. The assessment program seeks to improve understanding of the environmental processes, principally in the marine coastal regions, that determine how contaminants enter the marine waters; how these contaminants are transformed, transported, and stored; how they affect the ecosystem; and how their concentrations vary with time. This information is needed by water resource managers and planners and by regulatory agencies, both Federal and State, to assure a healthy marine ecosystem and to protect the public health. Marine assessment consists of four program elements: ocean use impacts, regional studies, hazardous materials response, and special studies under grants.

The program element concerning impact of ocean use conducts field investigations and supportive laboratory research to determine the consequences of ocean dumping of dredged material and municipal and industrial wastes. The ocean use element consists of a series of projects that deal with pollutant effects and the development of techniques to measure pollutants. A comprehensive program of research is conducted to

detect changes in the oceans and the Great Lakes that are caused by human activities and that may have long-term adverse consequences. Effects research focuses on the interaction of trace metals, synthetic organics, and hydrocarbons with marine ecosystems. The role of particulates as pollutants or as a transport mechanism for harmful compounds is emphasized. Studies at AOML seek to determine which natural or pollutant organic materials in seawater complex or bind toxic or essential trace metals, and what effect such complexing or binding has on marine productivity. Other research at this Laboratory seeks to determine the mechanisms by which particulate matter in marine ecosystems functions in the transport and removal of pollutants. The study focuses on a large river-ocean interface (the Mississippi River outflow). It investigates the extent to which mineral and biogenic particles scrub the outflow system of pollutants and bury them in deltaic sediments, and the extent to which this burial can be reversed by resuspension events such as storms. Research conducted by PMEL on the fates of trace elements in estuarine and coastal environments determines the mechanisms involved in the flocculation of trace metals in estuarine and coastal marine waters, determines their remobilization rates from sediments, and develops first-order models for maintenance of dynamic equilibrium for trace metals in estuaries. Studies of long-range particulate transport processes delineate the interplay between fluid and material fluxes in the estuarine and coastal environment and develop predictive models of pollution transport useful for resource management decisions. Research on organics in estuarine systems determines the fate and transport pathways of volatile and suspended organics in coastal and estuarine systems.

The regional studies are multidisciplinary investigations in selected coastal regions including Puget Sound, the Juan de Fuca System, the Gulf of Mexico, the Alaskan continental shelf, the Great Lakes, and the New York Bight. The objective of these studies is to improve understanding of the dynamics of these ecosystems and thereby strengthen the capability to predict the effects of pollutants and other human-induced changes to these ecosystems.

GLERL conducts research in the Great Lakes on water movements and temperature, particle dynamics, cycling of toxic organics, planktonic succession, eutrophication and nutrient cycling, and the development of environmental information services and environmental engineering models and applications. The water movement and temperature research develops improved climatological information (by means of observations, new instrumentation, and improved analysis) on the distribution and variability of coastal and offshore currents and temperature, develops and tests improved numerical hydrodynamic models that can simulate and predict lake currents and temperatures, and extends models to simulate and predict the transport and diffusion of pollutants. Research in the Great Lakes also emphasizes the interaction of particulates and pollutants, particularly the pollutant source/sink characteristics of bottom sediments. GLERL also develops ecosystem models that simulate the passage of toxic pollutants through the Great Lakes food chain.

Research in Alaska has focused on the eastern Bering Sea in recent years. Transport processes are studied to characterize circulation patterns and major hydrographic features on the Bering Sea shelf, and to determine what roles the phenomena of interest might play in the transport of pollutants during outer continental shelf ice development and production. Results from these studies are used in the calibration and verification of coastal circulation and pollutant transport models. Results of research on ice dynamics and distribution are used in models to predict both the effects of ice cover on the distribution of water-borne contaminants and the role of ice itself as a contaminant pathway.

In Puget Sound, studies of estuarine transport processes intend to characterize and understand processes that will be useful in environmental management related to pathways and fates of pollutants in estuaries; such studies quantify flushing processes, determine residence times for major subdivisions of the Puget Sound system, and determine interaction and exchange processes between coastal and estuarine waters.

The studies in the New York Bight attempt to describe, evaluate, and model tides, currents, and other physical oceanographic processes in relation to ocean dumping and other ocean management problems of the greater New York area.

The hazardous-materials response element provides support to the Coast Guard in the event of a spill of oil or other hazardous materials in coastal waters. Project personnel also assess the damage from spills of hazardous materials such as the damage caused by the 1979 IXTOC-I oil spill in the Gulf of Mexico.

MARINE RESOURCES RESEARCH AND SERVICES

The marine resources research program is accomplished through projects at AOML, GLERL, PMEL, and joint institutes. The program is designed to accelerate rational marine industrial development through research into the optimum use, development, and protection of living and mineral marine resources; to improve, through applied research, the technologies needed for efficient use of marine resources; and to provide significant information on the social, economic, and legal impacts of present and projected marine development. The program is subdivided into three elements: marine resource development, marine environmental research, and marine advisory services.

The resource development element is directed primarily toward discovering and developing marine mineral resources. Mineral resource development consists of studies relating to discovery, availability, recovery, and processing techniques, and legal implications of offshore mining of sand, gravel, polymetallic sulfides, and other marine minerals. ERL conducts a major metallogenesis program in support of NOAA's mission in the areas of ocean pollution and marine mining. NOAA scientists conducting studies for the program have been joined by other Federal and academic scientists and a variety of international sponsors and participants. In support of NOAA research focused on marine mining, the metallogenesis program objectives are to determine processes of concentration of metallic mineral deposits, with emphasis on polymetallic sulfides; identify types of metallic deposits and delineate their distribution; establish guidelines for seabed mineral exploration; and characterize the environment before, during, and after marine mining. In support of ocean pollution research the metallogenesis program is directed to determine the role of hydrothermal processes in controlling the chemistry of seawater and seabed; define the natural flux of metals from active sources in ocean basins; trace the interaction of the metals with the biosphere; and develop capabilities to evaluate the feasibility of radioactive-waste disposal and geothermal-energy utilization at sites in ocean basins.

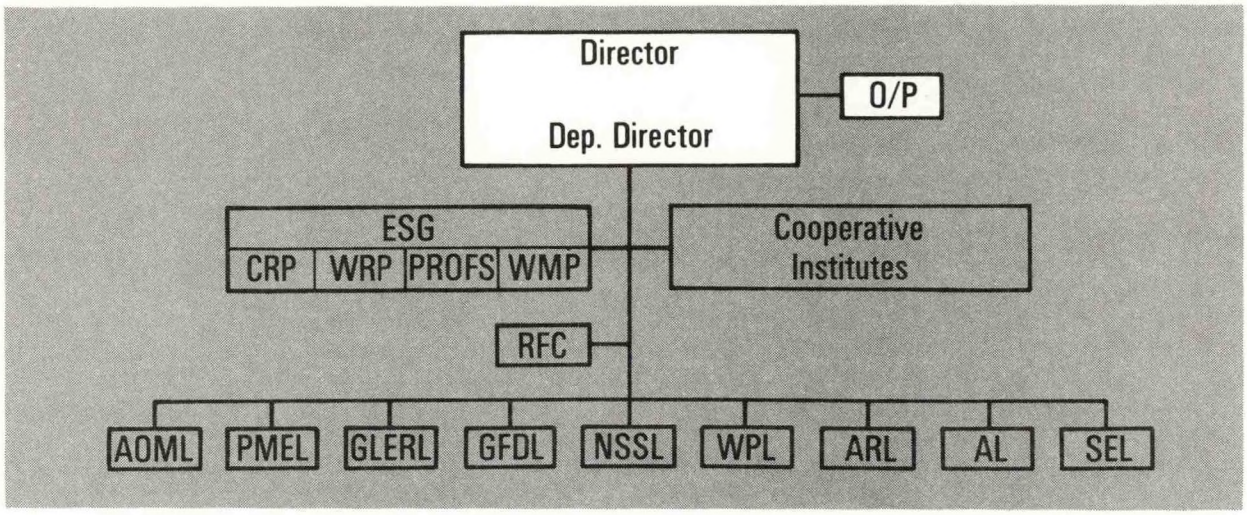
Marine environmental research attempts to manage and protect coastal resources in the face of increasing multiple-use conflicts. Projects and studies focus on understanding the various uses (e.g., waste disposal, industrial and commercial activities, food production, and residential and recreation uses) and their effects on marine and estuarine ecosystems. This understanding is essential to the wise use and protection of these resources.

The marine advisory services include informal education of the general public, technical advice and instruction in marine areas, identification and communication of local marine community needs, and the dissemination of research findings aimed at user problems through seminars, workshops, publication, and personal contacts. The marine advisors work with communicators to reach the general public through press, radio, television, and other media.

OFFICE OF THE DIRECTOR

Boulder, Colorado

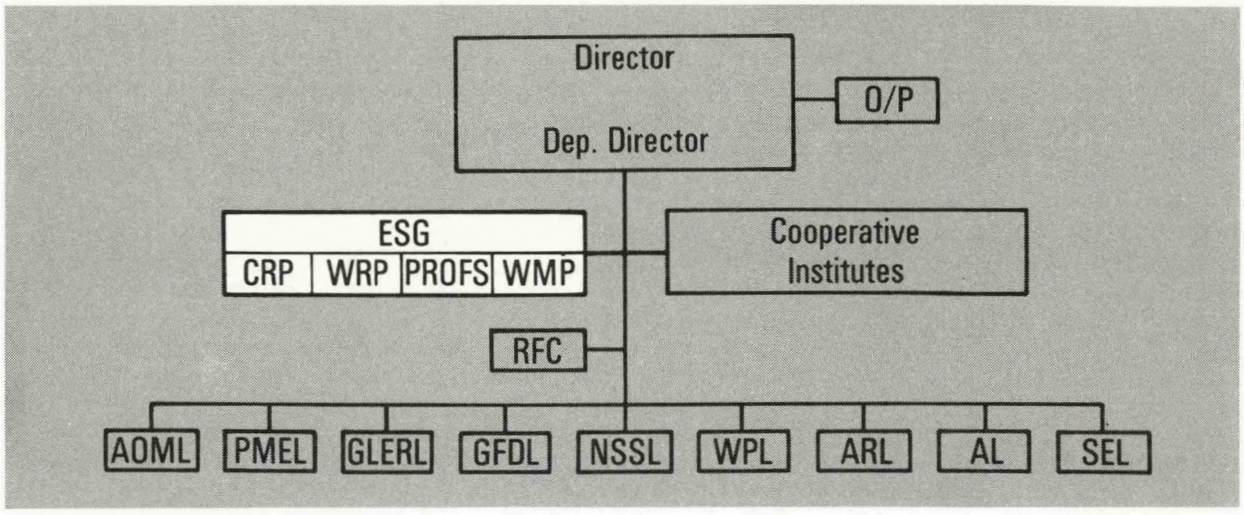
George H. Ludwig, Director
Vernon E. Derr, Deputy Director



The Director, assisted by the Deputy Director, establishes basic policies and manages the overall activities of the Environmental Research Laboratories. Within the Office of the Director, the Office of Programs provides advice and services to the Director as well as to the Laboratories and ESG. The Office of Programs provides policy, program, and management advice and support in areas such as program planning, budgeting, and analysis; program coordination and review; and implementation of management decisions. As a result of Department of Commerce (DOC) reorganization, the major functions of the Research Support Services, formerly part of the Office of the Director, have been absorbed into DOC Regional Support Centers. The remaining groups such as Budget and ADP Planning and Telecommunications have been combined with the Office of Programs.

ENVIRONMENTAL SCIENCES GROUP
Boulder, Colorado

Vernon E. Derr
Acting Director



The Environmental Sciences Group (ESG) plans, develops, and conducts programs of basic and applied research and technology transfer that cut across laboratory or program area missions, or that are less permanent than existing line elements within ERL, or that are in the formative stages of development. It provides planning, coordination, technical support, and documentation for these projects. The four components of ESG in FY 1983 are the Climate Research Project, the Weather Research Program, the Program for Regional Observing and Forecasting Service, and the Weather Modification Program.

CLIMATE RESEARCH PROJECT

ESG CRP

The Climate Research Project (CRP), directed by Joseph O. Fletcher, has three broad objectives:

- Construction of a global data set describing the fluctuations of climate during the past 130 years over both the oceans and the continents.
- Interpretive diagnostic studies of the climatic fluctuations during that period, on time scales ranging from weeks to decades.
- Modeling studies of polar ice sheets to clarify their evolution and their responses to climatic change.

Progress achieved in FY 1982 and further work planned for FY 1983 in each of these areas are summarized below.

Accomplishments FY 1982

CLIMATIC RECORD CONSTRUCTION

Ship Observations

Twelve data sets of ship observations were earmarked for inclusion in a Comprehensive Ocean/Atmosphere Data Set (COADS) describing the ocean climate of the past

130 years. Most of these sets were received by the end of FY 1982, many having been converted to TDF11 format by the National Climatic Data Center (NCDC) at Asheville, N.C. In Boulder, they are being converted to both of the packed-binary formats: CMR.3 (Compressed Marine Reports) and LMR.3 (Long Marine Reports). These contain, respectively, the 28 most-often-wanted parameters (at one-sixth the size of TDF11) and the entire original report (at one-half size). A modified version of a quality control program provided by NCDC in flow chart from has been received and is being coded; it will be tested early in FY 1983. A program for duplicate elimination is being coded, and the runs and necessary sorting have been planned in cooperation with the National Center for Atmospheric Research (NCAR).

The year's most important achievement was the reduction of the complete marine observation data covering the 1970's decade and of the data from a set of 4 million ocean current observations to monthly means for 2° × 2° boxes. Software was used for trimming extreme outliers from the first of these data sets, resulting in one 8 × 14 untrimmed matrix of variables versus statistics.

In addition three major groups of individual observations have been reduced to monthly means for 2° × 2° boxes. They cover the following periods and regions: (1) the entire Pacific for all years of record; (2) all high-latitude (>60°) data; and (3) the Indian Ocean prior to 1861. These data sets were used to test the procedures developed for the Comprehensive Set.

Climatic Data for Land Stations

The Northern Hemisphere land climate for 1851-1900 is being reconstructed under a grant from the U.S. Department of Energy. These results will supplement and extend the land averages for 1881-1981, compiled by the Climatic Research Unit of the University of East Anglia in Norwich, England. Particular attention has been paid here to North America. A set of data from 250 stations in the United States (including Alaska) was assembled. The next step will be to compile an equivalent gridded data set. Its analysis is expected to begin in the first half of FY 1983.

Highly Reflective Clouds

The monthly incidence of large convective clouds producing bright signatures in the visible imagery of polar-orbiting satellites has been shown to provide a good measure of tropical rainfall. A 10-yr record of this highly reflective cloud (HRC) frequency covering the entire tropical belt has been constructed and will now be analyzed against the background provided by the Southern Oscillation and El Niño "warming events" in the Pacific. An atlas of estimated monthly rainfall for 1971-1980 will be distributed to the research community in FY 1984.

Rainfall estimates made using the HRC technique are also being supplied to the NWS Climate Analysis Center on a near real-time basis, in support of efforts to monitor the current El Niño event in the tropical Pacific.

Stratospheric Aerosols

Estimates of global stratospheric aerosol loading were deduced from observed brightnesses of the moon during total lunar eclipses. A time series of such estimates, based on observations of 19 eclipses during 1960-1982, provides for a comparison of the effects of the volcanic eruptions of Agung, de Fuego, and El Chichón. The time series will be extended, using historic records back to ca. 1600, and possibly earlier.

DIAGNOSTIC STUDIES OF CLIMATIC FLUCTUATIONS ON ANNUAL TO DECADAL TIME SCALES

Monsoon Changes

The main focus of this research effort has been to understand the changes in global atmospheric and oceanic circulation associated with anomalies of global climate. The general research strategy is to reconstruct and analyze the surface fields of wind, atmospheric pressure, and sea surface temperature since 1854 over the global oceans, to determine the structural changes in these fields associated with variations in global climate.

A preliminary version of COADS was used to clarify the annual, interannual, and secular changes of the monsoon behavior over the Indian and western Pacific Oceans, and associated anomaly changes over the eastern Pacific and over the Tibetan Plateau.

The branching phenomenon of the southwest monsoon associated with the sea-land distribution was explored to interpret the major features of the south Asian monsoon climate. The thermal contrast between the tropical ocean and Tibet seems to be closely linked with the interannual variabilities of the Indian monsoon.

A number of well-marked signals of climate variations in the Asian monsoon region were found both over ocean and over land. The main characteristics of monsoon variations from one regime to another appear in the meridionality of monsoon currents, in a movement of Intertropical Convergence Zone (ITCZ), and in the cross-equatorial flow, which is probably related to the wave pattern in the Southern Hemisphere. Similar features also show up in single anomalous monsoon years.

Some highlights of findings are the following:

- Both interannual and decadal global variability are associated with changes in the pattern of heating of the atmosphere in the tropics, mainly the redistribution of rainfall (latent heat).

- Interannual variability is characterized by sudden, brief, and recurring (3- to 5-yr) shifts of tropical rainfall from the Indian Ocean and far western Pacific to the mid-Pacific. The forcing mechanism is not yet known.

- Longer term variability is characterized by sudden but stable adjustments of the atmospheric circulation patterns, which persist for decades. These adjustments appear to be related to variations in thermal forcing from high latitudes.

- The structural changes in the wind field associated with interannual and decadal scale variability are similar, but seem to be forced by different mechanisms. This is the main focus for future investigation.

It is planned to extend the analysis to the global scale, especially for the Southern Hemisphere winter, and to examine the feedback between equatorial air-sea interaction, middle-latitude teleconnections, and monsoon variability. It is suspected that the wave pattern in the southern winter--especially in the Australian-New Zealand sector, known to be a major region of preferred blocking--plays a key role in these processes.

Meteorology of the Asian Summer Monsoon

Boundary layer flight measurements supported by an NSF grant and made as part of Summer MONEX (Monsoon Experiment) were used to investigate the low-level flow blocking

upstream of the Western Ghat mountains of India as a trigger of deep offshore convection during the monsoon. A study of high-level forcing of deep convection during the summer monsoon was initiated with the preparation, from FGGE data, of a film of dynamic and thermodynamic fields associated with the upper tropospheric easterly jet during the summer monsoon. It is planned to continue both studies in 1983. Plans have also been developed for flight studies of the CO_2 balance in the oceanic boundary layer near Barbados, and of the structure of the trade winds and the Near-Equatorial Convergence Zone (NECZ) in the central Pacific.

Large-Scale Air-Sea Exchanges and Control of Convection

Data from the 1972-1973 El Niño event were used to study relationships between sea surface temperature (SST), surface wind, surface heat fluxes, and rainfall in the tropical Pacific east of the dateline. The maximum in SST anomaly appears not to be correlated spatially or temporally in any consistent manner with the sum of latent and sensible heat fluxes nor with rainfall as estimated from highly reflective cloud incidence. In particular, the position of the rainfall maximum and the time variation of rainfall in the NECZ are more closely related to moisture convergence than to the SST anomalies. It is planned to extend this study into the central and western Pacific by considering all the factors that might influence the location and intensity of rainfall on monthly time scales.

Cloudiness and SST Anomalies

Cloud data for the period February 1965 through February 1978 were analyzed against the background of the SST anomalies derived from the Historical Sea Surface Temperature Project (HSSTP) data set. No close relationship emerged in general for El Niños of 1965-66, 1972-73, and 1975-76. However a characteristic of the three warming events examined was a systematic decrease in the cloudiness over the dry zone of the central Pacific leading up to the increased cover of the event itself.

Changes in the Structure of the Upper Ocean

Evidence of historical changes in the thermal structure of the Southern Ocean and in the cross-Pacific depth profiles of the equatorial thermocline were sought in the Navy's Master Oceanographic Observation Data Set (MOODS), from expendable bathythermograph observations made available by Compass Systems, Inc., and in the measurements of various oceanographic cruises. The results have been largely inconclusive. The differences between soundings made only a few days to a year or so apart in the same area are as large as those between soundings made many years apart. The situation is somewhat similar for early observations of the time variations in the equatorial thermocline depth profile, but there are indications that east of 135°W the thermocline was deeper during the 1957-58 El Niño than before or after.

DIAGNOSTIC STUDIES OF SYNOPTIC ASPECTS OF CLIMATE

Tropical Cyclone Pairs of the Pacific: Interaction with the Equatorial Ocean and the Southern Oscillation

An analysis of historical features (formation data, place, intensity, and track) of tropical cyclone pairs observed over the Pacific during 1957-1981 established large-scale circulation features that precede and accompany these significant synoptic events. It appears that at least one pair gave rise to an oceanic Kelvin wave, which was observed and reported. It may also be significant that no cyclonic pair formation occurred in the early stages of the aborted 1974-75 El Niño. A statistical relationship has been established linking the longitude of cyclone pair formation with the change in the Southern Oscillation Index (SOI), from the northern winter season concerned to the same season a year later. It is planned to extend this investigation to cover the entire period of reliable tropical cyclone records, which started in 1939, and to include more fragmentary earlier data.

Transient Tropical-Extratropical Interaction

With funding from an NSF grant, synoptic-scale aspects of the claimed atmospheric teleconnection between the tropical Pacific and North America were examined for a convective outbreak over the tropical Pacific in February 1981, which was followed by intensive cyclogenesis over North America, ending a prolonged quiet interval. Similar sequences occurred during the low SOI event in 1972-73 but not in 1976-77. It is planned to extend the investigation first to the decade of geostationary satellite data (1972 to 1981) and subsequently further back in time by means of earlier conventional records of tropical convective activity.

Reconstructions of Northern Hemisphere Long Waves for the Early Part of This Century

The Fourier component amplitudes calculated from the daily Northern Hemisphere geopotential height of the 500-mb surface prepared by NCAR were used to analyze the Elementary Circulation Mechanisms (ECM's) that are cataloged for each day from 1899 to the present. Significant differences between the rudimentary spectra thus derived for the zonal and meridional ECM's hold the promise that with the synoptic insights embodied in that catalog it may be possible to describe the long-wave climatology during the first half of this century.

Western Aspects of the Southern Oscillation

The Southern Oscillation traditionally is described in terms of the surface pressures at Easter Island in the east and Darwin, Australia, in the west. Surface pressure observations made on ships in the Indian Ocean in locations corresponding in latitude and distance from land to those of Easter and Juan Fernandez Islands, and synoptic charts of the IGY period, have been used to examine the behavior of Southern Hemisphere subtropical and middle-latitude systems during some Southern Oscillation episodes. It is planned to carry out next a more detailed analysis for the warm event of 1982.

CRYOSPHERIC STUDIES

A Physical Description of the Greenland Ice Sheet

A detailed physical description of the Greenland ice sheet, constructed from the working hypothesis that the ice sheet currently is in an exact state of balance between its mass gains and mass losses, was completed during the year and embodied in an extensive report, together with a survey of climatic features contributed by staff of the World Data Center A--Glaciology (Snow and Ice). Two more specialized studies also included in this report are listed separately below.

Mass Balance Regime and Surging Potential of a Cross Section through Central Greenland

A cross section through the Greenland ice sheet from Jakobshavn Glacier in the west to Kangerdlugssuaq Glacier in the east was modeled with a hierarchy of assumptions about the ice dynamics. In absence of substantial basal sliding, the present mass balance profile appears to be slightly positive across the western side of the ice sheet, which agrees with measurements made by the Expedition Glaciologique International au Groenland. With self-lubricating sliding, the western half of the cross section was found to be undergoing steady fast sliding or periodic surging; both produced model ice sheet elevation profiles well below those observed at present. It appears from this that sliding primarily is limited to the Jakobshavn Glacier terminus and that its anomalous fast retreat during the past century could be part of a surge with a period of 300-400 years.

A Statistical-Dynamic Model of Accumulation on the Greenland Ice Cap

The current pattern of net annual accumulation on the Greenland ice sheet was related to the surface slope (magnitude and direction) and the intensity of the mid-tropospheric circulation, as represented by the mean monthly flux of positive relative vorticity at the 500-mb level. A statistical relation between this circulation parameter and measured accumulation values provided estimates of the mass balance at the height of the last glaciation, with the circulation anomalies of recent extreme winters serving as weak analogs for the glacial scenario.

Dynamic Features of a Flowline in the Wisconsin Ice Sheet

Extended lobes reconstructed for the southern edge of the Wisconsin ice sheet are generally believed to have been created by surging episodes. An objective analysis of the possibility was carried out with a surging model, defining more closely the range of conditions in which such surges could have occurred. At the same time controversial questions relating to the number and location of domes in the ice sheet have been rendered even more complex by the likelihood that these domes changed both in height and location as the result of surging. On the other hand, the analysis made it possible to understand the decay of the ice sheet along its southern edge without invoking marine-type conditions.

An Estimated Age-Depth Relationship for South Pole Ice

For an ice flowline from East Antarctic ice divide through the South Pole to the Weddell Sea, the assumption of steady-state mass balance was used to construct the trajectories of ice particles in a core extracted at the South Pole station. The estimated ages down to the depth of 200 m were subsequently found to be in reasonable agreement with those established from annual layers in the core.

Mass Balance Regimes and Dynamics of Antarctic Ice Shelves

The large, partially floating ice shelves of West Antarctica are regarded as the most climate-sensitive formations of Antarctica. A free-floating ice shelf model was developed. It includes both the dynamics of longitudinal straining with gravity and the thermodynamics governed by the heat and mass exchange at the ocean-ice and ice-atmosphere interfaces. Surface temperature observations for ice shelves in different locations were assembled to specify the present upper boundary conditions for the model. These temperatures will also be used to account for the present incidence of surface melt and to estimate the melt that may accompany a CO_2-induced polar warming.

MISCELLANEOUS PROJECTS

Comparison of SST Products

The monthly mean SST estimates for the eastern Pacific, constructed by the NOAA/National Marine Fisheries Service (NMFS) solely from ship observations, were compared with the corresponding estimates, prepared by the National Weather Service (NWS) from a mix of ship and satellite data, for their overlapping 12-mo period from April 1979 to March 1980. The differences were found to be only of the order of ±0.5°C, but showed a systematic latitude trend, with higher NMFS than NWS temperatures elsewhere, especially south of the Equator.

Errors of Wind Estimation from a Moving Ship

A simple procedure of eliminating the disturbing effects exerted by ship superstructures on the wind field from a wind estimate is to measure the relative winds

during a closed loop performed by the ship over an area and in a time sufficiently small to ensure a homogeneous field. A set of such measurements on a small ship was analyzed to determine the error magnitude of the wind observations as a function of wind speed and relative direction.

Plans FY 1983

RECORD CONSTRUCTION

It is planned to complete the construction of the Comprehensive Ocean/Atmosphere Data Set by the end of FY 1983, with cooperation from NCDC on duplicate elimination and quality checking, and from NCAR on computer runs. A total of almost 10^8 observations will be stored in a packed binary form readily accessed and handled by different computer types. These will contain the quality- and duplicate-checked individual observations plus synoptic sets of all $2° \times 2°$ latitude-longitude averages for each month from 1854 through 1979. Later (FY 1984), long-term averages and residuals will be calculated and various sets of gridded data will be prepared that can be easily used by climate researchers.

DIAGNOSTIC INTERPRETATION OF THE OCEAN CLIMATE RECORD

Once completed, COADS will be used for further diagnostic work with data aggregates and composites to identify regions and periods deserving closer examination. Ideally a more detailed analysis should use some of the observational record as input for climate models and should compare the model outputs with other observations; e.g., a model might be forced with observed SST anomalies and might then be expected to produce the observed anomalies in winds and surface pressures. This would provide searching tests for the models and, if successful, provide insight to the physical processes that create the anomalies. However, since model experiments require human- and computer-power resources well beyond those currently available to the CRP program, this type of experiment is envisaged as a potential future cooperative project with NCAR or GFDL. For the immediate future the program's emphasis will be placed on using existing climate modeling results as physically defined analogs for similar event sequences and changes in the historical record.

Other existing data will be used to clarify the dynamics of the variations in Indian monsoon circulation. The mapping and digital archiving of satellite cloud estimates of tropical rainfall will continue, and the determination of large-scale boundary layer fluxes will be pursued with existing data and with observations from further flight projects.

DIAGNOSTIC INTERPRETATION OF SYNOPTIC EVENTS

Apart from the continuation and extension of the current work on the synoptics of low-latitude/middle-latitude links, a compilation of data and synoptic reconstruction is planned in support of the EPOCS Atlas to be prepared for the 1982-83 warm event. This will include the details and analysis of aircraft soundings made over the region of the large SST anomalies along 100°W during normal conditions (negative anomalies) in 1980 and during the height of a warm event (large positive anomalies) in January 1983.

ICE MODELING

The ice modeling program currently faces several possibilities for the growth of a new group in Boulder. If such a group comes into existence, the future program may be able to address both the West Antarctic problem (with CO_2-induced changes in the polar environment as key factors), and the construction of long-term ice sheet histories, taking into account crustal changes and heading ultimately for a separation of

ice-dynamic effects (slow or fast changes in surface elevation) and climatic changes in the isotope records obtained from ice cores. A preliminary step for both of these lines of research would have to be the preparation of an updated summary of derived physical characteristics of the Antarctic ice sheet. As of early 1983, NSF and DOE have indicated their intentions of funding this work, but final arrangements are still be negotiated.

WEATHER RESEARCH PROGRAM

The Weather Research Program (WRP) was previously directed by Charles F. Chappell and is now directed by Robert A. Maddox, with Chappell as Chief Scientist. It is the core group from the Office of Weather Research and modification (OWRM), which was eliminated by the FY-1983 NOAA budget reduction for weather modification. WRP conducts research to improve short-range weather predictions and warnings, and to provide a scientific basis for weather modification. Emphasis is on precipitation, with research interest extending from microphysical processes to structure and behavior of large mesoscale precipitation systems. The office actively transfers promising techniques and technologies to NWS and other user groups.

The factors considered in designing WRP included the following:

- A well-focused research program area was preferred over an assemblage of several subcritical research efforts.
- WRP would conduct research clearly related to the needs of NOAA operational services (i.e., NWS).
- The program area would be of such a nature that synergetic interactions with PROFS, NSSL, and WPL are possible, and the current excellent interactions with NWS are preserved.
- The program area preserved would be, if possible, one that already enjoys national recognition and acceptance by both the scientific community and NWS operational components.
- The program area would be consistent with the research outlined in the FY-1984 Severe Weather Prediction Initiative and the FY-1985 Quantitative Precipitation Forecast Initiative.
- The program area would constitute a core program around which expansion could take place.

Accomplishments FY 1982

The following accomplishments are for OWRM groups that were eliminated during early FY 1983.

RESEARCH SUPPORT GROUP

The Research Support Group (RSG) supported other scientists and programs in OWRM by providing field program management expertise, computer hardware and software, and instrumentation and measurement techniques development.

In FY 1982, a new infrared radiometer, designed in FY 1981, was assembled and extensively laboratory tested. The sophisticated radiation model FASCOD was used to

determine the center frequency and bandwidth of the optical filter used in the radiation. The laboratory tests confirmed that the radiometer had a narrower field of view than the radiometer commonly used to measure temperature from an aircraft; this field of view was measured to be 0.45°C. The RMS noise was also determined to be low; the 1-sigma temperature change for 1-s integration time was measured to be 0.075°C. A final laboratory test showed that the calibration of the radiometer was linear between +30°C and -20°C. Flight tests of the radiometer were scheduled to be conducted on the NOAA WP-3D aircraft in July. However, because the system was damaged en route to Miami, the radiometer was not flight tested in FY 1982.

BOUNDARY LAYER DYNAMICS PROGRAM

A preliminary report was prepared on the utilization of multivariate analysis techniques to isolate effects of land use and terrain differences on atmospheric diffusion parameters. This analysis indicates that the discriminate function is independent of land use but is dependent upon two distinct regimes: the first comprising the low-level early-afternoon sampling runs, and the second comprising the mid- and high-level runs. The dominate factor contributing to variability in all three dimensions of turbulent energy is the entropy of surface IR temperatures. These preliminary results were derived from the statistical inference of the factor analysis and are in agreement with earlier results derived from physical considerations.

A preliminary report was prepared on the nature of updrafts and downdrafts in the subcloud layer as observed during the North East Regional Oxidation Study (NEROS) in 1979. It was found that thermal heating, water vapor, and ozone all followed the same diurnal pattern: positive upward flux during the morning, increasing during midday, and slowly decreasing in the late afternoon. A remarkable agreement was found in the order-of-magnitude change in all three variables from morning to midday and, with the exception of ozone, for the evening decay of turbulent activity.

CUMULUS DYNAMICS AND MICROPHYSICS PROGRAM

The Cumulus Dynamics and Microphysics Program (CDMP) was a long-term basic research effort to understand convective cloud processes and the potential for their modification. The program emphasized numerical modeling, laboratory work, and observations to understand cumulus formation, development, organization, and interaction with the environment. Knowledge gained in this effort should provide an improved basis for convective cloud modification experiments, and contribute to more reliable short-term precipitation forecasting.

FACE

The basic FACE-2 (Florida Area Cumulus Experiment) data sets were reduced and published as six NOAA Technical Memoranda before the treatment decisions were disclosed on 30 November 1981. Prior to this, data from these memoranda were mailed to selected members in the scientific community, and four documentary papers were submitted for formal publication.

The measurement errors of the FACE-2 gage and radar measurement systems were estimated for the FACE target. The standard deviation of the gage errors is 13% of the mean gage-measured rainfall, whereas for the unadjusted and gage-adjusted radar the comparable figures are 50% and 30%, respectively. For the detection of a seeding effect, however, the natural-rainfall variability is more important than measurement errors by a factor of 7 for the gages and by a factor of 3 for the adjusted radar.

Collaborative research among OWRM scientists and scientists from the Hebrew University of Jerusalem, Israel, produced interesting results. In both natural and AgI-treated clouds a strong, positive relationship (correlations 0.80 to 0.90) has been

found between the maximum height of a convective cell and maximum cell reflectivity, area, rain volume, and duration. These results support the dynamic seeding concept developed in FACE, which states that the increase of cloud height through AgI seeding is the key to increasing the rainfall from individual clouds.

Analysis of cell responses on 18 days of experimentation in FACE-2, when there were simultaneous scans of the echo populations by C- and S-band radars, has produced results that are strongly supportive of the Florida single-cloud experimentation of 1968 and 1970. In FACE-2, cell heights, durations, areas, rain volumes, and maximum reflectivities were found to be greater for AgI-treated cells than for sand-treated (placebo) cells. The size of the effect and its statistical (P-value) support increased as the amount of nucleant introduced into the cloud increased.

Analysis of FACE-2 B-day (26 no-seed days and 25 seed days) rainfalls for the 6 hours following treatment indicates that the apparent seeding effect in FACE-2 is less than in FACE-1. The overall seed-to-control rainfall ratios for the floating target were 1.49 and 1.08 and for the total target were 1.23 and 1.04, in FACE-1 and FACE-2, respectively. The preliminary statistical (P-value) support for the seed-vs.-control rainfall differences in FACE-2 is inadequate for confirmation of the FACE-1 results. However, if the one extremely wet control day is removed from the FACE-2 sample, the point estimates of treatment in FACE-2 are very similar to those of FACE-1 (e.g., 1.41 vs. 1.49 for floating target and 1.28 vs. 1.23 for total target).

Satellite-estimated, gage-adjusted rainfalls were calculated for all FACE-2 B days for a large area around the FACE target to determine whether seeding affected the rainfall outside the target. Analyses show more rainfall downwind of the target and less rainfall upwind of the target on seed days than on no-seed days. Although it is not possible as yet to infer causality, the spatial and temporal developments of the rainfall patterns are consistent with an effect of seeding.

Cumulus Dynamics and Microphysics

Research in the microphysics of clouds progressed substantially during the year. Electron microscope analyses of hydrometeor replicas obtained in treated cumuli revealed that up to 20% of the ice crystals sampled in cumuli seeded with AgI contained silver whereas only 0% to 1% of the ice particles in sand-treated (placebo) clouds contained silver. This indicates that the AgI nucleant was involved in some way in the precipitation process.

Additional microphysical measurements were made in Florida clouds in summer of 1982 during the ACT I (Active Cumulus Transformations) experiment to investigate further the origin of natural ice, especially graupel. Graupel was collected during the measurement program.

Analyses of several case-study storms within south Florida indicate that hydrostatic and nonhydrostatic pressure responses of the mesoscale and convective-scale regions of the storm constitute one of the primary feedback mechanisms between developing convective systems and the boundary layer. It appears that rapidly developing convective storms induce both a convective-scale surface low pressure beneath the system and a mesoscale surface low pressure surrounding the system. These conditions produce a pressure gradient in the storm region, which accelerates the air from the mesoscale area into the convective area. This increases the boundary layer convergence and ultimately the convective development.

Analysis of FACE radar data related to the basic physical processes of cloud formation and development continued during the year. The picture that is emerging of the development of the south Florida convective field is highly complex. The field is not just the result of external forces that produce a passive random ensemble of cloud

types. To the contrary, the resulting population seems to be the result of a highly interactive network of processes at different scales, which tend to lead to an increasing organization of the cloud field.

Work on the boundary layer characteristics and their relationship to cloud formation continued during the year. A paper on updraft and downdraft events in the atmospheric boundary layer over the equatorial Pacific Ocean was submitted. A study was completed on the dependence of fluxes and bulk transfer coefficients on atmospheric stability over the eastern tropical Pacific Ocean. Work also continued on the flux variation and cloud transport of ozone, heat, and momentum in an urban environment.

Other studies during the year included first-echo characteristics, thunderstorm outflows, development of predictor variables for rainfall, convergence-rainfall relationships, and cloud-to-ground lightning and echo parameter relationships. In addition, personnel at the Kennedy Space Center expressed an interest in having CDMP personnel help them solve the forecast problem for Space Shuttle operations.

MESOSCALE MODELING PROGRAM

The Mesoscale Modeling Program (MMP) was engaged in the development and testing of numerical models capable of providing short-range forecasts of precipitation and associated weather phenomena on the regonal scale. The primary emphasis was on the simulation of heavy snowfall events, heavy rainfall events including flash floods, and acid precipitation.

During FY 1982, MMP organized and jointly hosted a mesoscale workshop with NCAR, CSU, and NSSL to discuss on an informal basis the current status of their modeling programs and to lay the groundwork for closer cooperation in the future. The program manager presented an invited paper at the 1982 CIMMS Mesoscale Symposium.

Cooperative Agreements

The outcome of an informal cooperative agreement with the Laboratoire Associé de Météorologie Physique (LAMP) at Clermont-Ferrand, France, was the completion of two dissertations, the primary results of which will contribute directly to the OWRM modeling program. A new mixed-phase model was developed to link the warm-rain and cold-cloud mesoscale models. At Électricité de France (EDF) in Châtou, where the OWRM model has been installed on the Cray computer, the model was initialized with a larger scale operational French forecast model, thereby generating mesoscale circulation features that could not be obtained with the current initialization procedure that uses a single radiosonde.

A visiting graduate student from LAMP worked at OWRM since March to develop and incorporate new aerosol-scavenging processes into the OWRM mixed-phase model. The incorporation of explicit scavenging of aerosols by clouds, rain, and snow and their subsequent deposition on the ground is but the first step in the development of a regional acid precipitation forecast model.

Model Evaluation

The Boulder Upslope Cloud Observation Experiment (BUCOE) conducted along the Front Range in spring of 1982 provided a limited amount of data for testing and evaluating the mixed-phase aerosol model. Although preliminary results of aerosol scavenging are encouraging, some difficulties were encountered during simulations of actual meteorological conditions for specific experimental days. It is expected that the incorporation of improved real-data initialization procedures and time-dependent lateral boundary conditions for the clouds and airflow will be reflected in improved model simulations of clouds and precipitation.

Model Development

Considerable progress was made in the incorporation of the Fritsch-Chappell convective parameterization scheme into the OWRM mesoscale model. A graduate student from Pennsylvania State University spent 1 month in Boulder assisting MMP scientists in accomplishing this task.

An improved radiation-surface condition formulation was installed in the warm-rain model. A new treatment of soil and vegetative conditions at the lower boundary of the model is responsible, at least in part, for the agreement between predictions of clouds, rain, and airflow generated by the model, and observations made during the Hawaii Mesoscale Energy and Climate Experiment (HAMEC).

A CIRES post-doctoral appointee worked with MMP scientists in developing procedures to incorporate time-dependent, lateral boundary conditions into the WRP mesoscale model. An examination of three special NMC (National Meteorological Center) computer runs of the limited fine-mesh (LFM) model has been made, and it appears that it will be necessary to have output from the LFM model at every time step (currently 400 seconds). The Perkey-Kreitzberg formulation appears to be best suited for meshing and incorporating time-varying lateral boundary conditions into the OWRM model.

SESAME PROGRAM

The SESAME (Severe Environmental Storms and Mesoscale Experiment) Program continued to support the dissemination of information concerning the 1979 field experiment and its data sources. Numerous inquiries from within and outside the United States were received during the past year, most requesting the Data User's Guide and the Operations Summary. To assist the project in keeping investigators aware of data sources and problems, workshops, results, and other items of mutual interest, the office negotiated a contract with CIMMS (University of Oklahoma) to edit, print, and distribute an information sheet during the coming year. Future inquiries concerning SESAME should be directed to Dr. Stanley Barnes in WPL.

The SESAME program continued to support a modest grant program to investigators using the 1979 data sets. This year a grant to Brookhaven National Laboratory was sponsored (with assistance of CDMP) for the completion of a study of microphysical properties in Oklahoma thunderstorms.

WEATHER ANALYSIS AND STORM PREDICTION PROGRAM

The WASP (Weather Analysis and Storm Prediction) Program area was established late in FY 1982 to study the dynamics, kinematics, and thermodynamics associated with mesoscale convective precipitation systems and to understand their life cycles. The basic research, in addition to leading to better physical understanding of mesoscale weather systems, should lead to pattern-recognition forecast techniques built around synoptic-scale data and numerical forecast products. WASP developed highly synergetic interactions with NWS operational and training units.

Flash Flood Storms

NWS helped support a continuing study of heavy-precipitation and flash-flood events within and near the Tulsa River Forecast District (i.e., the south-central United States). The extensive study has been completed and a draft NOAA Technical Memorandum prepared. Two types of flash-flood meteorological patterns were identified that have not previously been considered. A NOAA Technical Memorandum entitled "Focusing Mechanisms in the Texas Flash Floods of 1978" was published, and copies were sent to NWS Southern Region Headquarters.

WASP personnel participated in the Flash Flood Forecasting course at the NWS Training Center by teaching 2 days (mesoanalysis and heavy-precipitation forecasting) at each of the FY-1982 courses.

NWS Interaction/Forecast Improvement Activities

WASP personnel interacted with a variety of NWS programs and offices during the course of FY 1982. Some of the more important efforts included (1) visits and seminars at all of the Regional Headquarters and at the Scientific Services Division; (2) interaction with the NWS unit assigned to the FAA Academy, and participation in courses at the NWS training center for Weather Service meteorologists; (3) day-long mesoscale analysis and convective forecasting workshops at NWS offices in Georgia, Mississippi, Alabama, and Louisiana; (4) interaction with the NWS Eastern and Western Regions and NMC/HPB (Heavy Precipitation Branch) on ways to improve heavy precipitation forecasts; and (5) provision of assistance and technical advice to offices involved in local forecast studies in Missouri, Louisiana, Texas, Hawaii, California, and Utah.

WASP personnel participated in NWS efforts to evaluate and improve methods of forecaster training and presented two talks at the August meeting of the National Training Council. WASP also provided classroom instruction for 5 days of the special training course developed for the staff of the new National Aviation Unit.

NESS Interactions

WASP personnel worked with NESS staff of the Kansas City Field Service to develop procedures for forecasting nocturnal precipitation systems. A real-time operational experiment was carried out throughout the FY-1982 convective season. Initial indications are that the experiment was very successful.

Mesoscale Convective Complexes

Metropolitan State College and WASP personnel studied the precipitation structure of two mesoscale convective complexes (MCC's) that occurred on 19-20 May 1979, concentrating on upper-air analysis and mesoanalysis. Hourly composite radar and hourly precipitation data analyses were completed. Analyses of the accumulated rainfall during the mature and dissipating stages of the MCC's and the 24-h rainfall were documented.

WRP

A summary of MCC activity over the United States during 1981 satellite images was used to document the life cycles and tracks of 23 MCC's as well as a variety of other significant mesoscale convective events.

Documentation of 1982 MCC's occurring over the United States has been completed in collaboration with personnel of the NESS Satellite Field Service Station in Kansas City. Thirty-nine MCC's were documented; the first occurred on 19 March and the last on 5 September. Work is under way on a summary article describing the MCC season. This article will highlight the storm that occurred on 13 August dumping up to 17 inches of rain on the Kansas City area.

Satellite Applications

(1) AgRISTARS. The first rain maps for the midlatitude wintertime cases from the AgRISTARS (Agricultural Resources Inventory Surveys Through Atmospheric Remote Sensing) program were successfully tested. The Florida, summertime, satellite rainfall relationships were tested for these cases. Three August 1979 case days (having little, moderate, and large rainfalls) were individually analyzed to determine the efficacy of the model adjustment factors. In general it appears that the model adjustment factors do not adequately model the situation in the strip along and immediately east of the Rocky Mountains.

A computer package has been put together from existing routines. It will objectively analyze a scalar field (by using Barnes' scheme) and plot the input data and the contour of the analyzed field on a geographic background (with the NCAR graphics package).

(2) Sea-breeze cases. Navigation and rain maps were produced for three sea-breeze case studies. These data will be analyzed with aircraft data collected by staff from NASA/Goddard.

(3) EPOCS. Hourly precipitation results for August 1979, inferred from satellite imagery by the Griffith-Woodley technique, were used to derive a mean diurnal rainfall curve for tropical, open-ocean rainfall from the Equatorial Pacific Ocean Climate Studies (EPOCS) program. This is probably the first determination of the diurnal trend of tropical oceanic rainfall independent of island-measured precipitation, which is often biased by daytime solar heating and orographic effects.

(4) PROFS support. A NOAA Technical Memorandum, describing surface meteorological features preceding eastern Colorado severe thunderstorms, was completed. Three hundred severe-thunderstorm days were examined, and from this data set four synoptic surface patterns were identified. A climatology of prestorm surface parameters (pressure, temperature, dewpoint, and wind) was presented, and a severe-storm index applicable to eastern Colorado was developed using surface data. On 14 December WASP personnel completed training (approximately 1/2 day each) of five visiting forecast teams as part of the OWRM-PROFS FY-1982 project. A study of the synoptic and mesoscale events leading to the 15 October 1980 severe (tornadic) weather in the Boulder area was completed. Although PROFS data were not yet available at this date, a significant amount of nonstandard data was located after the fact. These data were used to show that PROFS network data might have been useful for a more accurate and timely local forecast of the storms.

A mesoanalysis of the Denver tornado (3 June 1981) kinematic field using PROFS network data was completed. Three WASP staff members participated in the PROFS 1982 Real-Time Test as lead forecasters, using the POWS and AFOS systems. They also provided operational forecasts to the JAWS project.

Aviation Applications

(1) MERIT. WASP personnel consulted with the NASA head of the MERIT (Minimum Energy Routes Interactive Techniques) project. The aim of the project is to design a truly interactive computer system to do rapid mesoscale weather analysis. The MERIT project proposes to use the data base from the PROFS system and aircraft reports that relay wind and temperature data from wide-bodied jets to a central computer. The goal of the project is to be able to fine-tune the relatively coarse NMC forecast product. Software developments in the MERIT project will greatly boost development of the interactive graphics system.

(2) Analysis of the Pan Am flight 759 crash. Data were gathered for a mesoscale weather analysis for the NTSB (National Transportation Safety Board) regarding the crash of Pan Am Flight 759 at New Orleans on 9 July 1982. Rapid-scan (3-min) visual satellite imagery shows unusual cloud-top activities at the time of the crash in this narrow line of convective clouds. The public reported erratic, strong, gusty winds near the crash site accompanied by a core of extremely heavy rain. A short distance (1 km) from the crash site the rain was very light. These data seem to support the hypothesis that a microburst was making ground contact over the departure end of the runway just as the aircraft was attempting to take off.

(3) Hazardous downdrafts. A cooperative study with Colorado State University documented the occurrence of sudden, damaging gusts of wind at the ground, underneath very high-based (above 500 mb) benign-looking cumulonimbi that produce no cloud-to-ground lightning and no measurable rain. This phenomenon represents a significant

hazard to aircraft operations and seems not to have been generally appreciated by meteorologists heretofore. Computations using simple models are under design to test the hypothesis that the strength of the downdraft underneath such clouds is a consequence of the production of small precipitation particles that evaporate efficiently.

Plans FY 1983

Research efforts of the Weather Research Program (WRP) will focus upon mesoscale convective weather systems for a number of important scientific reasons:

(1) Our current level of understanding on larger meteorological scales, together with the operational numerical models and forecast guidance products developed for these scales, enables us to predict stable precipitation events reasonably well. However, shortcomings in predicting quantitative precipitation, flash floods, and severe storms are well known, and are described in detail in the FY-1984 Severe Weather Prediction Program Development Plan (PDP), ERL's draft Precipitation Research Program Plan, and UCAR's STORM (Stormscale Operational and Research Meteorology) PDP. These shortcomings are frequently caused by the occurrence of mesoscale convective events embedded within the synoptic-scale weather episode.

(2) In the WRP mission statement, mesoscale is emphasized because several universities, NCAR, the Bureau of Reclamation, and even some ERL laboratories have developed important research programs to investigate cloud and precipitation microphysical processes, and convective cloud dynamics and morphology. This statement applies equally well to larger scale research efforts, such as studies of synoptic and global weather systems and of climate dynamics. For example, NSSL has built an important research program around thunderstorm-scale problems. Similarly, the GFDL program emphasizes the larger scale aspects of weather and climate research. The proposed program for WRP would therefore be highly complementary to both the NSSL and GFDL research programs. It is important that the limited resources made available for WRP not be expended on duplicative research efforts.

(3) If all of OWRM's programs had been eliminated as a consequence of FY-1983 budget decisions, there would have been no substantial research program or group within ERL, NWS, or the universities primarily concerned with the important mesoscale weather problems discussed in the documents mentioned above. However, the evolving UCAR STORM PDP clearly indicates that the atmospheric science community has recognized the importance of mesoscale research to the Nation. The next decade will undoubtedly bring increased university involvement in the mesoscale research described in the PDP. It is, therefore, critically important that ERL preserve a strong and viable group to conduct research on mesoscale convective weather problems.

(4) In spite of 30 years of nearly continuous cloud-scale research on problems related to precipitation, the results of this research have not significantly impacted operational precipitation predictions. On the other hand, early research on mesoscale convective precipitation systems has already led to improved operational forecasts of flash-flood-producing storms. This suggests that research conducted on mesoscale weather systems is more likely to have both immediate and long-term impacts on improving short-term precipitation predictions than would additional efforts on the cloud scale. A solid research effort to understand and predict mesoscale weather systems is most consistent with the concept of supporting NWS operational needs.

(5) Within ERL important developments have occurred in remote sensing that will significantly enhance the capabilities of WRP in conducting mesoscale weather studies. These advances have occurred in WPL (for example, the Profiler) and in PROFS (the PROFS POWS and the Front Range Area Satellite Ground Station). Two extremely important data streams (Profiler and Digital Satellite Data) are thus most easily available to ERL researchers physically located in Boulder. The programs of WRP are designed to ensure use of these data streams in mesoscale weather research.

The goals for the Weather Research Program for FY 1983 (and FY 1984) are briefly described below.

BASIC RESEARCH

- Study the internal structure of mesoscale convective weather systems throughout their cycles. Particular emphasis will be given to understanding the relationship of thunderstorm-scale and mesoscale precipitation elements, and their variation as a function of time and life cycle.

- Study the dynamics and thermodynamics associated with mesoscale convective weather systems throughout their life cycles. Particular emphasis will be given to understanding internal mesoscale circulations and the interactions between mesoscale and both larger and smaller scale processes.

SHORT-TERM WEATHER PREDICTION (APPLIED RESEARCH)

- Develop pattern recognition techniques and process models for predicting the rainfall produced by mesoscale convective precipitation systems using conventional large-scale data and forecast guidance products. In addition, ways will be examined in which remote sensor data streams that are becoming available within ERL might be integrated into advanced prediction techniques.

- Maintain the synergetic interactions with NWS, and other agency, operational and training units that have been previously developed by OWRM.

Studies described in several recent OWRM proposals ("Predictability of Mesoscale Convective Precipitation Systems" and "Profiler Capabilities in Detecting Subsynoptic Mid-Tropospheric Waves") can be accomplished within the framework of WRP. However, given the limited personnel resources, it will not be possible to complete all of the efforts described in OWRM's NOAA proposal for FY 1983. Some of the work described in that document will have to carry over into FY 1984.

PROGRAM FOR REGIONAL OBSERVING AND FORECASTING SERVICES

The Program for Regional Observing and Forecasting Services (PROFS), directed by Donald W. Beran in FY 1982 and Alexander MacDonald in FY 1983, works to improve local weather services through the introduction of new technologies into weather service operations. PROFS is an ERL program, but it also receives guidance and review from the National Weather Service (NWS) and the National Earth Satellite Service (NESS). NWS has assigned two senior people, a meteorologist and a systems engineer, to the management staff of PROFS. Through this liaison, PROFS maintains a balance between research and operations.

Accomplishments FY 1982

The first achievement was the completion of the summer 1981 convective storm exercise. From mid-October through December 1981, data collected during the summer and stored on computer disks were played back in displaced real time (DRT) to teams of forecasters who made "forecasts" from them, which were then compared with actual weather events. The DRT test objectively evaluated the relative usefulness of many different types and combinations of data sets. Furthermore, the forecasters gave useful subjective feedback about the design of the 1981 PROFS operational workstation (POWS).

The forecaster advice produced a redesigned and improved workstation that was central to the major effort of FY 1982: the real-time exercise at the Denver Weather

Service Forecast Office (WSFO). The redesigned workstation was installed at WSFO, all PROFS data sets were transmitted in real time, and for 3 months senior members of PROFS' meteorological staff assisted the NWS forecasters who used the PROFS data as they prepared their regular forecasts. The Automated Warning and Dissemination System (AWADS), developed in PROFS, also was installed at the Denver WSFO; it was used in a pilot study to evaluate possible increased efficiencies in disseminating warnings to the general populace and to law enforcement and emergency assistance agencies in the 29 Colorado counties for which the Denver WSFO is responsible.

At the PROFS forecast office (PFO), a standard NWS and an advanced PROFS workstation were installed for forecast evaluation. Over the summer a trained group of 38 forecasters from WRP, NESS, and PROFS used both workstations to prepare terminal (point) forecasts for winds, visibility, and precipitation, as well as watches and warnings of severe storms. The PFO and WSFO forecasts are currently being evaluated.

Plans FY 1983

- To prepare and publish reports that describe the Phase I system (developed over PROFS' first 4 years) and present the evaluation results.
- To complete analysis of the FY-1982 exercise data and to plan and execute further limited tests on forecast applications and critical system components.
- To modify EDF and increase the capacity of the PROFS workstation to support the limited testing defined in the above objective and to lay the necessary foundation for more extensive tests of forecast applications after FY 1983.
- To identify and prepare standards for evaluation of forecast applications that use current and advanced data sets from single sensors and combinations of sensors.
- To establish the necessary interfaces, both physical and organizational (NEXRAD, NESS, NSSL, AFGL, NCAR, and WPL), for evaluation of advanced sensors (Doppler radar, VAS, and Profiler) and integration of the data and products from these sensors with the current PROFS test system.

SYSTEM ANALYSIS AND DESIGN (SA&D)

SA&D is responsible for the analysis and design of improved weather information systems. It provides the design methodologies to be used by all the PROFS staff, trade-off studies for future system elements, and conceptual operational system design.

Accomplishments FY 1982

SA&D completed the detailed design and implementation of the product generation subsystem for the 1982 real-time exercise, and provided training on the design methodologies to the PROFS staff. The group also completed the system specification document for the PROFS Phase II system.

Plans FY 1983

In addition to completing the top-level design for the Phase II system, SA&D will assist in implementation of portions of the system.

EXPLORATORY DEVELOPMENT FACILITY (EDF)

EDF is responsible for the detailed design, development, operation, and maintenance of the hardware and software used for weather information system and component development, testing, and demonstration.

Accomplishments FY 1982

In addition to the already-existing data-acquisition interfaces for conventional radar, satellite, and mesonet, EDF has initiated the ingest of many other kinds of data: NCAR CP-2 Doppler radar, surface aviation observation, upper air, lightning, local hydrologic observation, and WPL Profiler. EDF was reconfigured for real-time data acquisition, and for product generation, distribution, and display. A 95% reliability level was achieved during the 1982 summer storm season. Light-pen-controlled workstations with color image and graphics displays were deployed and successfully operated at the Denver WSFO and the PFO. A simpler graphics display of PROFS mesonet and Limon weather radar data was made available to the Center Weather Service unit at the FAA Longmont Air Route Traffic Control Center. Provisions were made for updating the archived 1982 data base with full-resolution CP-2 Doppler radar data and research rapid-scan day (RRSD) satellite data for FY-1983 test and evaluation activities.

Plans FY 1983

- To upgrade the EDF data-acquisition system to include national guidance products from AFOS, LFM grid fields, aviation digital forecast (ADF) spectral products, and pilot reports.
- To develop advanced interactive workstations based on 32-bit computer architecture and integrate them into the EDF system.
- To upgrade the FAA Longmont ARTCC display to include a wider range of products and functional capabilities.
- To support the FY-1983 element evaluation, testing, and advanced sensor development activities.
- To generate detailed documentation describing EDF and its functional capabilities.

EXPLORATORY DEVELOPMENT GROUP (EDG)

This group selects new technologies and tailors them for use in advanced system testing.

Accomplishments FY 1982

The main accomplishment was participation in the successful development of an advanced real-time weather system. EDG was responsible for the definition of requirements, product development, and workstation implementation. This system, POWS, was tested at the Denver WSFO and at PFO. The tests ran from May to August, with the majority of the staffing provided by EDG. The results of the test are preliminary, but they show that POWS does improve both areal and point forecasts in the short range (0-2 hours).

Plans FY 1983

EDG will concentrate on implementation of a more advanced workstation that by the end of FY 1983 will have the following major improvements:

(1) Configurability. The new workstation is really a system to create systems. For example, a radar workstation could be created to test advanced radar, and another to test combined satellite and radar. Each of these would be of value for determining future operational needs.

(2) Applications. The workstation will do more than merely display data; it will use the power of the computer to assist the forecaster with forecasting algorithms. EDG is developing advanced application programs for this purpose.

(3) Advanced sensors. The system will also accommodate use of data from new sources such as Doppler radar, the VISSR atmospheric sounder (VAS), and the Profiler.

ADVANCED DATA SYSTEMS (ADS)

This group will be formed in early FY 1983 to incorporate VAS, Doppler radar, and Profiler data into the advanced workstation. Staff will be transferred from within the program, principally from EDF and EDG, to form ADS.

Plans FY 1983

ADS will focus on the following activities:

- Establishment of dependable ingest, processing, and display of data from Profiler, VAS, and Doppler radar.
- Interactions with the Next-Generation Radar (NEXRAD) program office to assist with a nationwide network of Doppler radars.
- Element evaluation of selected meteorological application of data from the three advanced sensors.

TEST AND EVALUATION (T&E)

T&E designs nowcasting and forecasting experiments (jointly with EDF and EDG staff), evaluates improvements achieved as a result of the experiments, and prepares reports and articles for NOAA management and the open literature.

Accomplishments FY 1982

T&E directed the design, implementation, and evaluation of a real-time operational nowcasting/forecasting experiment during the 1982 convective storm season in Colorado. Three forecast workstations were used: two in PFO, the other in the Denver WSFO. One PFO workstation had an advanced computer-driven color image and graphics display system; the other, an AFOS station and a commercial radar imaging receiver. The WSFO station was identical to the first PFO workstation. They both displayed (1) color-coded radar echo intensity images, mesonet surface data, and combined radar-mesonet data at 5-min update intervals, and (2) visible and infrared satellite images,

and combined satellite/radar images at 30-min update intervals. Both advanced workstations were able to loop and zoom images and to combine image and graphics products. The PFO AFOS workstation had no looping capabilities for radar data, no mesonet data, and limited satellite data (available only on laser facsimile). Watch and warning statements were issued from all three workstations, and an extensive weather verification procedure was implemented to provide the data necessary for evaluation.

Plans FY 1983

T&E will concentrate on two issues:

- Evaluation of the 1982 operational nowcasting/forecasting experiments and publication of the results.

- Development and implementation of plans for further experiments in FY 1983 and FY 1984 that use case study approaches (with 1982 data in displaced real-time experiments) as well as real-time operational situations; advanced data sets from Doppler radar, a satellite sounding system (VAS), and a Denver-based remote upper-air sounding system (Profiler) will be incorporated in these tests.

INTERAGENCY COORDINATION AND PRODUCT IMPLEMENTATION (ICPI)

This group collects and analyzes local weather service requirements, is the liaison between PROFS and other governmental and private groups, manages PROFS-related programs of other government agencies that are conducted within the PROFS Program Office, and is responsible for coordinating operational implementation of PROFS systems.

Accomplishments FY 1982

A detailed analysis of mesoscale service users' requirements completed in 1981 was updated in 1982. A comprehensive requirements document, which provides the basis for PROFS system development activities, was published in September 1982.

Close liaison has been maintained with NWS to ensure compatibility with current and future NWS operational requirements.

Transfer of an automated warning dissemination network design was accomplished. This network was tested successfully in the Denver WSFO during summer 1982.

Continued contact with other agencies and the various service user groups has been maintained to update requirements as necessary and keep those groups apprised of PROFS development activities.

The cooperative demonstration program with the FAA involving the display of WSR radar and PROFS mesonet data for operational evaluation started in the spring of 1982.

The cooperative Minimum Energy Routes Interactive Techniques (MERIT) Project with NASA, involving the development of interactive techniques for improving winds-aloft forecasts for aviation flight planning, started in February 1982.

Economic value analyses of specific short-range forecasts to the electricity-generating industry were completed in FY 1982.

Plans FY 1983

Documentation of user service requirements will be further updated in 1983. Close coordination will be continued with NWS. Economic value analyses of short-range forecasts for urban snow removal operations and energy management will be completed. Cooperative demonstration programs with the FAA and NASA will be continued and expanded to test the utility of various mesoscale service products in the aviation operational environment. The FAA program will involve providing the Denver Air Traffic Control Center (located in Longmont, Colo.) with a VAX-based enhanced interactive workstation for testing PROFS display products. The NASA program will involve the continued use of the PROFS interactive workstation for operational testing of improved winds-aloft forecasts.

COOPERATIVE PROGRAMS

In addition to its internal work, PROFS does extensive cooperative work with other groups. Two of these are NOAA institutes: CIRA at Colorado State University, Fort Collins, and CIRES at the University of Colorado, Boulder. The joint effort with CIRA includes satellite product development, data archiving, work on a socioeconomic model, and design of an emergency alerting network. The design was completed, and the network installed and tested, at the Denver WSFO during the 1982 real-time exercise. The Director of Forecast Operations at the Royal Netherlands Meteorological Institute, who joined CIRES in January 1981, worked at PROFS until January 1982 on the application of research results to practical forecasting situations.

PROFS has also cooperated with the National Center for Atmospheric Research (NCAR) in several ways:

- Data from NCAR's CP-2 Doppler radar were routinely received at PROFS during the 1982 convective storm exercise and will become standard input to the advanced workstation.
- PROFS supplied daily weather charts and arranged for two extra daily radiosonde reports to NCAR's Joint Airport Weather Studies (JAWS) experiment of summer 1982.
- NCAR and PROFS jointly supported chase teams that verified reports of severe weather during the summer exercises of both groups.
- PROFS made its 1982 summer data archives available to JAWS.
- Two receiving stations for satellite data were set up by PROFS and NCAR.

WEATHER MODIFICATION PROGRAM

The Weather Modification Program (WMP) was formed from the Weather Modification Program Office (WMPO); the Acting Director is William L. Woodley. All FY-1983 WMP programs, except Federal-State Cooperative Research, were aborted in December 1983 when funding was eliminated by ERL.

Accomplishments FY 1982

The following are WMPO accomplishments.

RESEARCH AND COORDINATION OF WEATHER MODIFICATION PROJECTS--NATIONAL

WMPO was directly involved in the following four projects that were organized to provide information concerning the needed parameters for predictability in weather modification efforts.

COSE III

The Colorado Orographic Seeding Experiment (COSE III) was carried out in December and January of FY 1982.

BUCOE

The Boulder Upslope Cloud Observation Experiment (BUCOE) was used as a means of making intercomparisons of remote-sensing equipment and accumulating a data set for the study of upslope precipitation conditions.

Federal-State Cooperative Research--North Dakota

A summer program was conducted in North Dakota to extend the data set that was started in 1981. Emphasis was placed on defining the characteristics of non-seeded clouds, which may affect their potential seedability through either microphysical or dynamic changes.

Federal-State Cooperative Research--Utah

The report covering the FY-1981 field program was completed by the subcontractor, Utah State University. The report revealed areas where the data set produced inconclusive data. As a result it showed where the emphasis should be placed in the next field program, which will be implemented in FY 1983.

ADVISORY SERVICE--FOREIGN

The WMPO Director provided advisory service to the World Meteorological Organization concerning the weather modification program in Spain.

TECHNOLOGY TRANSFER

Airborne Doppler Radar

The airborne Doppler radar that was developed in WMPO was flight tested on the NOAA WP-3D aircraft during the CYCLES (Cyclonic Extratropical Storms) and JAWS (Joint Airport Weather Studies) experiments and successfully intercompared with ground-based Doppler.

WMPO's expertise in airborne Doppler radar was used by the Federal Aviation Administration to evaluate two commercial airborne Doppler radars that are proposed for use by the airlines in weather turbulence detection and avoidance. The radars' techniques were those currently used in both the NOAA ground and airborne Doppler systems.

Tri-Function Remote-Sensing System

A preliminary study was completed on a highly mobile tri-function (radar, lidar, radiometer) remote-sensing system. The system would be able to provide inflow, outflow, boundary, and internal data from a single platform for cloud systems that are being studied for seeding potential and seeding results.

ADDS

On the basis of the positive results achieved during the tests of the prototype ADDS (Airborne Distributed Data System), the Secretary of the Air Force has approved the development of a NOAA-USAF-USAFR ADDS under NOAA leadership. Additionally, a NOAA briefing team visited Saudi Arabia and authorized provision of six ADDS for the Saudi C-130 aircraft.

ODWS

A new contract was awarded to VIZ for the purchase of 4200 more ODWS (Omega dropwindsonde) units. The contract will be monitored by WMPO.

NEW CONCEPTS FOR WEATHER MODIFICATION STUDIES, PREDICTIONS, AND EVALUATIONS

WMPO became aware of two new concepts for evaluation and prediction of weather modification efforts. One method was developed by the Desert Research Institute (DRI) to determine the quantity of seeding agent that was actually involved in the precipitation process and the quantity that was scavenged by the already-formed precipitating particles. The second concept is the use of satellite data to deter- mine causes and locations of formations of convective cells that will have seeding potential.

Plans FY 1983

The following are WMP plans in the area of Federal-State Cooperative Research.

NORTH DAKOTA

Primary emphasis will be on analyzing the data that were collected during the FY-1981 and -1982 field programs. The data are to be analyzed and integrated with data analyses from prior years.

UTAH

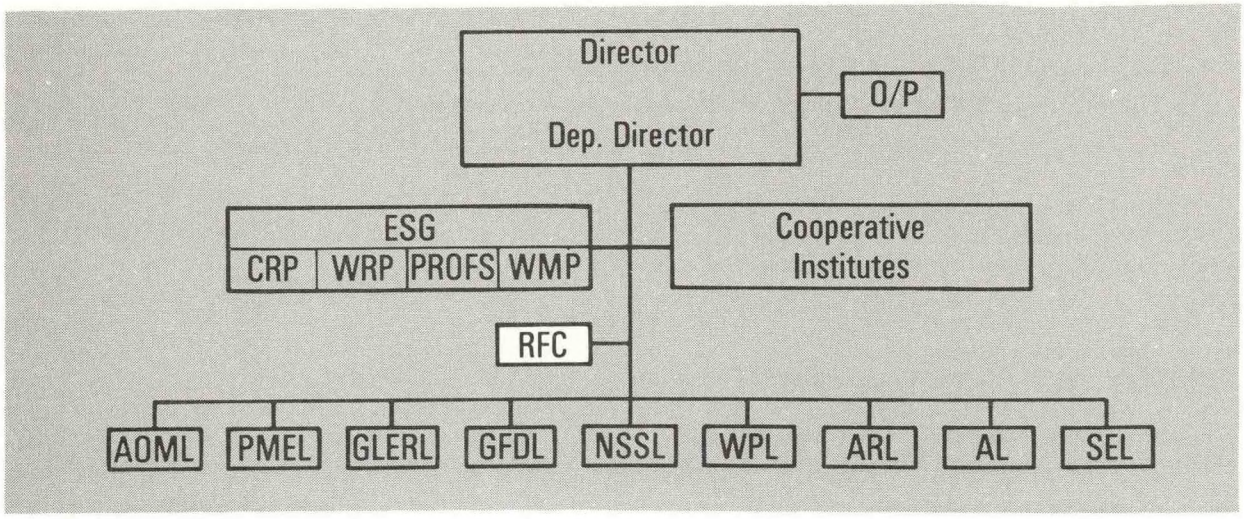
A field program is planned that will run from January through March 1983. The objectives of the program will be to provide data for (1) definition of the existence, characteristics, and extent of liquid water in wintertime Utah storms as a measure of seeding potential and (2) studies of cloud hydrometeor trajectories and potential seeding material trajectories.

NEVADA

A new cooperative research program will begin in Nevada. The principal research organization there will be DRI. The focus of research will be the "area of effect," i.e., not only the microphysical and dynamical aspects of cloud seeding but also questions of water budgets, optimization of seeding technology, and interstate issues.

RESEARCH FACILITIES CENTER
Miami, Florida

C.B. Emmanuel
Director



The Research Facilities Center (RFC) maintains, instruments, and operates aircraft to support a variety of environmental research programs of NOAA and other government agencies. The mission of RFC is carried out through four groups:

- The Flight Operations Group maintains and operates the aircraft and oversees all matters relating to flight safety.
- The Helicopter Operations Group maintains and operates four UH-1 helicopters in support of OCSEAP in Alaska.
- The Scientific Instrumentation Group provides, installs, and operates the aircraft research instrumentation.
- The Research Systems Group provides liaison with users; calibrates all sensors; writes, maintains, and upgrades software for the aircraft data systems; and processes collected data to meet user requirements.

During FY 1982, RFC operated two WP-3D, four-engine turboprop aircraft. Both aircraft carry a multitude of sophisticated research systems capable of measuring a wide range of atmospheric and oceanic parameters.

Effective FY 1984, RFC will be a part of the Office of Aircraft Operations in the National Environmental Satellite Data and Information Service.

Accomplishments FY 1982

RFC participated in its first Arctic program, the Marginal Ice Zone Experiment (MIZEX), operating one WP-3D aircraft from Elmendorf AFB in Anchorage, Alaska, during February. Since additional Arctic programs are foreseen, this was a particularly valuable experience.

RFC software for data quality control has been updated and augmented with

- A utility library for statistical and spectral analysis.
- An upgraded ground-based data preprocessing system.
- Renavigation and quick-look data quality control routines.

Data quality control has been further enhanced by

- Routine calibration of pressure sensors and radiometers.
- Aircraft intercomparisons and tower fly-by calibrations for major programs.

Nine-track tape decks were installed in the main data systems of both WP-3D aircraft (N42RF and N43RF). These afford a higher recording density and an onboard playback capability for both the radar and cloud physics tapes.

The analog patch panel of the data system was replaced with one of RFC design, which offers increased flexibility, reliability, and improved monitoring and testing capability, along with a substantial reduction in size and weight.

An aerosol sampling system was installed on N43RF for use in the study of the exhaust cloud produced during the launch of the shuttle spacecraft (STS-3).

Transducers for sensing angles of attack and sideslip were replaced on N42RF with newer units less susceptible to drift.

New Collins WXR700C nose radar systems were acquired. Installation on both aircraft is to be completed by January 1983.

Upgrading of the Aircraft Satellite Data Link (ASDL) has been undertaken. The new system, to be in operation for the 1983 hurricane season, provides for the transmission of radar pictures and a greater interaction with the operator, in addition to the previous transmission capabilities.

As a part of the NOAA mission, the RFC aircraft participated in a wide variety of programs. The extensive instrumentation carried by the aircraft permit the support of a diversity of research activities. Their endurance allows for observations in otherwise inaccessible regions, spatial and temporal.

In FY 1982, nine base-funded (492.2 hours) and five reimbursable (293.2 hours) projects were supported, for a total of 785.4 mission hours. The distribution of the flight hours and a brief description of the projects are in the following sections.

BASE-FUNDED PROGRAMS

The FY-1982 base-funded programs and the role of the aircraft in the programs are as follows.

Marginal Ice Zone Experiment (MIZEX), 76.5 Hours

The WP-3D aircraft with its standard and specialized instrumentation made several flights over the Arctic-Bering Sea regions collecting data in support of the program's objectives, which were to

- Map the heat and momentum fluxes as a function of ice concentration and floe size distribution.
- Resolve the dynamics of the intense cloud streets seaward of the ice edge, which account for massive transfer of heat and moisture from the ocean to the atmosphere.

- Determine the influence of ocean swell on ice edge processes.
- Provide estimates of drag coefficients for a model of sea ice behavior in the Bering.

Rainbands in Cyclonic Extratropical Storms (CYCLES), 38.6 Hours

The fully instrumented aircraft made several flights over the northeast Pacific to collect data in cyclone storms as they were approaching the coastline of Washington State. The experiment objectives were to

- Establish the mechanisms for the initiation and maintenance of the rainbands.
- Explore fully the dynamics and microstructures of the rainbands.

Lake Erie Directional Wave Study and Coastal Boundary Layer Measurements, 31.8 Hours

Flights were made over the lake during the passage of severe winter storms. Instrumentation on the aircraft supported the program objectives, which were to

- Measure the surface wind and wave conditions.
- Test and develop improved wave prediction models.

The aircraft flights were to document test cases for use in calibrating wave prediction models.

Ice Crystal Processes Studies, 46.4 Hours

The aircraft provided long-distance missions in winter storms over Colorado with full instrumentation. The cloud physics package was of special importance. The program objective was to gain fundamental understanding of cloud ice processes and their roles in regulating precipitation efficiency.

East Coast Winter Storms, 22.6 Hours

With aircraft operating out of Boston, this program was designed to study the thermodynamic and kinematic structure of mesoscale features preceding warm fronts to determine the mechanisms of their formation. Although their study may be characterized as basic research, it should benefit the development of accurate quantitative forecasts of the heavy winter precipitation that falls in the northeastern United States in advance of surface warm fronts.

RFC

This program provided an opportunity to compare the ERL/RFC airborne Doppler radar with the MIT ground-based Doppler radar system.

Radiative Properties of Clouds, 36.2 Hours

Cloudiness and the effects of clouds in modulating heat exchange between ocean and atmosphere are important processes in climate variability. The program objective was the measurement of scattering and absorption of radiation by clouds and the determination of the relation of radiative flux effects to microphysical and observable properties of clouds. The aircraft provided long-distance, over-water flights in clouds.

Hurricane Research, 139.3 Hours

The primary objective of the hurricane research program, 15 July-31 October 1982, was to improve the short-range (24- to 36-h) hurricane track prediction. Data obtained in support of this effort are also used in investigations of the interaction

between the synoptic-scale fields, vortex intensity, and tracks. Dropwindsonde missions in support of this effort were flown in Hurricane Debby in the Atlantic and Hurricane Olivia in the eastern Pacific.

RFC Training, Calibration, and Development, 69.8 Hours

To maintain and enhance the effectiveness with which RFC is able to support diverse programs, flights were made in this category for proficiency maintenance, systems calibration, tests, and development.

Joint Airport Weather Studies (JAWS), 31.0 Hours

Aircraft flights were made in the vicinity of Denver's Stapleton International Airport during the passage of severe thunderstorms. The objective was to collect data for better prediction of wind and wind shear conditions.

OTHER-AGENCY-FUNDED PROGRAMS

During FY 1982, other-agency-funded programs were as follows.

NASA Shuttle, 13.6 Hours

The aircraft, with standard and specialized cloud physics instrumentation, made multiple penetrations of the exhaust cloud produced during the launch of Columbia III. The program objective was to determine the acidity of the cloud, and its dispersion in the environment.

USAF-RFC Calibration Flight, 14.3 Hours

RFC developed, constructed, and installed some of the instrumentation carried by certain USAF weather aircraft. Periodically, intercomparison flights are made with the WP-3D's. One such intercomparison (two flights) took place in FY 1982 with excellent results.

Hurricane Reconnaissance, 96.6 Hours

Hurricane reconnaissance is conducted only when requested by CARCAH (Chief, Aerial Reconnaissance Coordinator, All Hurricanes). Data are transmitted via the ASDL to the National Hurricane Center (NHC) for use in and upgrading of forecasting models of hurricane tracks and intensities.

RFC responsibilities are to (1) augment USAF reconnaissance with accurate high-density data when storms are within 24 hours of landfall on the continental United States; (2) augment USAF reconnaissance when Department of Commerce needs exceed the capabilities of the Department of Defense resources; (3) assume responsibility for hurricane reconnaissance in foreign airspace from which military aircraft may be restricted; and (4) deploy rapidly, in response to NHC requests, to areas of disturbed weather that have potential for tropical storm development.

Alpine Experiment (ALPEX), 158.7 Hours

RFC participated in this Geneva-based international experiment, the last of the GARP series. Seventeen missions were flown around and over the Alps, and over the Mediterranean Sea, the Adriatic Sea, and the Pyrenees in support of this program. The goals were to

- Study airflow and mass fields over and around the Alpine mountain complex.
- Study lee cyclogenesis.

- Determine mountain drag and momentum flux.
- Determine turbulent fluxes over the Mediterranean Sea.

East Coast Winter Storms, 10 Hours

This is a continuation of the program by the same name in the base-funded section.

THE HELICOPTER OPERATIONS GROUP

In support of OCSEAP and the Bureau of Land Management, the four UH-1 helicopters flew 1180 hours in FY 1982. The program distribution was as follows.

Alaska Seismic Activity Monitoring Network

Installation and maintenance work were conducted on two seismic nets operated by Lamont-Doherty and the University of Alaska for OCSEAP. The coverage of these nets included Bristol Bay, King Salmon, and the Alaska Peninsula.

Arctic Shoreline Ice Buildup

An extensive survey was conducted to determine the shore buildup of sea ice along the Arctic coast. The area surveyed extended from Norton Sound north to the Canadian border.

Marine-Mammal Population Study

Investigations into the natural history, population, and effects of seismic activity on marine mammals were conducted in the Harrison Bay-Prudhoe Bay area. Helicopter support included transportation of gear, portable buildings, and personnel to the various camps that were set up on the ice.

Ice Pack Circulation in the Bering Sea

During the month of February, a NOAA helicopter, operating out of Nome, Alaska, assisted in deploying weather stations and positioning transponders placed on portions of the ice pack between Nunivak Island and St. Lawrence Island, and in the Bering Strait. The instruments were used to determine the relative importance of wind speed and direction, and surface currents on ice pack drift.

Beaufort Lagoon Ecological Study

RFC

This project was an extensive study of marine plant formations and animal populations in the Demarcation Bay area. Missions included installing and monitoring weather stations, deploying and recovering current meters, running bird transects, collecting specimens, and providing general helicopter transport of people and equipment between the study site and Deadhorse.

Polar Bear, Natural History, and Population Study

The area under investigation ran from Pt. Barrow to Barter Island. The study entailed locating polar bears on the ice. They were then tranquilized, tagged, measured, and weighed; in addition, a few of the adult females were equipped with a radio collar.

Offshore Conductivity, Temperature, and Depth (CTD) Measurements

A CTD instrument and several current meters were deployed through the ice pack between Cape Lisburne and Pt. Barrow, Alaska; two of the transect lines extended from

the coastline out to the U.S.-U.S.S.R. convention line. Because of the large amount of equipment to be carried and the long distances to be covered, two NOAA helicopters were used to accomplish this mission.

Plans FY 1983

An environmental chamber will be permanently installed in the RFC calibration laboratory. The control of pressure, temperature, and humidity afforded by this chamber will augment the existing capabilities.

Installation of new nose radars on both aircraft will be completed.

Upgrading of the ASDL hardware and software will be completed. This will permit the transmission of radar pictures during the 1983 hurricane season.

Updates and improvements will be incorporated in the Omega navigation system. These include corrections to accommodate the new location (Australia) of Omega station G, and updated Omega propagation tables and modal interference correction algorithms.

During FY 1983, the aircraft are again scheduled to support programs that require standard and specialized instrumentation in remote areas.

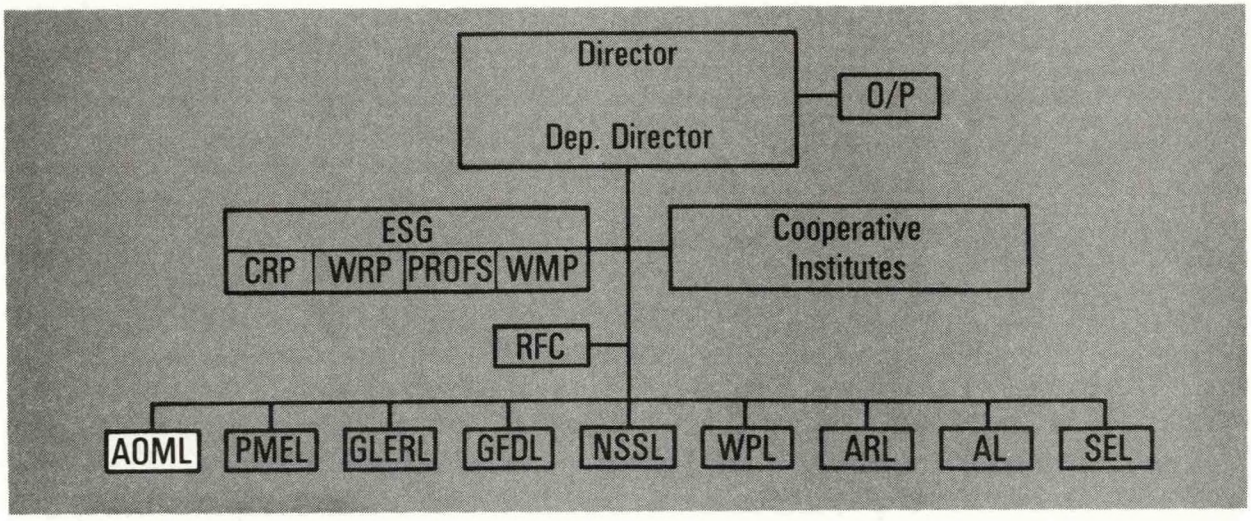
Although final program support has not been completed, the following are some of the programs already approved.

- East Coast Offshore Cyclogenesis, 38 flight hours.
- Cook Inlet Wind Study/MIZEX 83, 102 flight hours.
- Arctic Gas and Aerosol Sampling Program, 110 flight hours.
- Hurricane Program, 120 flight hours.
- CO_2 Flux, 20 flight hours.
- RFC Training, Testing, and Calibration, 100 flight hours.
- Hurricane Reconnaissance, as required.
- OCSEAP, 1200 helicopter flight hours.

ATLANTIC OCEANOGRAPHIC AND METEOROLOGICAL LABORATORY

Miami, Florida

Hugo F. Bezdek
Director



The Atlantic Oceanographic and Meteorological Laboratory (AOML) is organized to pursue basic and applied research programs in oceanography and tropical meteorology. Oceanographic investigations center on fluxes of energy, momentum, and materials through the air-sea interface; the transport and composition (thermal and chemical) of water in the ocean volume; and hydrothermal processes of mineralization at seafloor spreading centers. Meteorological research is carried out to improve the description, understanding, and prediction of hurricanes and to determine their potential for beneficial modification. The research program is enlarged by the Cooperative Institute for Marine and Atmospheric Studies (CIMAS), a joint enterprise with the Rosenstiel School of Marine and Atmospheric Science of the University of Miami. CIMAS enables NOAA and university scientists to collaborate on problems of mutual interest, and facilitates the participation of visiting scientists.

AOML's current research program addresses processes related to climate, marine assessment, marine resources, ocean and lake services, and weather observations and predictions. CIMAS scientists currently conduct research in climate, marine sedimentation, and tropical meteorology.

CLIMATE RESEARCH

Climate research at AOML is increasingly focused on investigations of the role of the oceans in determining large-scale climate and climate variability. The emphasis is on observational projects, based primarily on the NOAA research vessels, but making extensive use of data from satellites, buoys, and other instrument systems. The large scale of many of the phenomena addressed, and the diversity of the observations required, mandate that much of the work must be done through cooperative arrangements with investigators in other NOAA laboratories (primarily PMEL and GFDL) and university laboratories, and with overseas investigators, particularly in western Europe and South America. During FY 1982, and continuing for FY 1983, the program for climate research in AOML focuses on oceanographic aspects of three major investigations: (1) analytical studies of 1979 oceanographic data from the Global Weather Experiment, more

commonly called the First GARP Global Experiment (FGGE), for which NOAA has Federal lead-agency responsibility; (2) the Equatorial Pacific Ocean Climate Studies (EPOCS), initiated in 1979, which is a several-year investigation of the genesis, evolution, and large-scale atmospheric consequence of interannual sea surface temperature anomalies occurring in the tropical Pacific Ocean; and (3) the Subtropical Atlantic Climate Studies (STACS) project, which was initiated in FY 1981. STACS's long-term objective is to understand the role that ocean circulation in the North Atlantic Subtropical Gyre plays in the heat balance of the Earth. The near-term focus is on development of an economic methodology for monitoring the Florida Current (Gulf Stream) over extended periods.

Accomplishments FY 1982

FGGE

A compilation was begun of all data collected in the equatorial Atlantic Ocean during FGGE in 1979. A preliminary analysis of these and climatological data suggest that the cold-water tongue observed on and south of the Equator during boreal summer (which has been shown to have important implications in the global energy balance) is initiated by increased vertical mixing and equatorial upwelling during May and early June. During late June and July, advection by the South Equatorial Current plays a more important role in the development of the tongue.

Results of an analysis of CTD (conductivity-temperature-depth) sections across the equatorial Atlantic taken during FGGE have provided further evidence of the seasonal change of the zonal pressure gradient in response to the seasonal change of the zonal wind stress.

EPOCS

On the basis of the work in the far eastern Pacific this year a better understanding is developing of the circulation patterns in this area and how these are linked to annual and interannual temperature variations. A simple model was developed to explain the temperature changes observed during the 1972 El Niño. During March of 1982 the observed current patterns were weaker than, but similar to, those that are to be expected during a major El Niño. These were the first direct observations of such a flow field.

When the effect of the Earth's rotation is included in a thermohaline stability analysis, weak oceanographic vertical shear is sufficient to allow an overstable internal wave instability (which has also been referred to as a diffusive thermohaline instability). Also, the analysis shows that horizontally propagating internal waves in a gradient of heat and salt will induce fluxes that lead to multistep profiles if diffusion is included. Calculations of the first-order induced-horizontal-momentum transports suggest that instability of internal waves traveling transverse to a constant shear flow can contribute to formation of shear layers and velocity jets.

STACS

Data collection efforts for STACS began in earnest in FY 1982. The suitability of Pegasus as an instrument for obtaining absolute velocity profiles in the Straits of Florida was demonstrated, and three cruises conducted in conjunction with the University of Miami were completed. Preliminary data analysis suggests that the velocity and transport characteristics of the Florida Current at 27°N are very similar to those at Miami. Current meter data were collected by the University of Miami with support from AOML and the Office of Naval Research. Initial analysis indicates that greatest variability in the water column occurs near the bottom, where most of the historical data were collected. Confirmed by further analysis, this finding could result in a

reduction of future observational requirements. Historical current meter data were analyzed to ascertain what portion of the energy in the diurnal and semidiurnal bands is deterministic and what portion is nonstationary. Once determined, an estimate can be made of how much noise in the diurnal band will remain in the Pegasus data after removal of the tidal signal.

A study of monitoring strategies was initiated with the objective of developing a formalism for evaluating the effectiveness of systems for use in monitoring the Florida Current. The study emphasis is to evaluate the performance of purely acoustic systems, as well as acoustic systems that are augmented by other data. Tabulations of historical data and adaptation of sound propagation models were completed for this task.

The first complete description of the results from the 1981 Local Tomography Experiment was published during FY 1982. AOML scientists and the NOAA Ship RESEARCHER participated in this experiment along with researchers from Scripps Institution of Oceanography (SIO), Massachusetts Institute of Technology (MIT), Woods Hole Oceanographic Institution (WHOI), and the University of Michigan. The results demonstrate that changes in the oceanic thermal field over scales of hundreds of kilometers can be deduced from observations of variations in travel time of low-frequency acoustic transmissions between moored arrays.

Plans FY 1983

FGGE

Compilation of all the oceanic and surface atmospheric data collected during FGGE in the equatorial Atlantic will be completed. In addition, data collected during EQUALANT (Equatorial Atlantic Studies) 1963 and GATE (GARP Atlantic Tropical Experiment) 1974 have been obtained. Heat budget computations, using data from these years, will be made to better define those processes that are important in the development of the sea surface temperature field, and to begin the study of interannual variability in the Atlantic.

One important feature of equatorial dynamics is the formation and maintenance of the thermostad, the layer just below the Equatorial Undercurrent, which extends from about 5°N to 5°S. Little is known about the nature of the thermostad and the role it plays in the dynamics of the equatorial ocean. A broad definition of the thermostad will be used in analyzing FGGE data to understand the nature of the thermostad and study processes that may contribute to its formation.

EPOCS

The final two cruises in the EPOCS far-eastern Pacific program will be carried out. The planned studies are especially exciting because the atmospheric circulation pattern in the western and central Pacific became very El Niño-like during the latter half of 1982. The planned EPOCS field studies will provide good documentation of the effects of these atmospheric changes on thermal and velocity fields in the eastern Pacific. Analyses of FY 1982 data will continue; reports are planned on findings relating to the oceanic heat budget, dynamics of vigorous mesoscale currents observed in the north equatorial eastern Pacific, large-scale features of circulation in the South Equatorial Current, and the pattern of low-frequency current variations off the coasts of Peru and Ecuador.

Analysis of thermohaline stability, wave-induced flux processes, and likely turbulent structure of the equatorial current system will be used to interpret data obtained with a dual-sensor probe and other instruments in the eastern equatorial Pacific and to understand the processes contributing to the formation and maintenance

of features such as layer structures, thermostads, velocity jets, and various fine-scale features.

STACS

Three cruises for profiling temperature, salinity, and currents are planned in FY 1983 to complete the 1-yr observational effort. Analyses to remove high-frequency variability (in particular tidal and several-day periods) from the data will be developed through continued analysis of historical data and the current meter data being collected. Once the seasonal signal has been determined, a more efficient cruise and current meter strategy can be developed to monitor this signal. Causes of various scales of variability will also be studied through comparison of the oceanic observations with atmospheric observations. Work will begin on evaluation of candidate designs for observational systems early in FY 1983, and by the end of the year a recommendation will be made for the design of an acoustical sampling system for use in the Straits of Florida. Work is also being started on development of a numerical model to be used for interpretation of electrical-potential differences induced by the passage of the Florida Current through the magnetic field of the Earth. Measurement projects complementary to this modeling work are under way at PMEL and the University of Washington Applied Physics Laboratory.

Work will also begin on the development of a bottom-mounted, high-frequency profiling current measurement system for use in the Straits of Florida. It is intended that the system will sample the current locally over the full depth. It is hoped that a test of a prototype system can be made within the year.

There will be further work to improve on the initial results of the Local Tomography Experiment. It is expected that the additional effort will result in recovery of more usable information from the acoustic travel time records and that this, along with improved computational techniques, will result in improved reconstructions of variations in the oceanic thermal field.

MARINE ASSESSMENT

A major goal of the AOML research programs in marine assessment is to develop an understanding of ocean processes, their variations, and the effect of these variations on ocean resources, especially living marine resources. Present research is of two types: (1) generic research programs, such as Transformation and Assimilation of Pollutants by Natural Processes (TAP), Pollutant-Particle Relationships in the Marine Environment (P-PRIME), and the program on Natural Marine Sources of Acid Rain Precursors, where natural processes are studied to develop information essential to addressing specific environmental problems; and (2) application of the results of these generic programs to recognized or perceived problems, e.g., the recently completed Flower Garden's Reef project, the New York Bight Mud Cap study for the dredge spoil dump site, and the Mississippi River Outflow project.

Accomplishments FY 1982

AOML continued research efforts in understanding natural processes affecting fish resources in the northern Gulf of Mexico and the impacts of metallic and organic pollutants. The work is conducted cooperatively with the NMFS/SEFC (National Marine Fisheries Service/South East Fisheries Center), Beaufort, N.C., laboratory and focuses on the synergistic effects of natural and pollutant organic matter and bioactive metals on the food web. In contrast with previous years, research focused on conducting sophisticated experiments designed to uncover the coupling mechanisms between biological and chemical phenomena observed in the field. The most recent cruise of NOAA Ship

RESEARCHER occurred in August-September 1982. Recent results show the following:

- Complexation of toxic metals with dissolved humic substances reduces their toxicity.
- Structure or age of the humic metal complexers found in seawater is more important than their quantity in complexing toxic metals. The strongest complexers are found in the highly productive waters of the northern Gulf of Mexico.
- Metal complexes with dissolved humic substances are formed in seconds to minutes and are broken down only after several hours.
- The fragility of the metal complexers in light was demonstrated in laboratory studies. This correlates with our observations that the complexing capacity of the ocean is greater at night.
- Marine humic acid reduces insoluble manganese oxide to soluble manganese salts by a light-catalyzed reaction. (Manganese is an essential nutrient.)
- Methods other than carbon fixation for more realistically measuring phytoplankton growth rates were developed, focusing on sulfur metabolism.
- A testable conceptual model of the complex interrelationships between biota, dissolved organic matter, toxic and nutrient metals, and sunlight was constructed and is consistent with all our observations to date.

In FY 1982, the NOAA-EPA R&D program progressed to its final stages. No field work was done, but chemical analyses have been completed from previous studies. Acoustical analysis with emphasis on acoustical characterization of the bottom boundary layer and the thermocline region in the Texas Flower Gardens Bank area is under way.

A joint program with the U.S. Army Corps of Engineers (COE) was conducted from the COE test pier located in Duck, N.C. AOML personnel used a 3-MHz acoustical system mounted on a tripod in the seaward area of the surf zone to monitor sediment movement along the bottom, created by surface wave activity. A manuscript is in preparation as analysis proceeds on the acoustical data.

A Doppler current measurement system was developed and was tested in the Chesapeake Bay. This test was conducted jointly with the NOAA Office of Technology and Engineering Services. The Doppler current measurement system uses the transverse Doppler principle and measures velocities with a resolution of 0.75 cm s^{-1} after an 80-s observation time. Comparison with a propeller current meter in the Chesapeake shows agreement with Doppler-measured currents within 2 cm s^{-1}. Acoustical intensity measurements were also made to estimate concentrations of particulate materials.

AOML

Acoustical analysis has been completed on the New York Bight Dredge Material Tracking Experiment (DREMATREX). Floor and ceiling effects were revealed in the dredge-dump plume structure as observed on concentration contour maps. Peak concentrations in the plumes from the dredge material decayed as a function of the second power of time (t^2). Particle budgets, based on acoustic calculations, decreased exponentially as a function of time for each of three layers observed and for the water column as a whole. Direct and linear relationships were found among the observed acoustic intensity, measured total suspended material, theoretically calculated acoustic intensity, and total suspended material using particle numbers and sizes. These data were presented at the Third International Ocean Dumping Symposium.

The New York Bight Mud Cap study was completed and a report to COE is in the final stages of preparation and review. The project studied the erodibility of a

"sediment cap" that COE had emplaced, as a cover for "contaminated" dredged materials at the New York Dredged Materials Dumpsite. (Note: The sediment cap was primarily fine-grained sand, clean for ocean dumping purposes, which varied in thickness from 4 to 8 ft.) Project results indicated the following:

- Under "normal" yearly conditions, the cap should be slightly eroded at a rate of between 0.02 and 0.05 ft yr^{-1}; i.e., it should be eroded by 1 ft in 18.3-45.7 years. Thus, in the absence of an extremely severe storm, the cap appears to have a fairly long life expectancy.

- The cap is most susceptible to erosion during the winter season when the water column is unstratified. Storm conditions when the wind blows from directions of open-water fetch (e.g., east-northwest to south-southeast) are especially important for transporting bottom sediments.

- Severe weather conditions did not occur during the measurement period, but sediment transport did occur--primarily toward the south.

- Since fine-grained sands are the most easily eroded materials, the cap could be improved by adding additional materials, consisting of a mixture of sand, silt, and clay containing mostly mineral grains, with little or no organic matter and preferably with relatively low water content.

During FY 1982, AOML initiated a program designed to develop an understanding of the role that oceans play in the cycles of atmospheric trace gases, to assess present and potential human impact on these cycles. Budgets of most atmospheric constituents indicate that even though natural release rates are small, natural sources are larger than anthropogenic sources on a global basis, primarily because of the large area from which they are released. This effort includes research on those constituents of the atmosphere important in understanding the hydrogen ion content of precipitation as well as atmospheric chemical processes. These compounds can be precursors or ameliorative agents, and/or can affect ancillary atmospheric chemical processes related to precipitation chemistry. The program approaches ocean-atmosphere source and sink relationships primarily as biochemical and photochemical processes, and studies the natural cleansing mechanisms operating in the atmosphere.

One research cruise dedicated to this program was conducted in FY 1982, and additional data were obtained as an ancillary effort on a second cruise. The data indicate that a definite relationship exists between the production of reduced sulfur gases (and other gases) in the water column and primary productivity. There is also a relationship (other than biological) between water column concentrations of these volatiles and light-related processes. Concentrations of these compounds vary over an order of magnitude in the water column during time frames on the order of hours to days, thus indicating a very dynamic system. Exchange of volatiles from the water to the atmosphere is strongly related to wind speed; however, the average concentrations of dimethyl sulfide in the atmosphere over the open ocean under low to moderate wind speeds are very small, even with high water column concentrations. Dimethyl sulfide appears to be unable to readily leave the water column, and/or it has a short lifetime in the atmosphere. These data on low atmospheric concentrations of dimethyl sulfide in the open ocean confirm other observations and have caused a reevaluation of the role of this compound in atmospheric cycles.

In FY 1982, AOML also initiated the P-PRIME program to study pollutant-particle relationships in the marine environment. The program is designed to test the hypothesis that major river outflows can effectively deal with relatively large pollutant loadings because of packaging of the pollutants by particles and rapid sedimentation

and burial. Efforts are designed to determine the efficiency of this packaging, the permanence of removal of pollutants to the sediments, and the rates of any fluxes back to the overlying water column. Two major cruise efforts, conducted in FY 1982 on board the NOAA Ship RESEARCHER, focused on the Mississippi River Outflow and the nearby Gulf of Mexico waters.

Plans FY 1983

AOML/SEFC cooperative research on chemical processes affecting productivity and health of larval fish will test the conceptual model formulated in FY 1982, from which several specific predictions have been made. These predictions will be tested in a major upwelling system during a May cruise aboard the NOAA Ship RESEARCHER. In addition, interactive effects of metals and organics will be tested on cultures of the phytoplankton species that dominate either the oligotrophic or the eutrophic waters of the Gulf of Mexico.

A bulk-drilling mud study will be conducted in the Gulf of Mexico with the cooperation of Mobile Producing Texas and New Mexico, Inc. Present plans call for the use of acoustical systems developed by AOML to track and map material that has been shunted into the bottom boundary layer. Hydrographic and chemical data will also be taken for later use in developing a qualitative map of the shunted plume.

AOML's work on Doppler current meter development will continue at its present pace. Emphasis in FY 1983 will be on upgrading the present prototype system and conducting a test in the Miami area. A research survey of the Hudson Raritan Estuary system will also be conducted to develop plans for Doppler current meter usage in that area.

AOML's acid rain research effort will focus on a major cruise studying the role of biological processes in determining water column concentrations of atmospheric trace gases and the release of these gases to the atmosphere. Research will be concentrated on processes affecting inorganic sulfur incorporation by bacteria and plankton, and the release of reduced volatile sulfur species and other trace gases by organisms. This cruise will be conducted in the highly productive waters of the Peru upwelling region. In addition, laboratory work will focus on those species that do release these volatile compounds to the water column and on the conditions under which this occurs. This laboratory work will be confined to closed culture systems of single species of organisms.

AOML will continue its research on pollutant-particle relationships (P-PRIME) in FY 1983. Efforts will be focused on pollutants such as lead, cadmium, polychlorinated biphenyls, and toxaphene. Special emphasis will be toward learning the effects of the recent decline in amounts of tetraethyl lead in gasolines on fluxes of lead to the ocean via rivers. As in FY 1982 this research will be focused on the Mississippi River Outflow.

MARINE RESOURCES

AOML research in marine resources is directed to the investigation of hydrothermal processes at seafloor spreading centers with reference to the role of these processes in concentrating metallic mineral deposits and in controlling the heavy-metal chemistry of seawater. Research at AOML is closely coordinated with research at OME, NOS, PMEL, and NMFS as part of the NOAA 5-yr research plan, "Deep-Sea Metals: Polymetallic Sulfides."

Accomplishments FY 1982

AOML organized and directed a NATO Advanced Research Institute (ARI) on the subject of "Hydrothermal Processes at Seafloor Spreading Centers," which brought together scientific leaders from 15 nations for the first interdisciplinary consideration of the geological, geophysical, geochemical, and biological aspects of this pioneering field of research. Participants in the ARI evaluated the state of the art and established ties for international cooperation in research in this rapidly developing field.

A team of scientists from AOML, WHOI, and MIT, who were jointly supported by NOAA and NSF, carried out a cooperative investigation of hydrothermal processes at a representative site on a slow-spreading oceanic ridge--the Trans-Atlantic Geothermal (TAG) field on the Mid-Atlantic Ridge--utilizing a submersible (DSRV ALVIN) and deep-towed geophysical instrumentation.

AOML participated in the Rift Acoustic Imaging Experiment (RAIE), which was a cooperative research cruise conducted by the Chief Scientist's office of NOS. The cruise also included scientists from academia, Lamont-Doherty Geological Observatory (LDGO), and observers from private industry. The cruise utilized NOAA's Sea Beam system to guide LDGO's unique Sea MARC (Sea Mapping and Remote Characterization) system (a deeply towed side-scan sonar) and a thermistor chain over the entire length of the Juan de Fuca Ridge. A successful camera tow and dredge haul were also completed during this cruise.

Plans FY 1983

A volume of proceedings of the NATO ARI, "Hydrothermal Processes at Seafloor Spreading Centers," is in preparation for publication by Plenum Press as part of the NATO Conference Series in Marine Sciences.

Data acquired by the cooperative NOAA-WHOI-MIT investigation of hydrothermal processes at a representative site on a slow-spreading oceanic ridge will be analyzed to provide the basis for comparison and global generalization of the role of hydrothermal concentration of mineral deposits and control of heavy-metal chemistry on slow-spreading (Atlantic) and fast-spreading (Pacific) oceanic ridges.

The geophysical data collected on RAIE during 1982 will be analyzed to delineate the physiography and morphology of the Juan de Fuca Ridge. This information will greatly enhance our understanding of ridge processes and will also reveal the most promising sites for the occurrence of hydrothermal activity and its associated mineral deposits. The heat flow measurements will point out areas of present seafloor volcanism. Dredged rock samples from the cruise will be analyzed for metal and mineral content.

OCEAN AND LAKE SERVICES

AOML research in ocean and lake services is presently concentrated on surface effects at the air-sea interface. These effects, especially under extreme conditions, are important to short-term forecasting of coastal and marine weather and wave conditions. Additional research is aimed at improving the observational equipment and

techniques that are used to collect data on the marine environment, with particular emphasis on ocean acoustic and airborne radar techniques.

Accomplishments FY 1982

A slanting-fetch-wave growth experiment was conducted by the experimental wave group in the Great Lakes in cooperation with GLERL. The AOML airborne imaging radar and laser profilometer were used to observe the two-dimensional wave structure during a severe October storm in Lake Ontario using NOAA's WP-3D aircraft.

An evaluation of the directional properties of hurricane waves was completed. Model predictions of directional wave properties were compared with SEASAT Synthetic Aperture Radar imagery of Pacific Hurricane Fico. Very good agreement was found for this storm that had a forward velocity of 5.0 m s^{-1}.

Wave imagery obtained in shallow water in the Cape Hatteras region during the Atlantic Remote Sensing Land Ocean Experiment (ARSLOE) was examined. Two-dimensional fast Fourier transforms of the radar imagery revealed refraction patterns in the shoal regions. ARSLOE, which was an extremely complicated situation because of strong onshore easterly winds that shifted south and then become southwesterly offshore winds, represented a severe test of the radar's ability to track various wave components. The radar observed both sea and swell components that accurately reflected the changing nature of the wind pattern over the previous 24-h period. Swell components from 0.09 to 0.16 Hz were observed as they propagated across the Hatteras shelf.

In collaboration with groups from seven different countries, a numerical wave model intercomparison study was brought to completion. The exercise compared the performance of 10 different numerical ocean wave prediction models in a series of test cases designed to explore specific characteristics of the models. Among the test cases was a simulation of a fast-moving hurricane. All models exhibited, to some extent, very high sea states in the right rear quadrant of the storm (the "resonance" effect). The reality and magnitude of this apparent effect remains to be ascertained. The study has established a benchmark for future work in ocean wave modeling.

A collaborative research project between AOML and the Max-Planck Institute for Meteorology in Hamburg, Germany, has been initiated. The purpose of the project is to develop an objective analysis scheme capable of assimilating data from the next generation of oceanographic satellites to produce, in near-real time, global analyses of surface wave and wind fields. Eventually, the technique will be extended to the full field of atmospheric prognostic variables, yielding optimal estimates of the state of the atmosphere so that numerical weather prediction schemes can be initialized. By-products of the analysis include research in climate and ocean circulation. The structure of the analysis scheme has now been identified and the necessary mathematical background worked out. Construction of a preliminary computer implementation is under way.

In support of the NOAA-identified need for systems to provide real-time monitoring of currents in shipping channels, AOML began analysis and evaluation of the capabilities and limitations of acoustic Doppler current-profiling systems. Available commercial systems were found to have severe limitations in shallow-water applications. As a result, concepts from Doppler radar and from Doppler laser were combined in an acoustic setting to produce the concept of transverse Doppler sonar. Transverse Doppler appears to be unique, and a patent application has been filed. It has a much more favorable combination of system characteristics that should work well in shallow

ship channels. As mentioned under Marine Assessment, an acoustic system was tested in Chesapeake Bay. Acoustic signals were recorded and processed to show that transverse Doppler is capable of measuring water velocity in shallow water.

Plans FY 1983

Efforts will continue to obtain airborne radar imagery of the directional properties of hurricanes moving at a cross section of forward velocities. Evaluation of the resonance effect for fast tropical and extratropical cyclones remains a priority area because of increased emphasis on oil- and metal-related activities in the offshore east coast region. The resonance effect results in higher-than-normal waves depending upon the reality of directional relaxation parameterizations of all existing wave prediction models. Radar imagery obtained during prior-year hurricane and winter storm events will continue to be analyzed with respect to model hindcast predictions.

The effect and presence of waves in the Marginal Ice Zone (MIZ) will be addressed experimentally, in collaboration with PMEL, in the Bering Sea MIZ experiment. The utility of the airborne radar to obtain measurements of ice roughness, waves in the MIZ, and ice concentration will be examined.

Collaboration will continue with Max-Planck Institute for Meteorology in the development of an objective scheme to produce global wind and wave fields from mixed data sets, including satellite observations. At present, the scheme has four elements: (1) a numerical atmosphere model, (2) a four-dimensional data assimilation procedure, (3) a numerical surface wave model to be driven by the atmosphere model, and (4) a procedure for deducing wind field corrections from satellite observations of the surface wave field. Elements (1) and (2) will be developed at Max-Planck Institute; (3) and (4) will be implemented at AOML. System integration and testing should begin by the end of FY 1983.

Analysis of the data obtained during the Chesapeake Bay experiment will continue in order to evaluate various algorithms for the extraction of velocity information from the recorded transverse Doppler system. This analysis will provide the basis for designing and building a prototype transverse Doppler package suitable for real-time current monitoring in shipping channels.

WEATHER OBSERVATION AND PREDICTION

AOML is NOAA's primary focus for research in tropical meteorology and hurricanes. Research teams concentrate on field programs, numerical hurricane modeling, and theoretical studies of hurricanes. The Laboratory's hurricane field program makes use of RFC aircraft to acquire unique data sets.

AOML interacts with the National Hurricane Center (NHC) and the National Meteorological Center (NMC) of the National Weather Service (NWS) in problems of hurricane prediction and with the National Center for Atmospheric Research (NCAR) on scientific investigations of the inner cores of hurricanes.

Accomplishments FY 1982

During the 1982 hurricane season, NOAA research aircraft collected data in Atlantic Hurricane Debby and eastern Pacific Hurricane Olivia. Both aircraft operated on 2 days in each storm. On the first day of the Hurricane Debby operation, one aircraft carried out a Doppler radar evaluation mission and a boundary layer experiment while the second aircraft dropped Omega dropwindsondes in the storm's periphery. On

the second day of Hurricane Debby flights, as well as on both operational days of Hurricane Olivia, Omega dropwindsondes were dropped by both aircraft in the storm's surrounding flow. These data were transmitted to NHC and NMC in real time.

The initial data processing and analyses of two hurricane rainband experiments (Hurricane Allen on 5 August 1980; Hurricane Floyd on 7 September 1981) were completed. The analyses present a striking contrast in band structure between the mature eyewall (Allen) and the outer rainband (Floyd). The principal differences in structure are the organization of the ascending air and the thermodynamics of the downdraft air. Within the eyewall, this ascent is highly organized on the mesoscale. The updraft cores (above 500 m) are consistently observed 1-5 km inward of the radius of maximum winds. Mesoscale vertical velocities computed from measurements of radial divergence agree fairly well with vertical-velocity observations composited with respect to the location of the tangential wind maximum. This implies that a substantial part of the eyewall is dominated by organized mesoscale ascent rather than by a few discrete convective cores.

The rainband's vertical-motion pattern is much more stochastic, resulting from the actions of convective cells that move down the band. The radar echo pattern reveals many more discrete cores of 40-45 dBZ in the rainband than in the more uniform eyewall.

The microphysical analyses of Hurricanes Allen and Irene show voluminous amounts of ice and very little liquid water, except in strong updrafts in the eyewall. The data show evidence of large-scale recirculation of ice particles throughout the storm from deep convection in the eyewall.

A study of the changes in boundary layer wind structure before and during the landfall of Hurricane Frederic show that the frictional effects of landfall acted to shift the region of maximum inflow angle to the landward side of the storm and to decrease coastal wind speeds by 20% relative to winds over the nearby water. Most of the damage caused by the storm was associated with the northern eyewall and occurred about 2 hours before landfall of the actual center.

Detailed analyses of airborne expendable bathythermograph (AXBT) and infrared radiation thermometer data have shown that hurricanes decrease sea surface temperatures (SST) in a consistent pattern with respect to the hurricane center. The pattern of cooling is crescent shaped. Maximum cooling occurs in the right rear quadrant of the storm in an area between the radius of maximum wind and twice that radius; little or no cooling occurs in the left front quadrant. The size of the area cooled is independent of storm speed U for $U > 5$ m s^{-1}, but increases nonlinearly as U decreases for $U < 5$ m s^{-1}. In addition, the magnitude of the cooling is a linear function of storm intensity. No significant cooling occurs at any storm speed or intensity for mixed-layer depths (MLD) exceeding about 70 m. Maximum cooling > 5° occurs for storms moving slower than 2 m s^{-1} in regions of shallow MLD (30-40 m).

AOML

MLD decreases beneath the storm center, beginning with the passage of the positive wind stress curl (negative in the Southern Hemisphere) associated with the leading edge of the hurricane eyewall. The maximum MLD decrease occurs to the rear of the storm and along the track at a distance proportional to the speed of the storm. MLD increases are observed beyond the radius of maximum winds right of the track; very little change is evident left of track. The maximum surface and mixed-layer cooling occurs to the right of the storm track, where the thermocline gradient is maximum. In large, slow-moving storms, surface cooling induced by a storm can cause a reduction in the sensible heat flux by up to a factor of 4, and in the latent heat flux by up to a factor of 2.

A paper on the initial results of airborne radiometer- and scatterometer-derived winds and rainfall rates in Hurricane Allen was published in the 16 October 1981 issue of Science.

Tracking of the easterly wave troughs from Central Africa to Central America was completed and compared with the operational tracks compiled by forecasters at NHC and with subjective and objective tracks determined by GATE researchers. The operational tracking has been carried out since 1967 and is based on radiosonde observations at three stations and on satellite images. The GATE analyses have used the full set of data available for research. The operational tracks indicate that about 5-15 of the wave troughs passing Dakar each summer decay over the Atlantic and that an additional 5-15 new synoptic-scale wave troughs form in the Atlantic. These tabulations suggest that some mechanism is initiating synoptic-scale disturbances over the Atlantic. The GATE tracking, however, indicates that operational methods overestimate both the total number of waves passing Dakar and the number of waves that decay over the Atlantic, and that all of the wave troughs passing Dakar actually reach the eastern Caribbean. Whereas this comparison is possible only for the summer of 1974, it suggests that synoptic-scale disturbances are probably not being initiated in the tropical Atlantic north of the Intertropical Convergence Zone (ITCZ) on a regular basis.

Development of a general-purpose base hurricane model using an accurate and flexible numerical method called QSTING (quasi-spectral time integration on nested grids) was continued. A two-dimensional (x-y) version of the base model (code name, QVADIS), which may run on any level of nesting with general boundary conditions, was completed and showed that all the theoretical expectations of the QSTING method, as derived in the previous year, were met perfectly.

The first application of QVADIS to a hurricane problem was performed in association with semianalytic work on the asymmetric boundary layer flow of a moving hurricane (a translating circular pressure field was prescribed). The model results, which were fully nonlinear, confirmed the analytical theory within the anticipated levels of accuracy. The model test also revealed that the interface conditions by the QSTING method worked flawlessly on the vortical flow that cuts corners of nested square meshes.

A new scan analysis, using the method of successive corrections, was operationally implemented to provide a revised, large-scale, deep-layer mean wind field as input to the operational SANBAR (Sander's Barotropic) hurricane-track prediction model. The modification was tested in both the research and operational modes. The average forecast error for the new system was lower at almost all forecast times than it was for the old system. The introduction of a movable grid, an additional modification that has been completed, will allow storms to be centered in the grid to minimize boundary problems. The first application of this has been the operational implementation of an eastern Pacific SANBAR during the 1982 season.

New statistical models for hurricane-track forecasts are being developed. Predictors are now represented on a grid that translates with the storm. Rotation of the grid with respect to the direction of current storm motion (as defined by the -12-h to +12-h displacement vector) reduces the mean forecast error to about 125 nm and the speed bias to only about -0.5 kn. The reduction in mean forecast error is associated with the reduction of the variance of the 24-h displacements in the rotated system and the reduction in speed bias, with the tendency of the 24-h displacement vectors to be close to the direction of current storm motion. The root-mean-square expected forecast error is decreased from the nonrotated grid system in nearly the same proportion as the mean forecast error.

The roles of linear and nonlinear asymmetric effects, relevant to slowly and rapidly translating hurricanes, respectively, in determining the boundary layer response, were analytically modeled. Faster translation of the hurricane tends to move the radius of maximum wind radially inward, as well as to concentrate winds and convergence more on the right side of the storm. The distribution of convection in Hurricanes Frederic and Allen compares favorably with boundary layer convergence diagnosed from the model. Differences between the hurricanes are related to the greater translation speed of Hurricane Allen.

Plans FY 1983

A major effort will be made to determine the operational impact of the Omega dropwindsonde data from Hurricanes Debby and Olivia. Comparison of the forecasts, from the operational, dynamical, and statistical hurricane models, with and without Omega dropwindsonde data, will help to determine the impact of increased data coverage on the hurricane-track forecasts. The dropwindsonde data will be reprocessed at AOML and a final data set will be prepared for researchers at AOML and other institutions. After data processing is completed, subjective analyses of the observations at one or two pressure levels will be prepared. At the same time, work will begin on diagnostic studies of the environment near the hurricane and on incorporation of the data in simple prognostic hurricane models.

After the 1982 airborne Doppler hurricane data are evaluated, planning will be completed and goals will be finalized for the proposed 1983 Hurricane Convective Dynamics Experiment. The 1983 experiment will be carried out using the two WP-3D aircraft to study further the convective rainbands of the hurricane. Emphasis will be on the upwind structure and on the modification of the boundary layer by convective-scale downdrafts and the possible effects of the modification on storm intensity.

Preparation of a major manuscript describing the production and distribution of ice in hurricanes is planned for FY 1983.

Further work on the land-based radar data from Hurricane Frederic will be conducted. The motion, growth, and dissipation of convective and mesoscale areas relative to the storm's center will be determined from radar scans every 2 minutes during the time Hurricane Frederic was within quantitative range of the Slidell WSR-57 radar. This research on storm structure will emphasize (1) differences between the eyewall and outer mesoscale bands, (2) relationships between wind speeds at various levels and echo motion, and (3) changes caused by landfall of a tropical cyclone. A black-and-white, animated film is planned. The printouts will be filmed approximately every 2 minutes during Hurricane Frederic's landfall. In this manner, echo motion and changes in eyewall characteristics should become easily discernible. Since each of the printouts is produced relative to the storm center, echo motion components caused by Hurricane Frederic's translational speed will be removed, and an accurate depiction of the transition upon landfall should result.

Installation of a 70-mm Hasselblad camera and data annotation system on one of the NOAA WP-3D aircraft is planned this year to obtain higher quality sea-state photographs.

SEASAT precipitation measurements will be recalculated for several tropical storm cases, using passive microwave data without the grid-point averaging inherent in previous data, and will be compared with airborne rain-rate measurements. Satellite microwave techniques for measuring tropical cyclone rainfall will be evaluated. **AOML**

The QVADIS base model will be extended to spherical geometry, and use of moving submeshes will be implemented. Experimental barotropic prediction of real hurricanes will be carried out. The barotropic version of QVADIS will also be used in an investigation of the interaction of an isolated vortex and its environment. The interactions will be studied for initially symmetric and asymmetric vortices in idealized large-scale flows. Interactions with boundary layer frictional drag may be included in some experiments, using a two- or three-layer formulation. Special attention will be given to understanding the dynamics of the short-period (trochoidal) oscillations in hurricane path, which are central to the short-range prediction of hurricane tracks. A comparison will be made between the simulated and observed trochoidal oscillations.

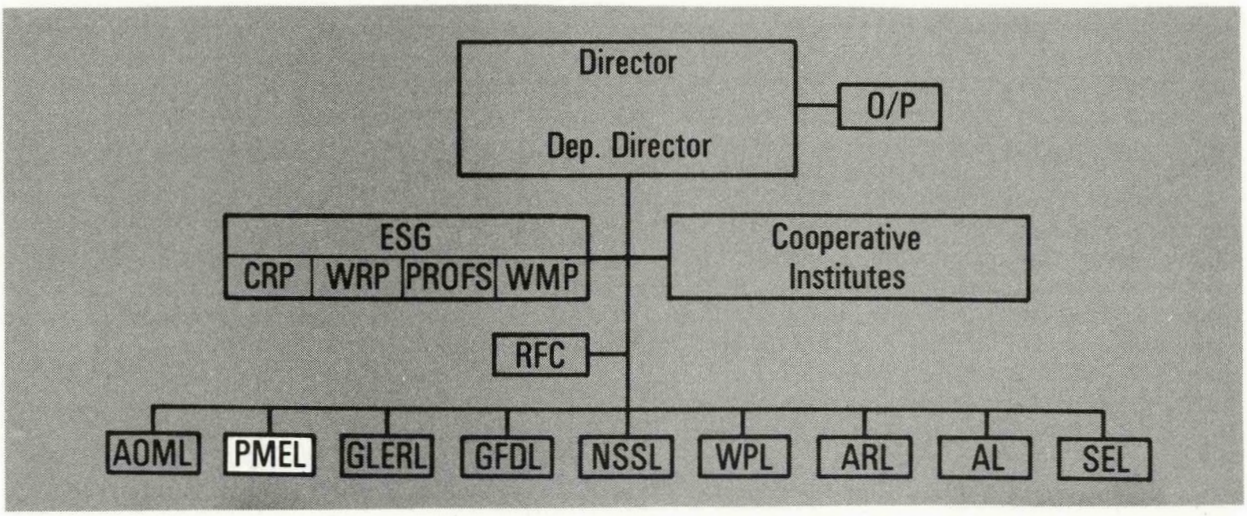
Evaluation of the results of the statistical hurricane-track forecast models will be completed. A feasibility study will be made for a statistical forecast model of

hurricane intensity changes with an empirical orthogonal function (EOF) analysis using deep-layer mean heights and height changes. If the results are encouraging, the analysis will be extended, and an evaluation will be made of the expected forecast skill of such a model.

PACIFIC MARINE ENVIRONMENTAL LABORATORY

Seattle, Washington

Eddie Bernard
Acting Director



The Pacific Marine Environmental Laboratory (PMEL) is an interdisciplinary research laboratory that carries out scientific investigations in oceanography, marine meteorology, and allied disciplines. Its mission is to assist NOAA and other Federal agencies by conducting research directed toward understanding processes in coastal and open-ocean systems. The current research programs of PMEL focus on four general subjects: climate, marine environmental assessment, marine observation and prediction, and marine resources. Research results provide information necessary for effective management of marine assets and improved marine environmental forecasting. Two cooperative institutes, the Joint Institute for Study of the Atmosphere and Ocean (JISAO) and the Joint Institute for Marine and Atmospheric Research (JIMAR), established between NOAA and the Universities of Washington and Hawaii, respectively, provide a bridge between the academic community and PMEL scientists working in such areas as climate dynamics, estuarine processes, tsunamis, and environmental chemistry.

CLIMATE RESEARCH

PMEL

PMEL climate research focuses on three areas: climate predictability, ocean climate dynamics, and the uptake of carbon dioxide by the oceans. Studies of climate predictability include the development of season-ahead forecasts for the U.S. mainland and of tools for assessing the validity of those forecasts. Ocean climate dynamics research is designed to develop an understanding of the large-scale, long-term interactions among major ocean currents, heat transport, and general atmospheric circulation. Carbon dioxide research is assessing the role of the oceans in removing excess carbon dioxide from the atmosphere.

Accomplishments FY 1982

The climate predictability project at PMEL in cooperation with the Climate Research Group of Scripps Institution of Oceanography (SIO), who supplied the data, has made a detailed examination of an 8-yr record (December 1973-February 1982; 33 seasons) of seasonal temperature and precipitation forecasts over the U.S. mainland.

This was an unprecedented study in forecast verification in the following sense. For the 8-yr period, four distinct parallel efforts produced forecasts each season over the U.S. mainland. The forecasts were all made in the same mode, namely terciled maps indicating above-normal, normal, and below-normal temperature and precipitation forecasts. Furthermore, the forecasts were made for the same set of seasons over the same 99-point set. The forecasters were from SIO, the National Weather Service (NWS), an SIO-PMEL collaboration (the so-called Analoger), and the Atmospheric Science Department of Creighton University, Omaha, Neb.

A record was kept of each forecast map and each observed map. For each forecaster, 33 such comparisons were possible for temperature, and 33 for precipitation. These forecast/observed pairs (about 264 in all) were then compared and skill scores compiled for each forecaster. From these records the predictability of temperature and precipitation over the U.S. mainland was also derived by combining the forecasters' prediction scores. (A detailed account is in the NOAA/PMEL Technical Memorandum entitled "Climate Forecast Verifications, U.S. Mainland 1974-82.") One salient set of results is the following: (1) temperature was better predicted than precipitation, as a function of either season or region over the U.S. mainland (during 1974-1982); (2) it was on the average easier to predict temperature and precipitation in winter than in summer; (3) temperature was better predicted, as a rule, in the Pacific Coast, Southwestern Desert, and Northern Plains regions, and was less well predicted in the Southern Plains, Gulf Coast, and Atlantic Coast regions; and (4) precipitation was better predicted, as a rule, in the Southwestern Desert, Great Northern Basin, and Atlantic Coast regions. In addition to evaluating the four human forecaster efforts, the efforts of various nonhuman forecasters were evaluated (such as the Most Probable Markover and the Best Analoger). It was found that the forecast skills of these were competitive with those of the human forecasters. Further study of these nonhuman forecasters is planned.

Ocean climate dynamics research has focused on the eastern equatorial Pacific and the major western boundary currents of the Northern Hemisphere--the Gulf Stream and the Kuroshio. During the past year, our field program has included measuring wind, currents, and temperature from deep-sea moorings at the Equator in the eastern Pacific; making north-south transects to measure velocity, temperature, salinity, and oxygen across the major components of the current system in the eastern Pacific; recording sea-level measurements at the Galápagos Islands; and analyzing ship-of-opportunity sea surface temperature data in the tropical Pacific. These measurement programs were PMEL contributions to the EPOCS (Equatorial Pacific Ocean Climate Studies) oceanographic program in the eastern Pacific.

In the upper equatorial ocean, mixing occurs through upwelling, the process of vertical movement of water toward the surface. In the interior of the ocean, the magnitude of vertical motion beneath the layer of wind-driven horizontal currents is estimated to be small: approximately 10^{-7}-10^{-6} m s^{-1}. Because direct measurement of vertical motion anywhere in the ocean is extremely difficult, upwelling is usually inferred, with caution, from changes in the relative position of properties such as constant temperature layers or isotherms. Another method of determining upwelling is the analysis of spatial variation of horizontal currents, using the principle of conservation of mass. Conservation of mass requires that all water entering a given volume of the ocean be equal to water leaving that volume. Thus horizontal currents that converge (or diverge) must be accompanied by vertical currents to remove (or bring in) an equal amount of water.

Measurements from an array of current meter moorings at 110°W show the mean direction and velocity of vertical movement. Between the surface and about 175 m the mean vertical velocity was upward and its maximum value occurred near the core depth of the Equatorial Undercurrent, a major subsurface current. The bottom depth of the near-surface upwelling zone was about the same as that found by other researchers through the analysis of tritium data. At 200 and 250 m the mean vertical motion was directed downward. The observed reversal of the mean vertical velocity provides an

explanation for the upward and downward spreading of the isotherms and oxygen isopleths (surfaces of equal concentration) frequently observed above and below, respectively, the core of the Undercurrent.

The persistent occurrences of relatively large biological productivity and low sea surface temperature in a narrow band along the Equator in the central and eastern Pacific are thought to be related to the upwelling of cold, nutrient-rich waters from the thermocline. However, at 20-m depth, no statistically significant relationship was found between the temperature observations and the computed vertical motion. Instead, the temperature fluctuations on a 10- to 15-day time scale observed at 20 m were correlated with north-south velocity variations.

The following puzzle is further evidence that the role of upwelling in changing sea surface temperature is poorly understood. If the thermocline was moving upward at $\sim 2.0 \times 10^{-5}$ m s^{-1} (as our estimates of mean vertical velocity indicated), why did the mixed-layer thickness remain unchanged and the temperature in the mixed layer gradually increase? One possible cause for this is the wind-induced divergence, which can have two effects: it can cause entrainment of cold water across isotherms into the mixed layer, or it can raise the isotherms and decrease the depth of the mixed layer. However, the wind stress was too small and the thermocline was too strong for wind-generated entrainment at the bottom of the mixed layer to be a significant process. This requires further investigation.

Another area of interest has been geostrophic transport across north-south lines, its contribution to the North Equatorial Countercurrent (NECC)and the Northern Subsurface Countercurrent (NSCC), and their relation to the Intertropical Convergence Zone (ITCZ), which is a large area of northern and southern hemispheric wind convergence. The seasonal variability of all of these phenomena is also of interest. Our analysis of nine hydrographic sections from 10°N to 5°S along 110°W longitude shows that eastward geostrophic transport (computed relative to 500 db) north of the Equator reflected contributions from both NECC and NSCC. Whereas NECC indicated large seasonal variations from 3×10^5 m^3 s^{-1} to 12×10^6 m^3 s^{-1}, NSCC was relatively constant at 14×10^6 m^3 s^{-1}. The variability of the NECC transport was correlated with the position of the ITCZ: NECC is weak in the northern spring when the ITCZ is southernmost and strong in the northern fall when the ITCZ is northernmost. This correlation of the annual NECC transport variability with the wind field substantiates previous analyses based on less data and raises an interesting question concerning the strength of the NECC during large interannual warming events, the so-called El Niño. (El Niño is the large warming in the equatorial eastern Pacific accompanied by heavy rains and flooding beginning in mid-December, near Christmas; hence its name, El Niño, the child.)

El Niño is associated with a large southward shift or displacement of the ITCZ, so we would expect a weak NECC during El Niño if the dynamics of both events were similar. However, historical data in the western and central Pacific suggest large NECC transport during El Niño. Understanding this difference will require monitoring by moored arrays during several annual cycles and at least one El Niño. Our study of spatial scales of the geostrophic currents indicates that long-term monitoring of the NECC-NSCC system can be achieved using an array of four moored thermistor chains.

A study completed this year concerns the dynamics of the Equatorial Undercurrent. Most undercurrent models assume that there is a balance between the Coriolis force and the meridional pressure force. (At the Equator $\rho\beta u = p_{yy}$, where ρ is the density, β is the meridional gradient of the Coriolis parameter, u is the zonal velocity, and p_{yy} is the second meridional derivative of pressure.) This relationship was checked by using several sections at closely spaced stations measuring conductivity, temperature, and depth (CTD) across the Equator to estimate p_{yy}, and comparing the results with moored or profiling current measurements. The geostrophically estimated current (current estimates derived from horizontal density differences) agrees quite well with the

direct measurement except near the sea surface. The velocity change from the Undercurrent core (75-m depth) to the deepest current meter (250-m depth) was estimated with a root mean square error of about 15%. This agreement compares favorably with estimates of the error in midlatitude geostrophic computations and constitutes the first demonstration of geostrophic balance at the Equator. Thus, even at the Equator, the force associated with the Earth's rotation, the Coriolis force, remains a dominant term in the equations of motion.

We began analysis of continuous records of sea surface temperature (SST) from shipboard flow-through systems on EPOCS cruises (1979-1982). The thermograph temperatures were compared with bucket temperatures and good agreement was found. The data show an annual temperature progression for the eastern equatorial SST minimum that agrees with other findings. Between March and June, SST increased by more than 1°C; by June, the temperature had begun to drop; and in late October, a minimum occurred. In the five 1981 sections at 110°W that we analyzed, fronts of 2°C change along a 20-km path were found at approximately 3°N in the November and January data, but not in the February, March, and June tracks. The transition to the equatorial temperature minimum is characteristically much sharper to the north than to the south. Fronts detected in the analog records will be compared with satellite measurements of fronts to determine what atmospheric (heat flux) and oceanographic (current) conditions exist when the fronts occur.

One of the critical elements in the development of successful models of the general ocean circulation is the correct parameterization of the transfer of heat and momentum in the ocean. An intensive study of ocean eddies was carried out in 1978 near Bermuda (POLYMODE Local Dynamics Experiment), to advance our understanding of the role of eddies in the transport of heat and momentum in the ocean.

Analysis of temperature, salinity, density, and dissolved oxygen data from that study has revealed the presence of relatively small horizontal-scale (25-50 km) and thin (100-1000 m) water mass anomalies with a large signal. Profiles of salinity against density were obtained in one of these features with an anomalously low salinity. The maximum anomaly departs from the mean of the experiment by 8 standard deviations. These features, and most others, normally have a dynamical structure and thus have circulation different from the background. Study of particular features shows that they are moved by the large-scale flow and are not self-propelled. Tracing of the probable origin of the water in this feature suggests that it came from the northwest coast of Africa and mixed only slightly with its surroundings en route. The occurrence of these eddies suggests that mixing on the mesoscale is not as intense as hypothesized by theoretical studies of quasi-geostrophic turbulence. New formulations of mixing are being explored.

In 1982 NOAA began a program named the Subtropical Atlantic Climate Study (STACS) to study the transport of equatorial heat to higher latitudes in the Atlantic. The initial phase of this program is concentrating on measuring the transport of the Florida Current. At PMEL transport is being measured by a novel method utilizing the Earth's magnetic field. This method is based on Faraday's discovery, reported in 1832, that conductors moving through a magnetic field produce electromagnetic fields. He suggested that the Gulf Stream would produce a measurable signal. These ideas were refined by British mathematician M. S. Longuet-Higgins (1949) and applied to the Florida Current from 1952 to 1961 by H. Stommel using a submarine cable connecting Key West, Fla., to Havana, Cuba; and from 1969 to 1974 by T. Sanford using a submarine cable connecting Jupiter Inlet, Fla., to Settlement Point, Grand Bahama Island.

Cross-stream voltage differences reveal large annual and interannual variations caused by the Florida Current. The annual variation occurs mainly during the summer and fall; a fairly constant winter and spring value is followed by a 13% increase to the summer maximum and then a 20% decrease to the fall minimum. The interannual variation (total variation minus annual variation) often exceeds the annual variation and for the present data has a maximum excursion of 30% occurring at the end of 1972.

The electromagnetic field project, which is part of STACS, resumes measurements of the voltage difference across the Florida Current using the same submarine cable connecting Jupiter Inlet to Settlement Point. An inland electric field site was also installed along with a magnetic field site at Jupiter Inlet. Measurements from these sites are being collected and will be compared with the direct measurements of the Florida Current that are being provided by current meter moorings and current profiling.

The conversion of electromagnetic data to water volume transport data requires special attention to geomagnetic noise and to leakage electric current. The geomagnetic noise, induced by ionospheric and magnetospheric variations in the earlier data, can be removed by using the north magnetic component from both San Juan, P.R., and Fredericksburg, Va. The results using these distant sites and removing the geomagnetic noise are equivalent to using local magnetic data.

Leakage electric currents are electric currents that flow from the Florida Current into the Earth because the Earth is not an insulator. These leakage currents are studied because (1) they reduce the cross-stream voltage difference from its maximum value that is set by the volume transport, and (2) they provide an independent means for observing the time variations in the Florida Current. The strength and distribution of the leakage electric currents are influenced by the distribution of electrical conductivity beneath the Florida Current, by the width of the stream, by the spatial variations of velocity within the stream, and by the position of the stream with respect to the coastline and bottom topography.

Another PMEL project is based on the theory that interaction of strong currents and bottom topography is important in the transfer of energy from large to small scales, and the ultimate dissipation of energy. Studies of data from the Kuroshio Extension have suggested that the strength of the Kuroshio is affected as it flows across the Emperor Seamounts. In the summer of 1982, a joint PMEL-University of Washington cruise was carried out in the vicinity of the Seamounts. West of the Seamounts (167°E) the Kuroshio was well developed, and its volume transport was 25×10^6 m^3 s^{-1} (relative to 1500 db). Comparison of this transport with estimates far to the west (152°E) suggests an eastward decrease of near-surface transport ($\sim 1 \times 10^6$ m^3 s^{-1} per degree of longitude). A measure of the cross-stream structure of the Kuroshio is the distribution of temperature at 300 m; there the temperature gradient is proportional to the geostrophic velocity shear. Data show that the current broadens and weakens over the Seamounts and then reintensifies east of them. A similar pattern was seen in a previous study of the Kuroshio as it flows over the Izu-Ogasawara Ridge (140°E). Therefore, it is suggested that this may be a characteristic response of deep oceanic jets to topography, and thus, that it could be used to evaluate the dynamical studies of topographic influences. A surprising result was the occurrence of a second jet to the north whose transport was 20×10^6 m^3 s^{-1}. The presence of the second jet raises the question of whether there is branching of the Kuroshio west of the Emperor Seamounts, or whether there is a separate current that can be related to the wind field.

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During fiscal years 1981 and 1982, PMEL sponsored two interdisciplinary studies of the dynamics of the carbon dioxide system in the surface and intermediate waters of the North Pacific. The purpose of these studies was to determine the penetration and reactivity of fossil carbon dioxide in these waters. When fossil fuels are burned they release carbon dioxide to the atmosphere; the long-term increase in atmospheric carbon dioxide beginning around 1800 is thought to be affecting the Earth's radiation balance and thereby increasing the Earth's temperature. The oceans act as a major sink for atmospheric carbon dioxide particularly at areas of downwelling where surface waters descend below 100 m.

Measurements of total carbon dioxide, alkalinity, chlorofluorohydrocarbons (freons), tritium, calcium, and suspended matter were made during three north-south transects of the North Pacific aboard NOAA Ships MILLER FREEMAN and DISCOVERER. The results of these studies indicate that fossil carbon dioxide has penetrated to depths

between 500 and 1300 m in the region, with the deeper penetrations occurring in the western North Pacific. The data have also been used to determine the effect of fossil carbon dioxide on the calculated degree of saturation of these waters with respect to calcium carbonate minerals. Uptake of fossil carbon dioxide by the oceans over the past 130 years has resulted in a significant change in the carbonate chemistry of the North Pacific Ocean. The results indicate an apparent reduction in the thickness of the supersaturated lenses and upward translation of the 100% saturation level by as much as 70 m for aragonite in the region north of the Subarctic Front. Since our sediment trap studies have shown that aragonite, from pteropods (planktonic marine molluscs), is the major solid phase contributing to the carbonate flux in these waters, in situ dissolution reactions involving aragonite particles may play an important role in the neutralization of fossil carbon dioxide in the North Pacific.

The chlorofluoromethanes, trichlorofluoromethane (CFC-11) and dichlorodifluoromethane (CFC-12), are gaseous tracers of anthropogenic origin. Their historical release into the atmosphere has provided oceanographers with a valuable new chemical tracer with which to investigate mixing and circulation processes in the ocean. The near-exponential growth of these gases in the atmosphere parallels similar growth patterns of fossil-fuel-derived carbon dioxide; thus the chlorofluoromethanes can be used in a direct way to estimate excess CO_2 inventories and mean penetration depths. More importantly, they provide a quantitative measure of diffusion and convective mixing scales.

In the early summer of 1982, observations were made of the distributions of chlorofluoromethanes in the western Pacific. This region is known for its sharp contrasts in water masses and deep mixing characteristics, thus it remains a principal locus for the assimilation of fuel-derived CO_2. Salient features of the distribution include the penetration of CFC-11 within and below the subtropical-mode water and strong horizontal gradients near the Subarctic Front at 42°N. It is noteworthy that the chlorofluoromethanes are associated with the Intermediate Water (low salinity) in the western Pacific, but were not found in the same water mass in the eastern Pacific. From this distribution, estimates can be made of vertical diffusive and advective scales, and when coupled with tritium and carbon-14 (bomb tracers), estimates can be provided of circulation times within the subtropical-mode water and ventilation rates of the North Pacific Intermediate Water.

Plans FY 1983

The first of a series of volumes on data intercomparison theory applicable to climate predictability will be published.

Investigators from the Deep-Sea Physics group will continue with field measurements in the EPOCS program to study the circulation in the eastern equatorial Pacific east of the Galápagos Islands (90°W). A zonal array of current meter moorings and sea-level gages will be maintained at the Equator to study east-west propagation of thermoclinic displacements and sea surface temperature anomalies.

Central Pacific (NORPAX) and eastern Pacific (EPOCS) hydrographic (CTD) data will be used together to study the large-scale geostrophic meridional heat flux and its relation to changes in equatorial heat content.

At the conclusion of FY 1983, the regional study of the circulation off the west coast of South America will be completed. Planning for a major study within EPOCS of the response of the currents in the central Pacific to changes in atmospheric forcing will be done by scientists from the Deep-Sea Physics group in conjunction with other NOAA and academic scientists.

CTD data from the Emperor Seamounts cruise will be analyzed. The changes in structure of the currents and fronts will be described, and the processes involved will be evaluated.

The geomagnetic noise from the cable and inland electric field data will be removed, and realistic numerical electromagnetic models will be constructed for assessing the magnitude of time variations in the electromagnetic transport data caused by time variations in the position and internal structure of the Florida Current. The models will be verified by comparison with direct observations of volume transport and with inland electric field data.

A major cruise combining observations for the Marine CO_2 program and the Acid Rain program will take place in late Spring 1983, occupying stations between Dutch Harbor, Alaska; Hawaii; San Diego; and Seattle. This cruise will provide a fourth line of stations in the North Pacific and will reoccupy several GEOSECS (Geochemical Ocean Section Study) stations.

MARINE ENVIRONMENTAL ASSESSMENT

Marine environmental assessment constitutes the research activity for about 40% of the PMEL staff. Emphasis is on understanding the complex physical and geochemical processes that determine the extent of human impact on the marine environment. Although the geographic focus of these studies has been Pacific Northwest and Alaskan coastal and estuarine waters, the scientific knowledge acquired and methodologies developed are applicable to other marine systems.

Accomplishments FY 1982

Research in the Puget Sound-Strait of Juan de Fuca system has been under way for several years. These studies will lead to a better understanding of the Sound's ability to accommodate pollutant inputs. Many pollutants adhere to and move with particles, and ultimately are buried or transported out of the Sound along with particles. The emphasis of much PMEL research, therefore, has been particle transport and fate.

The overall goal of water circulation research in Puget Sound has been to provide a better description and understanding of circulation and mixing processes important in determining the capacity of Puget Sound to accommodate municipal and industrial wastes from the growing urban complex. Toward this end, all available historic data on currents in Puget Sound from 1908 to 1980 have been collected--jointly with MESA (Marine Ecosystems Analysis program) and private consultants--for synthesis to understand the flow variations better. PMEL collected about 50% of this data.

A conceptual model of Puget Sound derived from earlier studies indicates that considerable seaward-flowing surface water mixes with new water entering the deep basin at the southern end of Admiralty Inlet, and that this mixture is refluxed back into the Sound in the deep water below sill depth. Observations from Admiralty Inlet and the main basin were used for a first approximation of the average flux through the Inlet, which supported the conceptual model. Only about half as much water was entering the Inlet as the average southward flow observed about midway along the main basin. However, the sets of observations were from different seasons and different years, and it was unclear whether the speculations might be false because of as-yet-unknown seasonal changes in the transport.

During this year observations were made to better determine (1) the simultaneous flux of both water and sediment through sections in the main basin and on the Admiralty Inlet entrance sill and (2) the downward entrainment or reflux of water in the entrance region where no prior measurements existed. In the lower 48 states this

downward mixing of seaward-flowing water is possibly unique to the Puget Sound estuary. Most other U.S. estuaries mix incoming water upward, which dilutes the seaward-flowing surface water. Puget Sound, however, is a fjord-type estuary with a sill and strong tides that mix seaward-flowing surface water downward.

The implications of the potential refluxing of part of the seaward-flowing water are significant for the flushing time of the Puget Sound main basin. This fraction (maybe up to 70%) makes additional trips through the Sound and might lead to some long-term accumulations of pollutants that never leave the basin.

Most particles in the seaward-flowing surface layer are removed to the landward-flowing bottom water by two processes: (1) biological aggregation and settling, or (2) downward mixing over Admiralty Inlet and entrainment into the landward-flowing deep layer. Removal of particles from the surface by settling over the entire main basin was estimated from sediment trap studies at 6×10^{11} g, an amount roughly equal to the combined annual sediment input of the Puyallup and Duwamish Rivers.

Once particles are removed to the deep layer, the net landward circulation tends to move them toward the southern terminus of the main basin. Particles in the bottom water are episodically moved by alternating periods of erosion and deposition. Field data show that diurnal and semidiurnal tidal currents with a combined speed near 40 cm s^{-1}, a frequent occurrence, raise concentration levels as much as sixfold over the background concentration of approximately 1 mg ℓ^{-1}. A preliminary comparison with a process model for tidally-forced resuspensions suggests that the resuspended material has a bimodal settling spectrum, with coarser material (settling velocity of 0.1 cm s^{-1}) causing rapid concentration changes against a more slowly changing background of fine particulates. Bottom sediments are reworked to a depth of about 0.2 cm over a tidal cycle under these conditions.

Direct measurements of the horizontal flux in the deep layer were carried out for over a year at a single location in the main basin. These measurements indicate that the southward sediment flux is about 9.5×10^{11} g yr^{-1}, roughly equal to the amount of material introduced to the deep layer by vertical settling. The emerging picture is one of pronounced sediment mobility and rapid mixing of particles throughout the estuarine system.

At the present time, municipal and industrial waste effluents constitute the ninth largest input of fresh water to the Puget Sound region. These effluents are processed to conform to water quality standards, but they still represent an important source of trace metals and organic toxicants, pollutants that may adversely affect local fisheries. Local concern over wastewater standards is a relatively recent phenomenon, and as recently as 20 years ago substantial quantities of untreated effluents were routinely discharged in Puget Sound. (The West Point Sewage Treatment Plant opened in 1965.) There are virtually no records of these discharges. To properly establish a budget for pollutants in the Puget Sound region (and thereby make possible forecasts of trends), we are using sediment cores to estimate the historical input of pollutants to the system.

Work is presently under way to create a demographic, economic, and environmental data base that will provide some guidance on the likely input of pollutants over the last eight decades of the Puget Sound region's industrialization. The data base is organized by the region's principal watersheds extended somewhat to accomodate the various municipal and industrial effluent discharge points. Data pertaining to the various demographic characteristics of the watersheds' population are being culled from census records. Land use information has been obtained from a variety of sources, most importantly LANDSAT imagery. Various Federal and State agencies have been contacted to obtain relevant economic data such as gasoline consumption and motor vehicle registrations. These data are being archived in computer files, and software is presently under development that will allow us to determine statistically significant relationships between the many different parameters. These relationships will be

used to extrapolate and interpolate the discontinuous and sporadic time series we are now acquiring.

Once humans introduce pollutants, they are delivered to the sediment by means of horizontal transport and vertical deposition processes. The rate at which pollutants are accumulated in sediments, however, is a complex function of both the sedimentation and bioturbation (mixing) rates. Sedimentation and bioturbation signals must be separated from measured sediment constituent profiles before particle and pollutant budgets and/or models can be formulated. Geochemists under contract to PMEL are currently determining the lead (^{210}Pb) and thorium (^{234}Th) geochronologies for gravity cores, box cores, and Kasten cores collected from Puget Sound in an effort to resolve these processes. Sediment inventories for several trace metal and organic pollutants from these cores have been established.

During the past few years, PMEL scientists have undertaken studies to provide an understanding of the transformations and fates of toxic trace elements and organic compounds in estuarine and coastal environments. These studies have focused on flocculation, scavenging, diagenesis, and remobilization processes in estuaries receiving municipal waste effluents.

In FY 1982, PMEL scientists completed a year-long sediment trap study in the main basin of Puget Sound, one purpose of which was to determine the seasonal and vertical variations of the fluxes of particulate trace elements associated with oxide, organic, and acid-resistant phases of suspended matter in the Sound. The results show that for iron, manganese, cobalt, zinc, and lead, acid-resistant and oxide phases controlled the vertical flux; whereas, for copper and chromium, acid-resistant and organic phases controlled the vertical flux. The cadmium flux was predominantly controlled by oxide and organic phases. For several trace elements, notably manganese, cobalt, chromium, nickel, and zinc, the flux in the organic phase was higher in summer than in winter. The elemental flux data for winter show a slight decrease from the 50-m to the 100-m sediment trap followed by a striking increase in the sediment traps located at 160 and 205 m, the increases being due to resuspension of bottom sediments. The elemental concentration data show that the sedimentary material from the 50- and 100-m sediment traps are significantly elevated in manganese, zinc, and lead relative to the underlying sediments. These enrichments are attributed to formation of manganese and iron hydrous oxide in the water column and adsorption of trace metals on the newly formed oxide phases. This mechanism provides an important means for scavenging and removal of trace metals in Puget Sound. That both manganese and iron are rapidly remobilized in the underlying sediments suggests the process is cyclic, with the hydrous oxides being major agents for trace metal transport to the bottom of the Sound.

In FY 1982, PMEL scientists initiated studies of trace element recycling processes in the underlying sediments. Porewater samples were extracted and analyzed for nutrients, major and trace elements, and dissolved gases. In cooperation with University of Washington scientists, a Bottom Lander (a device to measure directly the fluxes of primary constituents across the sediment-seawater interface) was deployed on the seabed in the main basin of Puget Sound.

The results suggest that the sediments are a major source for ammonia, phosphate, silica, manganese, alkalinity, and total carbon dioxide, and a major sink for oxygen. The concentrations of copper and cadmium in the interstitial porewaters are sufficiently low as to indicate that the sediments are not a major source for these metals.

During the past 3 years, PMEL has conducted research on the sources, transport, and distribution patterns of polycyclic aromatic hydrocarbons (PAH) in Puget Sound. Many of these compounds are mutagenic and carcinogenic, and thus pose a significant threat to the marine environment. The origins of these water-insoluble compounds are petroleum products and combustion processes; their modes of entry are principally atmospheric deposition, riverine input, and wastewater discharge.

The distribution of PAH in the sediments of Puget Sound reflects the increased industrialization and urbanization of the area since the early 1900's. PAH concentrations in the sediments increased markedly between the turn of the century and the 1940's, and then decreased to present-day levels. The concentration maximum in the 1940's is probably related to the change in home heating fuels from coal to oil, gas, and electricity. Although not as pronounced, the complex mixture of branched and cyclic alkanes, and the normal alkanes, both show maxima near 1965, the point at which Seattle terminated the dumping of raw sewage into the main basin of Puget Sound. Concentrations of PAH in sediment trap samples show significant differences between summer and winter, probably reflecting the amount of fuel oil used in seasonal home and commercial heating. Clearly, the industrial influences of man are reflected in the sedimentary record of organic compounds.

Research in Alaska, primarily under OCSEAP sponsorship, has focused on defining the environmental conditions that may affect or be affected by future petroleum exploration and development on the Outer Continental Shelf. The results of this research are also now being applied to studies of the fisheries of the region in an attempt to understand better the effects of the environment on fish recruitment.

Studies along the north side of the Aleutian Peninsula were conducted to determine the potential role of particulates in transporting spilled crude oil. The vertical distribution of water properties over the southeastern Bering Sea Shelf is known to define three structurally distinct hydrographic domains separated by fronts where horizontal property gradients are steep. Recent investigations into the distribution of suspended particles have characterized domains and fronts analogous to those defined by the hydrography. The coastal domain (depth <~50 m) is typified by vertically homogeneous particle concentrations and size distributions caused by vigorous wind and tidal stirring. In the middle domain, particle distributions are three layered, with high turbidity layers at the surface (phytoplankton detritus) and bottom (resuspended sediments) separated by a thick minimum turbidity zone of weak horizontal and vertical gradients. These domains are separated by a particle front that is expressed in the surface and bottom waters as a particle concentration minimum and in the middepth region as a pronounced horizontal gradient in particle concentration and size distribution. Other particle minimum zones (fronts), located seaward of the middle domain, are associated with both surface and bottom water regions where the horizontal density gradient is steep.

During a 1-yr study of the circulation of the southeastern Bering Sea, methane was used as a tracer of circulation along the North Aleutian Shelf and in the bottom waters of St. George Basin. In both cases, methane arose from localized biological sources. Methane is largely contained within the coastal zone (depth 50 m) and moves northeasterly along the shelf. The distribution was simulated with a stationary, two-dimensional, diffusion-advection model in which lateral diffusion (y-direction) was balanced by horizontal advection (x-direction) and air-sea exchange. Strong tidal mixing in the coastal zone permitted the model to be depth averaged. Methane, which was transported to the coastal zone by tidal pumping, served as the upstream boundary condition. The results of the simulation indicate that the mean current trajectory was to the northeast at 3-5 cm s^{-1}, in agreement with current meter measurements of 1-6 cm s^{-1}. Although circulation and mixing processes are more complex than the above model would suggest, the main features of the methane distribution model were indeed observed.

Tide models tuned by observed tidal currents have been developed to predict the vertical profiles of tidal currents. A comparison of profiles for different forms of the vertical viscosity shows that the viscosity that gives the most physically reasonable profiles for a wide variety of tidal regimes is the one based on the turbulent energy equation (using level II, second-order closure). This form of viscosity works well for the tidal regimes in the Bering Sea where semidiurnal tidal currents occur near their critical latitudes thus increasing the vertical extent of bottom boundary effects. For this case maximum bottom stress, as derived from a bottom-roughness

length parameter, was used to determine a viscosity profile, which in turn was used to construct theoretical current profiles. The theoretical current profile agreed well with observations. Other forms of viscosity become ambiguous in this case because these forms contain numerical coefficients that must be chosen arbitrarily.

Five current meters on two moorings in the Alaskan Stream off Kodiak Island were recovered ending a year-long deployment designed to provide information on the shear and scale of features in the stream and on the energy transfer to shelf waters. Analysis of data from two cruises in the Alaskan Stream (winter 1980 and summer 1981) reveals marked differences in the flow. The winter data showed a typical inflow of stream waters into the Gulf of Alaska and relatively constant transport from the head of the Gulf westward; the summer data indicated reduced transport in the eastern part of the area and a greater inflow across the southern boundary of the stream between 150°W and 165°W. Earlier work did not reveal a correlation with transport and wind-stress curl integrated from the coast, but spatial differences in the local wind-stress curl (Ekman pumping effect) do appear to account for the flow variations. This is the same mechanism previously found for inducing seasonal variations in the flow of the Kuroshio. Thus a forcing function has been identified that can cause large changes in the Alaskan Stream, and further work will focus on the detailed features resulting from these fluctuations.

A circulation regime in which the mean flow is strongly influenced by the complex topography has been identified on the Kodiak Shelf. A numerical potential vorticity model shows that streamlines follow isobaths and form a cyclonic vortex, or Taylor column, over the Kiliuda Trough. This result is in good agreement with direct current measurements. Areas of steeper topography concentrate streamlines, causing current speeds to be dependent, in part, on the local topographic gradient. The measured mean flow pattern did not change significantly between winter and summer in spite of drastic changes in magnitude and direction of seasonally averaged local wind stress. Thus the dominant driving mechanism for the mean shelf flow is the Alaskan Stream boundary current instead of wind forcing.

Plans FY 1983

Analysis of Puget Sound data will continue. In 1983 the analysis will provide a quantitative description of the surface and bottom flows across Admiralty Inlet, and of the entrainment on the south side of the sill.

A major experiment will be performed in Puget Sound to determine the bulk transport of water, suspended particulate matter, and related pollutants in an area presumed to be the final resting place of pollutants introduced into the Sound.

PMEL

In FY 1983 we propose to continue to explore the rates of accumulation of sediments by expanding our use of geochronometers to include long-lived isotopes ($^{239,249}Pu$) to delineate deep-mixing processes; by examining natural sedimentation horizons using physical techniques (visual/textural searches for ash layers in deep cores) and the available geophysical records (seismic profiles); and by comparing sediment pollutant inventories with demographic data (pollutant source strength and time relationships with sediment column profiles). We will continue our studies of trace element and PAH fluxes in Puget Sound. These data will provide a basis for determining the relative importance of several possible removal mechanisms for these toxic pollutants in coastal waters. Work will continue on trace element recycling processes in the underlying sediments. Emphasis will be placed on processes occurring in the southern main basin, a region of fine-grained sediment accumulation, where the largest buildup of trace metals in sediments has been observed.

Research on the fate of organic pollutants and trace metals will focus on burial and transformation processes and on relating concentration profiles in the sedimentary record to historical events in the surrounding watersheds.

MARINE OBSERVATION AND PREDICTION

Marine observation and prediction research is directed toward understanding and improving the prediction of phenomena of importance to marine warning and forecasting services. PMEL scientists work closely with colleagues from NWS to define research needs and assure that products of the research are made available to operational elements of NOAA. Research subjects include near-shore winds and waves, Arctic ice dynamics, and tsunami propagation and run up.

Accomplishments FY 1982

During 1981, PMEL sponsored a February-March cruise aboard the NOAA Ship SURVEYOR along the Bering Sea ice edge to study the ice structure and its response to oceanographic and meteorological forcing. This study was carried out in conjunction with researchers from the Department of Oceanography and the Polar Science Center at the University of Washington, the Scott Polar Research Institute in England, and NASA.

The 1981 experiment investigated and successfully recorded the effects of storms on the marginal ice zone. Swell generated by a storm with southerly wind fields broke up the floes more than 100 km into the pack and contributed to roughening the surfaces. Ice stations and ARGOS position buoys were deployed after the storm passed. The experiment produced a 64-h time series of ice drift, wind velocity, and relative current for a floe in the inner marginal ice zone (MIZ) and an 8-day record of ice drift at three stations. The ice velocities during the experiment were among the largest ever measured for sea ice (0.5 m s^{-1}). During 1982, analysis of these data produced a number of results with important implications for ice modeling. Ice drift was influenced by the tides on this shallow shelf; floes were advected by the tidal current and accelerated by the sea-surface tilt due to the slope of tidal height. The ratio of atmospheric drag coefficient to oceanic drag coefficient, calculated from the relative wind and current velocities, was similar to ratios determined for Arctic ice. The magnitude of atmospheric drag coefficient, calculated from 168 20-min samples of velocity measured at four levels on a meteorological tower were among the largest observed for pack ice: 3.1×10^{-3} for a 10-m reference level. We attribute the large ice velocities to the validity of the free-drift assumption (i.e., 95% of the force balance is accounted for by wind stress and current drag), so the effect of the aerodynamic roughness of the broken ice is large.

In February 1982, with the aid of the Office of Naval Research, PMEL completed the BERING-82 experiment, a study of ice drift and thermodynamics in the central Bering Sea. For the experiment, an array of two meteorological-oceanographic ice stations and six ARGOS buoys were deployed from Nome by helicopter, and five research flights were made by NOAA WP-3D aircraft from Anchorage. The intent of the experiment was to provide research support in the Bering to the Navy-NOAA Joint Ice Center and the Alaska Region of NWS as part of the marine observation and prediction program.

The ice stations oscillated north and south through the Bering Strait in response to wind and current. This result is of critical importance because it shows that some Arctic sea ice is actually produced in the Bering Sea. The aircraft experiment also documented the types of ice in the ice growth regions, the central Bering Sea, and the ice edge. Results of this research have been incorporated into a sea-ice prediction model for the Bering Sea, which calculates the balance between advection by wind and the growth and melting of the ice.

An important aspect of both the Puget Sound Wind Study and Bering Sea experiments has been the development of a data collection platform, GEM (GOES Environmental Monitor), which transmits data through GOES (Geostationary Operational Environmental Satellite). This development was particularly important for sea-ice studies, because the cost of ships and helicopters for deployment is often more than the cost of the data collection platforms. In the BERING-82 experiment two ice stations were deployed;

they reported wind, current, air and sea temperature, floe rotation, and position. The expendable nature of these platforms allows for long time series. The collection system also permits scientific analysis to begin shortly after data collection by providing the appropriate computer program library. PMEL has been a leader in the development of such technologies. We now consider that such development is complete for the needs of our program.

In the last few years a great deal of interest has focused on the impact of salinity enhancement caused by brine rejection during ice formation. This process alters both flow and water properties. Salinity is generally thought to be increased by wind-driven surface divergence. The process of salinity enhancement begins with the creation of ice-free areas within the ice field by the wind. When the winds repeatedly separate ice in this manner, extremely large effective ice production is possible, with an accompanying large vertical salt flux. If the water is contained in an appropriate reservoir, such as a shallow and broad shelf, its salinity can be enhanced significantly.

Over the winter of FY 1981, we collected long-term (~230-day) measurements from three moorings in the vicinity of St. Lawrence Island on the northern Bering Sea shelf. One mooring was deployed near the polynya that often occurs south of the island. These data confirm the existence of strong (~0.15 m s^{-1}) flow toward the Bering Strait northwest of the island (in Anadyr Strait) and suggest that regional circulation results in a moderate (~0.035 m s^{-1}) mean flow eastward along the southern coast of St. Lawrence Island. Variations in the regional circulation and variations in the wind field were coherent with, and accounted for, many of the current fluctuations south of St. Lawrence Island. In addition, 11 events occurred when offshore wind coincided with increasing salinity, decreasing water temperature, and reversal of the current. This suggests that ice formation and the ensuing brine rejection affect flow in the vicinity of the polynya.

Scaling of a simplified momentum equation indicates that the cross-shelf density gradient is a possible mechanism for some of these reversals. Salinity data show a seasonal cycle with an increase of about 1 g kg^{-1}, as well as individual events of brine rejection. During an average event time of 65 hours, the salinity increased by 8×10^{-3} g kg^{-1} h^{-1}; the heat flux can be estimated as 535 W m^{-2}. These fluxes correspond to an ice production of ~5 m per square meter of water surface during the winter of FY 1981. Extrapolation of our results and comparison with the freshwater cycle suggest that brine rejection is an important component of the regional salt budget.

The waves project provides improved wave-forecasting techniques to NWS, particularly for major river entrances and other hazardous coastal areas. Analysis is proceeding on a unique data set collected at the Columbia River entrance, one of the most dangerous navigation regions in the world. Results indicate that (1) refraction by currents is the primary physical mechanism responsible for wave amplification on the bar; (2) in terms of significant wave height, this wave-height amplification can exceed 40% for a peak ebb current of 2 m s^{-1} (4 kn); and (3) there is agreement between published tidal current prediction tables and subsurface observations (at 7-m depth) at a midchannel location 5 mi from the river entrance (however, surface currents at the entrance can exceed predicted upriver values by 20%).

A side-looking airborne radar (SLAR) was flown by the Oregon Army National Guard within 30 minutes of the predicted time of peak ebb current on 11 September. Near the entrance, surface current estimates of 2 m s^{-1} were derived from surface drifters tracked by shore-based radar; the corresponding prediction for a point 2 mi upriver was 1.6 m s^{-1}. Waverider deployments provided significant waveheight estimates increasing from 1.5 to 3.6 m approaching the entrance. On the basis of these data, it is reasonable to assume that the significant waveheight at the entrance was in excess of 4 m. Since the offshore significant waveheight was 2.9 m as measured by a NOAA buoy, the wave amplification was in excess of 40% on the bar. The SLAR imagery illustrates that the primary physical mechanism responsible for focusing wave energy on the

entrance was wave refraction by currents. Close examination of the image shows that the refraction is so severe that crossing of wave crests occurs in the entrance. Such extreme refraction is not evident on similar SLAR imagery taken during the previous slack period when offshore wave conditions were nearly identical.

Results from the Puget Sound Wind Study, completed in 1981, were transferred to NWS. In addition, four seminars with NWS forecasters were conducted by PMEL and University of Washington researchers to discuss applications of recent research to Puget Sound forecasting. A guide to the marine weather of western Washington was produced in addition to a set of composite surface wind and wind persistence field representations for the inland waters of western Washington, keyed to the wind direction measured at 850 mb by an atmospheric balloon sounding on the coast at Quillayute, Wash. The 850-mb wind is used as an indicator of the large-scale weather pattern. The composite fields show that the wind directions in the sea-level channels of the region vary in a regular fashion as the large-scale weather varies. These maps were given to NWS forecasters as an aid in improving predictions of marine winds in Puget Sound. The transfer of recent research results for operational use by NWS continues to be PMEL's main thrust in this one research area.

A significant barrier to the further improvement in forecast capability for the Puget Sound region is the lack of a local data synthesis and display capability. To explore various approaches, PMEL sponsored a workshop on data assimilation that included participants representing NWS; PMEL; the University of Washington; the Atmospheric Environmental Service, Vancouver, B.C.; and PROFS. Discussions centered on availability of data sources for real-time display and approaches for operational implementation. As a result of this workshop, the University of Washington, in cooperation with NWS, is designing a data collection and processing system for analysis and forecasting in the Puget Sound region.

Two pressure gages have been deployed in the eastern Pacific in anticipation of attaining the signature of a passing tsunami. One gage is in 16 m of water on the east side of San Cristobal Island in the Galápagos Archipelago. The gage is collocated with one of four gages placed in the EPOCS sea-level-variation study area. The other tsunami gage is at 95°W and 2.5°S at a depth of 3,800 m. Both gages utilize a Paros Scientific Digiquartz pressure gage and sample approximately once a minute. The expected sensitivity of the deep gage is less than 90 Pa, which will allow the observance of a 1-cm-high wave. Present laboratory and field efforts are directed at determining the actual response characteristics of these high-pressure gages and measuring the ocean background level of waves in the tsunami period range (4-90 minutes).

Plans FY 1983

PMEL will deliver and evaluate forecast products of NWS for sea ice in the Bering Sea and for hazardous waves at the Columbia River entrance.

The Marine Meteorological Studies group and the Coastal Physics group will participate in the Marginal Ice Zone Experiment in the Bering Sea (MIZEX-WEST) during February 1983. The experiment involves measurements taken from the ice breaker WESTWIND and the NOAA Ship DISCOVERER, and aircraft measurements from the NOAA WP-3D research aircraft. Data will be used to evaluate the sea-ice forecasting model and document regional sea-ice physics in the Bering Sea.

We will improve our capability to process large meteorological and sea-ice data sets and begin study of large-scale air-sea-ice interactions of importance to climate and long-range weather prediction.

The tsunami observational program will continue and analysis of FY-1982 data will provide energy estimates of waves from 4-min to 3-h periods.

MARINE RESOURCES

PMEL participates in research activities that provide information for resource management decisions by NOAA and other agencies. For instance, the Deep Ocean Mining Environmental Study (DOMES) in 1978 was managed by PMEL. Analysis of processes relevant to deep ocean mining continued through FY 1981. These studies have laid the groundwork for current investigations of polymetallic sulfides.

Research in Alaska centered on environmental quality, and sea-ice forecasting is expected to have spinoffs for living marine resources in the near future.

Accomplishments FY 1982

Recent investigators of sea floor volcanic vents have discovered metal deposits, in the form of sulfides, which are potential sources of several metals of importance to the U.S. economy. Geochemical investigations of hydrothermal venting systems, which are sometimes associated with polymetallic sulfide deposits, have been conducted by PMEL oceanographers during the past 2 years. These studies are designed to improve our understanding of the characteristics of sulfide formation and the location of deposits. Near-bottom water samples have been collected along the axis of the Juan de Fuca Ridge from its juncture with the Blanco Fracture Zone to the Cobb Offset, and along the northern 150 km of the Gorda Ridge. Along with measurements of the standard hydrographic variables, samples have been analyzed for methane, dissolved manganese, total dissolvable manganese, and the elemental composition of suspended matter. The manganese data have been particularly useful in the search for regions of active venting, because the emanating hydrothermal solutions are rich in dissolved manganese. Upon mixing with seawater, manganese undergoes a transition to the particulate phase and, in the process, becomes a likely scavenger for other trace metals. The several hundred meters of near-bottom water over both ridge systems display a greater than fifteenfold enrichment of particulate manganese, relative to open-ocean values. Similar elevated manganese concentrations have been measured over other active venting regions such as the Galápagos Spreading Center and the East Pacific Rise, and have been related to hydrothermal sources.

A cooperative effort in living marine resources was begun with the Northwest and Alaska Fishery Center (NWAFC). Efforts in FY 1982 explored areas of mutual concern and opportunities for synergistic research. Problems identified as needing the expertise of both organizations include recruitment failures of king crab in the Bering Sea, population fluctuations of pollock, and environmental effects on the early sea life of salmon.

Plans FY 1983

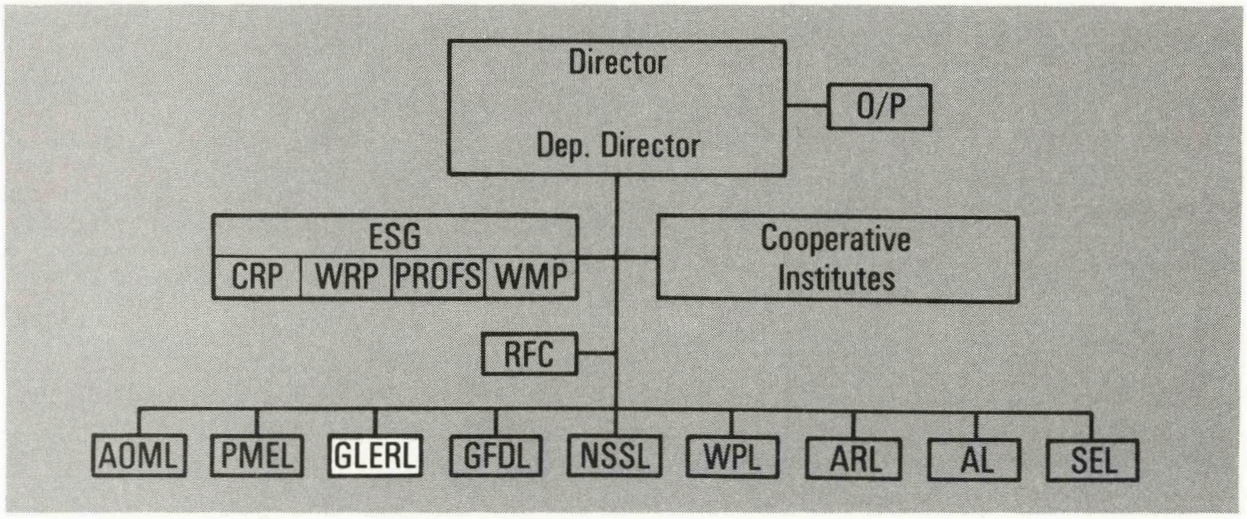
PMEL scientists will participate in a joint, interdisciplinary cruise in late 1983 to explore for active hydrothermal venting on the Juan de Fuca Ridge and Gorda Rift. Chemical tracers will be analyzed aboard ship to map the distribution of vent plumes in quasi-real time. Areas of presumed venting will have been detected earlier by geophysical prospecting and photographic techniques.

Research on living marine resources will commence with the joint development by PMEL and NWAFC of an environmental data base of the Bering Sea organized to support fisheries oceanographic research.

GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY

Ann Arbor, Michigan

Eugene J. Aubert
Director



The Great Lakes Environmental Research Laboratory (GLERL) conducts integrated, interdisciplinary environmental research in support of resource management and environmental services in coastal and estuarine waters. Special emphasis is on the Great Lakes. GLERL performs field, analytical, and laboratory investigations to improve understanding and prediction of coastal and estuarine processes and interdependencies with the atmosphere, land, and sediments; places special emphasis on a systems approach to problem-oriented environmental research, to develop environmental service tools; and provides assistance to resource managers and others in obtaining and applying the information and services developed. The environmental information is provided to government and private organizations to facilitate planning and decision making in water resource management. The GLERL program includes both background and applied studies and combines experimental, theoretical, and empirical approaches.

Research is carried out through five groups: Synthetic Organic and Particle Dynamics, Ecosystem and Nutrient Dynamics, Lake Hydrology, Physical Limnology and Meteorology, and Special Projects. Their disciplines and activities include meteorology, geology, hydrology, physical oceanography, aquatic chemistry, aquatic biology, applied mathematics, systems engineering, computer systems applications, instrument design and development, and experimental design and analysis.

The multidisciplinary program reflects the need for specific information about the Great Lakes. Studies of selected chemical and biological properties are needed to understand the ecological status and trends in the lakes and to manage waste, water supplies, and fisheries. Models to show the eutrophication process and the transport and fate of contaminants as a function of human input to the lakes are needed for wastewater management and regulation policies. Information on lake water levels, connecting channel flows, and ice distribution is useful to those concerned with erosion control, transportation, recreation, and power generation. Lake circulation studies are pertinent to the transport and diffusion of pollutants. Surface waves, seiches, and surges affect shipping activities, shoreline flooding, and erosion.

OCEAN AND GREAT LAKES RESEARCH AND DEVELOPMENT

Ocean and Great Lakes research and assessment activities at GLERL are directed toward (1) improving understanding and prediction of natural marine ecosystems, physical phenomena, and the impact of anthropogenic stresses on the ecosystem; and (2) developing a sound scientific basis for management decisions pertinent to marine resources, marine pollution, and environmentally sensitive marine activities. Activities in support of this program include investigation of the short- and long-term effects of human, agricultural, and industrial wastes on aquatic life and water quality, particularly in the nearshore zone, which is the area of maximum use and conflict; development of applied environmental service tools such as engineering models; measurement, analysis, and prediction of physical phenomena such as currents, lake levels, river flows, and sea-air-sediment interactions; and participation as representatives of NOAA and the Department of Commerce in regional, national, and international organizations addressing problems of the Great Lakes.

Accomplishments FY 1982

A modeling team, consisting of chemical, toxicological, ecological, and physical scientists, was set up in-house as part of a program on cycling toxic organic compounds. The modeling group is supported by researchers working on primary ecosystem processes. The program has expanded to include several research groups, an arrangement that allows for maximum flexibility. During the past year, a long-term, near-equilibrium model in which all decomposition processes are handled as first order has been calibrated for PCB's (polychlorinated biphenyls).

The association of synthetic organic contaminants with particulate matter in an aquatic system plays a large role in determining the compounds' behavior and fate. During the past year, measurements of PAH's (polycyclic aromatic hydrocarbons) and PCB's in laboratory experiments and sediment/pore water matrices have shown very high concentrations of contaminants in the dissolved phase. This indicates that desorption occurs at the sediment/water interface and it appears that the desorbed contaminants are being complexed with high-molecular-weight organic compounds. To improve our model estimates of sedimentation and resuspension, 111 sediment traps were deployed at 12 locations throughout the stratified period, and a subset of these were redeployed throughout the winter.

Box and gravity cores were collected from locations of maximum sediment accumulation in the four lower lakes. At the same time, cores were collected a few kilometers away, where accumulation was significantly slower, our assumption being that the distribution of compounds reaching these locations would be similar. Analysis of these sets of high- and low-sedimentation cores will provide information on the rates of early diagenesis of compounds in recent lake sediments.

Major pollutants are probably entered into the food chain by benthic organisms that ingest the sediment, directly absorbing and thus remobilizing the pollutants. The kinetics of uptake, depuration, and biotransformation of selected PAH's by selected benthic organisms is currently being examined. Bioconcentration factors of 10^4-10^5 from water have been measured in several types of benthic organisms. These organisms can contribute a substantial fraction of PAH exposure to fish.

Microchemical kinetic techniques were developed to provide more information about zooplankton nutrient regeneration through assessment of patterns and amounts of nutrient release for individual animals. These techniques were used to demonstrate that phosphorus was released both discontinuously and continuously by freshwater cladocera. Information quantifying these rates and interactions will be incorporated into ecosystem models to allow more accurate simulation and prediction of nutrient cycling and biological changes in the lakes.

Since aerobic sediments are the major sink for phosphorus in lake systems, processes releasing phosphorus from sediments back into the water must be understood and quantified for the development of predictive models of nutrient cycling in lake ecosystems. Preliminary laboratory studies of intact sediment cores at GLERL indicated that significant quantities of nutrients were released from aerobic sediments. Invertebrates from these same intact sediment cores were partially counted and identified to determine if phosphorus release was correlated with faunal abundance. No correlation was evident. However, laboratory microcosm experiments have indicated that invertebrates significantly increase the release of phosphorus. More detailed experiments using intact sediment cores and adding invertebrates at various densities are planned.

The composition and availability of phosphorus compounds in lake water and in input sources must be known to evaluate the impact of phosphorus from different sources on the biota of the lakes. GLERL studies have shown that the composition of the soluble reactive phosphorus pool in lake water is heterogeneous, that free orthophosphate is often an order of magnitude lower than indicated by chemical measurements, and that the major fraction of the soluble reactive phosphorus pool is unavailable for immediate use by microorganisms.

Space heterogeneity in nutrient supplies caused by excreted nutrient plumes around zooplankters has been proposed as a phenomenon important to controlling both growth and species selection of phytoplankton in the lakes. Using autoradiographic techniques, GLERL scientists were the first to demonstrate microscale heterogeneous phytoplankton uptake of nutrients excreted by zooplankton. This finding explains the apparent paradox that observed phytoplankton growth in lakes is much greater than would be expected on the basis of measurable concentrations of "available" phosphorus in the lake water. Demonstration of this phenomenon changes traditional theories of phytoplankton-zooplankton nutrient interactions and increases our understanding of possible mechanisms responsible for plankton succession patterns in lake and marine ecosystems.

Zooplankton feeding processes and rates must be understood to determine the role of these invertebrates in cycling nutrients and controlling phytoplankton successional patterns in the lakes. The feeding rate of an important zooplankton species in the Great Lakes was related to selectivity, effective food concentration, and food concentration, by describing the functional relation between feeding rate and food concentration for natural seston.

The biological aggregation of small particles into larger fecal pellets by zooplankton is an important mechanism for the transport of nutrients and toxic organics to the sediments because large particles settle more rapidly than small ones. Particle egestion and fragmentation by zooplankton were studied by microscopically examining prerinsed algae from control and experimental bottles of feeding experiments on natural seston. Results indicate that (1) fecal pellets are more numerous and smaller than expected; (2) fecal pellets sink at a rate of an order of magnitude faster in summer because of the presence of calcite crystals in the pellets; and (3) large amounts of some algae are left behind after attack by zooplankton.

Benthic fauna communities integrate and reflect environmental changes over long periods of time. Progress is continuing in evaluation of present-day distributions of benthic invertebrates in southern Lake Michigan. By comparing the number and kinds of organisms now in the lake with those found 17-50 years ago, we are gaining insight about the lake's changing trophic nature.

GLERL's interdependent tank-cascade model of basin runoff, employing analytical solutions of climatological considerations relevant for large watersheds, has been refined and applied to the Lake Ontario Basin in both lumped- and distributed-parameter approaches. Predictions are limited by available meteorological information,

but forecasting is practical if near-real-time data requirements are met. Formation of necessary data links with agencies in the United States and Canada is under way. The model has been chosen by the International Joint Commission for use in its assessment of data network needs in the Great Lakes area.

During the past year a monthly climatic water balance model was developed and calibrated for Lake Erie. The model was used as part of a study to determine the impact of secular changes in precipitation and air temperature on the water supplies to the Lake Erie basin. The study concluded that the primary cause of the recent high water supplies since 1966 has been an increase in precipitation averaging 6%. The model indicated that this increase resulted in a 16% increase in runoff. Tests have also indicated that a 0.5°C decrease in air temperature will increase runoff by 6%. The model is currently being used to improve water supply forecasts for Lake Erie.

This year marked the end of field data acquisition for the Unsteady Overland Sedimentation project conducted by GLERL in cooperation with the USDA Science Education Administration (SEA), with input from USGS. Specially prepared plots of agricultural lands were exposed to computer-controlled rainfall from SEA's rainulator at Purdue University. The theory developed and tested in these experiments is useful in ultimate assessments of sediment loadings to the lakes from agricultural lands.

The study of winter flow regimes of the St. Clair and Detroit Rivers was advanced with successful completion of the first field season for continuous velocity measurements in the St. Clair River. Preliminary analysis of data indicates substantial differences between winter flows obtained from current meters and from GLERL dynamic flow models. Ice effects are suspected as the main reason for these deviations.

A considerable effort was mounted this year to develop and refine a toxic substances budget model that is easy to implement and could be useful for management. The model simulates the concentration of a contaminant in the sediments and overlying water column of a lake. The contaminant being considered is divided into that associated with organic and inorganic particulate matter and that dissolved in the water. The principal application of such a model is to predict the year-to-year and steady-state responses of the water column and sediments of the Great Lakes to changes in the loading rate of a contaminant and/or particulate matter.

Beginning this year a procedure was established to update U.S. tributary pollutant inputs of total phosphorus, soluble reactive phosphorus, suspended solids, total nitrogen, nitrate, ammonia, and chloride. The procedure uses a ratio-estimator technique that accounts for the variability of flow on pollutant loads over an annual cycle. This data will provide a long-term estimate of the variability of pollutant loads necessary when trying to understand lake dynamics.

Phosphorus continues to be the key nutrient considered in Great Lakes management, but not all of the phosphorus entering the lakes affects biological productivity. GLERL scientists, in cooperation with university researchers, found that 40% or more of the phosphorus loaded to the lakes in association with particulate material cannot be used in the growth of algae and higher plants. A mathematical model was used to illustrate the special importance of positional limitation. Information of bioavailability is of great practical importance, since it can lead to considerable savings in the cost of phosphorus control programs.

With water in short supply in many areas of the United States, national attention has been focused on the vast reserve of high-quality water held in the Great Lakes system. Nevertheless, a drop in lake levels of only a few centimeters has an important effect on many activities and natural processes. International treaties restrict the amount of water that can be exported. On the basis of a preliminary analysis done this year, it was concluded that considerable water could conceivably be withdrawn

from the system without causing a large drop in lake levels relative to natural conditions. A diversion of 60 $m^3 s^{-1}$, less than the current diversion out of Lake Michigan through the Chicago Sanitary Canal, would supply the water needs of New York City.

Another concern for the future is increased water withdrawn from the system but not returned. Examples of this consumptive use include evaporation losses from powerplant cooling systems and incorporation of water into industrial products. Recently it was estimated that consumptive use could increase about 5 times the current level over the next 60 years. A hydrologic response model was used to indicate that the average lake level on the unregulated lakes (Michigan, Huron, and Erie) could be lowered about 21 cm by the year 2035.

A barotropic circulation model was used to simulate kinetic energy spectra observed in previous years in Lake Michigan. Impulsive (white noise) wind stresses were applied and the generated currents studied to determine the frequencies and spatial structures of long-period rotational modes. Observed 3-hourly wind stresses were applied, and spectral analyses of the current velocity components revealed kinetic energy distributions very similar to those observed with current meters.

Fifteen current meter moorings were deployed on a widely spaced grid in Lake Michigan to study on a large scale the important properties of rotational waves in the lake basin. Earlier studies revealed a powerful mode present in the lake's southern basin. This study will determine the lake-scale structure of the waves and their propagation characteristics.

Analyses of current meter data collected in Lake Erie in 1979 and 1980 continued. Current patterns are being related with the wind-stress-driven movement of the important, oxygen-deficient, thin hypolimnion layer that forms near the bottom in summer.

A principal GLERL activity is maintenance of an advisory service as a means of providing scientific information in a form compatible with user needs. GLERL provided over 3600 research products in response to over 2400 documented requests in the areas of ocean and Great Lakes research and assessment, and ocean and Great Lakes services research. Of these, 42% came from institutions of higher learning, 31% from U.S. and foreign Federal governments, 15% from private industry, 7% from domestic and foreign State governments, and 5% from private citizens. This is in addition to regular mailings to those who have indicated interest in a 6-mo listing of available publications and one or more of the five types of GLERL publications.

Plans FY 1983

The experimental study of the St. Clair River winter flow regime using remotely monitored electromagnetic current meters will be continued and expanded to include the Detroit River. **GLERL**

The climatic water balance modeling of the Lake Erie basin will be expanded to the Lake Superior basin and will serve as one of the bases for developing water supply forecasts for Lakes Superior and Erie.

The refinement and application of the GLERL Large Basin Runoff Model will use near-real-time snowpack and soil moisture data from the upcoming joint U.S.-Canadian gamma snow surveys over the Lake Superior Basin. Use of other near-real-time meteorological information will enable use of the models for forecasting basin runoff on each of the Great Lakes.

Current meters deployed in Lake Michigan in June and July of 1982 will be retrieved in the summer of 1983. After data translation and editing, the currents will be examined for rotational wave structure and results will be compared with those of Lagrangian experiments.

A three-dimensional model of Lake Michigan will be verified and fine tuned using archived current meter records.

Detailed analysis of the 1981 Lake Erie measurements is planned to study momentum flux in the coastal boundary layer and surf zone. Studies of wave energy dissipation in the refraction zone and generation of edge waves will be included.

The importance of both substrate type and macrobenthos composition to the regeneration of phosphorus from sediments will be investigated using laboratory microcosms.

Mechanisms of particle (food) capture by Great Lakes zooplankters will be observed by high-speed microcinematography.

The effects of species, life stage, and food ingestion rate on nutrient release rates of coastal marine copepods will be examined.

The significance of small-scale nutrient patchiness to phytoplankton competition among species will be demonstrated. Species competition will then be modeled on the basis of small-scale processes.

The tendency of phosphorus to associate with dissolved metals and/or organic materials will be examined by high-performance liquid chromatography.

A large, continuous data base from Lake Washington will be used tc formulate and test ecosystem models applicable to Great Lakes and coastal marine ecosystems.

The availability of phosphorus in atmospheric precipitation (normal and acidified) to Great Lakes phytoplankton will be examined in a cooperative study with the U.S. Fish and Wildlife Service.

The long-term equilibrium toxic model will be modified to become a coupled Great Lakes model. It will incorporate resuspension input, and time steps will be shortened to 1 month in order to incorporate the variances associated with changing particle characteristics.

The sensitivity of contaminant models and their responses to perturbations in input information and coefficients will be analyzed.

In addition to work on behavior and fate of toxic organic substances, a major new program on the modeling of contaminant uptake by fish will begin.

Another new area in the toxic organics program is work on effects of contaminants. Studies of bioturbation and mixing rates will provide information on mixing of recent sediments. The experiments are designed to use mixing rates as a behavioral indicator of chronic stress in worms exposed to increased levels of contaminants. A second stress test, the lysosomal enzyme release rate, is under study.

Initial analysis of samples of sediment cores from the high-depositional areas of the four lower Great Lakes will be completed.

Ongoing applied modeling efforts will focus on refining a toxic substances budget model that is easy to implement.

Techniques such as risk assessment, cost-effectiveness analysis, and optimization analysis will continue to be used to focus studies on high-priority items such as pollutant inputs to water systems, land runoff pollution, and dredging. The long-term significance of pollutant accumulations in deep depositional basins will be given further attention.

Studies on Great Lakes water quantity management, such as consumptive use and export, will continue.

Estimates of average annual pollutant inputs to the Great Lakes from various sources will be updated. Key products expected to be derived from this research are a Great Lakes sediment budget and the relationship between tributary flow and pollutant inputs.

OCEAN AND GREAT LAKES SERVICES RESEARCH

Ocean and Great Lakes services research activities have focused on better understanding leading to improved prediction of phenomena primarily involved with marine warning and forecasting services. GLERL research includes field and analytic investigations of waves, flooding, water level oscillations, storm surges, overwater winds, and lake ice formation, growth, transport, and decay. Researchers in these areas work closely with their colleagues at such agencies as the National Weather Service (NWS) to assure that GLERL products meet the needs of operational forecasters. Followup on forecast accuracy and fine tuning of forecast procedures, in collaboration with these operational forecasters, are often included. GLERL staff participate as representatives of NOAA and the Department of Commerce in regional, national, and international organizations addressing Great Lakes services research problems.

Accomplishments FY 1982

The Great Lakes connecting channels are used intensively for navigation and are the location of a large number of industrial concentrations and municipalities, with the related risk of oil or other chemical spills occurring in these channels. The possible occurrence of spills and their attendant trajectories, travel times in the channels, and containment is of primary interest to the National Response Organization for Oil and Hazardous Materials Spills. At the request of the Response Team, GLERL prepared travel time tables for the St. Clair, Detroit, and St. Lawrence Rivers, and the Illinois Waterway.

A report that documents the file structure and format of the computerized 20-yr ice concentration data set was completed in 1982. That report will facilitate distribution of the data set, which is scheduled to be archived at the National Snow and Ice Data Center in 1983. It is hoped that this data set will prove useful to a broad spectrum of users in the fields of research, operations, and planning.

Over the past year a set of ice-forecasting techniques has been developed for the U.S. Army Corps of Engineers. The general problem was to determine how well ice cover formation, growth, and breakup could be predicted on the St. Marys River. Although the river is one of the busiest commercial waterways in the world, it is ice covered for up to 4 months, causing significant problems for ship movement. To provide the greatest flexibility in forecasting leadtime, methods were chosen that relied on observed ice cover, water conditions, and air temperature projections only.

An analysis of near-shore ice thickness data for 30 stations around the Great Lakes was completed this year. The purpose of the study was to evaluate to what extent ice growth was a function of air temperature as measured at the nearest reporting weather station. The results suggest that site-specific forecasts could be developed solely on the basis of air temperature projections.

A deterministic Great Lakes ice dynamics simulation model was developed and calibrated under contract, to be used as an aid in forecasting Lake Erie ice conditions. The model permits short-duration forecasts on the order of days to be made on the basis of predicted winds and air temperatures, and known ice conditions at the beginning of the forecast period.

Preliminary analyses of currents, waves, water levels, and winds recorded in a cross section of the coastal boundary layer and surf zone of Lake Erie during 1981 has been completed. Data were collected during the passage of four major storm events, of approximately 2 days duration each. Momentum fluxes during the growth and decay phases of the four episodes are now available. The experimental setup consisted of a surf zone array designed and operated by the University of Michigan, and a deep-water current meter, Waverider buoy moorings, and a tower operated by GLERL.

Two Waverider buoys were deployed east and west of the western Lake Erie basin island chain. One of these is in the proximity of a NDBO (NOAA Data Buoy Office) NOMAD buoy. Hence the measurements, in addition to providing a study of island chain effects on wave characteristics, can also be used to make a comparison between Waverider and NOMAD buoy measurements. The real-time data is available to NWS for marine wave forecasts.

Available data were used to test three different methods for determining overlake wind speed as a function of overland wind speed and air-sea temperature difference. The results show that different statistical methods for determining overlake wind speed from overland wind speed have not improved markedly.

Satellite-tracked drifter buoys were deployed in Lake Michigan to test the usefulness of these Lagrangian measurement systems for Great Lakes applications. Trajectories of their movements will be compared with predictions from spill model forecasts and with progressive vector compilations from the fixed current meters.

Plans FY 1983

A task will be initiated to investigate the variability of Great Lakes ice cover, using the digital ice concentration data base developed for the Ice Atlas.

Ice breakup forecasting development for the St. Marys River will be completed and become operational. Research on the stochastic characteristics of the St. Lawrence ice cover between midwinter and breakup will continue.

A mathematical model of ice transport for Lake Erie will be refined and evaluated for application to the other Great Lakes.

Improvements will be incorporated into the spill model, and predictions of trajectories will be tested by satellite-tracked drifter-buoy movements.

The Lake Erie Waverider wave measurement program will be continued, and island effects will be studied.

Continued development of numerical wave modeling is planned using 1981 and 1982 Lake Erie measurements and 1981 NDBO data from the NOMAD buoys in the Great Lakes.

FACILITIES

Personnel in GLERL's marine instrumentation laboratory deployed 15 moorings in Lake Michigan using 35 vector-averaging current meters and sediment traps. Fabrication of a flow tank has made possible the calibration and evaluation of several current meters and sensors. A data concentrator was developed for use in multisensor, slow-process environments, such as in chemical analysis.

The research vessel SHENEHON successfully participated in several studies involving toxic organic materials, nutrient cycling, and lake currents and waves. The range of the ship included Lakes Michigan, Huron, and Erie.

The computer systems group supported the work of GLERL scientists by designing, coding, debugging, and testing systems and applications programs. Counsel was provided to programers, to facilitate their effective use of computing resources.

A tailored research collection is maintained by the GLERL library. Materials on toxic organics and nutrients are now being included as major subject areas. During the last fiscal year, the library staff performed 118 online literature searches, retrieved 544 interlibrary loans, and added 303 books and 215 reports to the collection.

Analysis of trace synthetic organic materials and nutrients continued in the chemistry laboratories. Personnel in the particle dynamics laboratory initiated analysis of the cores from high sedimentation areas in the Great Lakes. Nutrient cycling processes continued to be studied in the biology laboratories.

INTERNATIONAL AND INTERAGENCY ACTIVITIES

GLERL staff members were active in several International Joint Commission boards and committees, including the Levels and Flows Advisory Board, Technical Information Network Board, International Great Lakes Diversions and Consumptive Use Reference Working Committee, and Nonpoint Source Task Force.

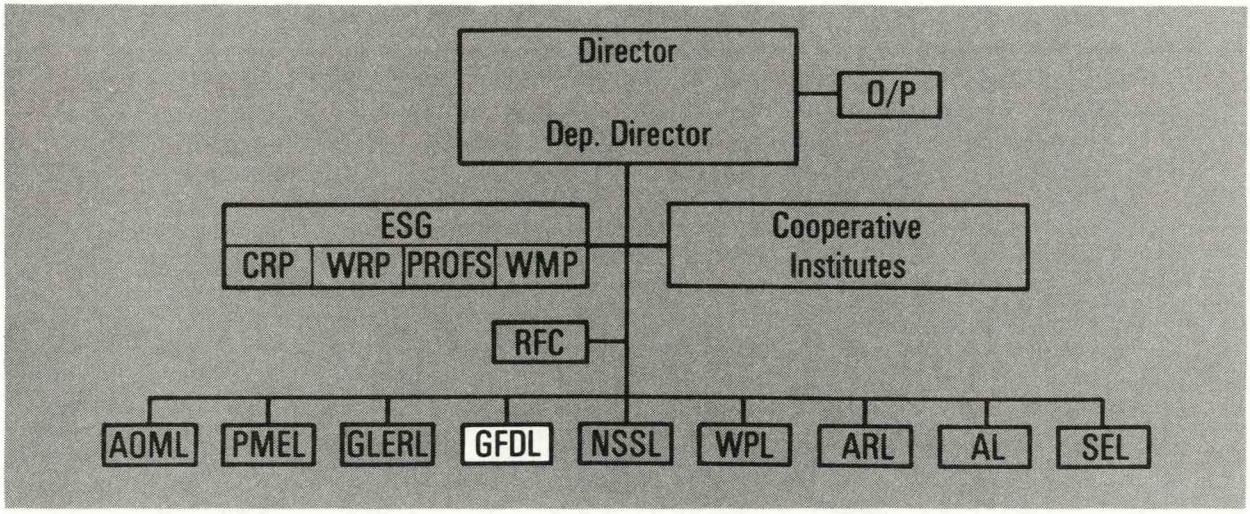
A GLERL staff member serves on the Natural Resources Management Committee (Subcommittee on Land and Air, Subcommittee on Water) of the Great Lakes Commission.

GLERL participated in activities of the International Coordinating Committee on Great Lakes Hydraulic and Hydrologic Data; Regional Response Team for Oil and Hazardous Spills; Joint United States-Canadian Ice Information Working Group; International Association for Great Lakes Research; Science Education Administration of the U.S. Department of Agriculture; NOAA-U.S. Geological Survey Coordinating Committee for Hydrologic Research; International Association for Hydrologic Research; Interagency Great Lakes Hydromet Steering Committee; and Research Institute for Hydraulics, Hydrology, and Glaciology at ETH-Zurich.

GEOPHYSICAL FLUID DYNAMICS LABORATORY

Princeton, New Jersey

Isidoro Orlanski
Acting Director



The Geophysical Fluid Dynamics Laboratory (GFDL) is engaged in comprehensive long-lead-time research fundamental to NOAA's mission. GFDL's goal is to expand the scientific understanding of those physical processes that govern the behavior of the atmosphere and the oceans as complex fluid systems. These fluids can then be modeled mathematically, and their phenomenology can be studied by computer simulation methods. In particular, research is conducted toward understanding the following:

- Predictability of weather, large and small scale.
- Particular nature of the Earth's atmospheric general circulation within the context of the family of planetary atmospheric types.
- Structure, variability, predictability, stability, and sensitivity of climate, global and regional.
- Structure, variability, and dynamics of the ocean over its many space and time scales.
- Interaction of the atmosphere and oceans, and how they influence and are influenced by various trace constituents.

The scientific work of the Laboratory encompasses a variety of disciplines: meteorology, oceanography, hydrology, classical physics, fluid dynamics, chemistry, applied mathematics, high-speed digital computation, and experimental design and analysis. Research is facilitated by the Geophysical Fluid Dynamics Program, which is conducted collaboratively with Princeton University. Under this program, regular Princeton faculty, visiting scientists, and graduate students participate in theoretical studies, both analytical and numerical, and in observational experiments, both in the laboratory and in the field. The program is partially supported by NOAA funds. Visiting scientists to GFDL may also be involved through institutional or international agreements, or through temporary Civil Service appointments.

The following sections describe GFDL's contribution to five major research areas that correspond to NOAA's missions in oceanography and meteorology. Additional information on the Laboratory's program is available in its Annual Report.

WEATHER SERVICE

During the past two decades synoptic-scale weather forecasts have improved considerably because of the development of numerical models that include more of the physical processes of the atmosphere, that have high spatial resolution, and that parameterize turbulent processes accurately. Successful forecasts for periods up to a few days are now possible, and the limits of atmospheric predictability have been extended to several weeks; however, quantitative precipitation forecasts remain elusive. Regarding phenomena with small spatial scales, considerable progress has been made in determining the mechanisms that generate severe storms, in explaining how mesoscale phenomena interact with the large-scale flow, and in simulating the genesis and growth of hurricanes.

This success in the extension of atmospheric predictability encourages us to pose more challenging questions. Can weather be predicted on a time scale of months? Are mesoscale weather systems and regional-scale precipitation patterns predictable, and if so, is the prediction dependent on predicting the ambient synoptic flow? Research to develop mathematical models for improved weather prediction will also contribute to the understanding of such fundamental meteorological phenomena as fronts, hurricanes, severe storms, and tropospheric blocking.

Accomplishments FY 1982

A new method for generating cloud fields was tested. In this procedure the observed short- and long-wave radiative fluxes are expressed as a function of layered cloud amounts. The distribution that minimizes the variance of the fluxes is the optimal solution. Monthly mean fields of low and high cloudiness calculated by this method are consistent with satellite measurements.

An economical "anomaly model" was tested. The model calculates the long-term departures from climatological mean variables. Integrations with large time steps are possible by filtering the more transient waves. Monthly anomaly predictions from time-dependent and stationary anomaly models (which use an existing spectral model as a control) are promising.

Operational production of FGGE (First GARP Global Experiment) Level III-b data was completed satisfactorily. The processing and analysis of this global data set, with a spectral GCM (general circulation model), includes nonlinear, normal model initialization and four-dimensional data assimilation. Periodic controls on the results revealed a very restricted data rejection criterion. Relaxation of this criterion resulted in a satisfactory level of transient kinetic energy.

Mesoscale prediction experiments, using a meso-α (200- to 2,000-km) model nested in a global spectral model, indicate that precipitation forecasts for 9-11 April 1979 over the United States are more accurate when the global model is initialized with the recently analyzed FGGE data rather than with the NMC (National Meteorological Center) Level III-a data.

In addition, the severe storms that occurred on 10-11 April 1979 in Oklahoma and Texas are being simulated by means of a finer scale meso-β (200- to 20-km) model nested into the limited area covered by the meso-α model. The solutions indicate that higher resolution alone does not significantly alter the location of the convection as predicted by the meso-α host model. Sensitivity tests suggest that, on meso-α and

possibly meso-β scales, the observed horizontal structure of moisture in layers close to the ground is required to produce accurate prediction of the locations of convective activity on meso-β scales.

It has been recognized that subgrid parameterizations used in GCM's are not necessarily appropriate for mesoscale, limited-area models. Two important developments in mesoscale modeling are the inclusion of orography in the meso-α research model and the use of the quasi-hydrostatic approximation in the meso-β research model. Previous schemes to test orography in finite-difference models have drawbacks. A new approach in which a parameterized body force has the shape of the actual orography has been tested in the three-dimensional model with considerable success.

The sensitivity of tropical storm genesis to the sea surface temperature (SST) was investigated with a channel-type, 11-level numerical model. An idealized easterly wave can develop into a tropical storm, under realistic environmental conditions, only when the SST is higher than 26°C. This is in accord with observations.

Analysis of a quasi-stationary compact hurricane eye in a quadruply-nested model indicates that its asymmetric features contribute to cooling and moistening the eye, which otherwise tends to be warmed and dried by the mean motion.

Calculations of deep, moist convection over a 4-h period, with a model that uses a tropical maritime sounding of temperature and water vapor, show that the ratio of total rainfall reaching the ground to the total water vapor condensed is the same for two different profiles of the atmospheric convergence.

Plans FY 1983

A finite-difference model will be used to evaluate the effect of SST anomalies and the effect of different initial conditions on 1-mo forecasts for six Januaries between 1972 and 1982.

One- and three-dimensional models will be used to evaluate the effects of mixed-layer parameterization, initialization procedures, and surface boundary conditions on the forecasts of SST for 1976-1977.

A new method for representing the effect of orography by means of body drag in a mesoscale model will be tested.

The quasi-hydrostatic approximation in a meso-β model will be tested to see whether it can represent convection and gravity waves.

Simulations of moist atmospheric convection will be made with a model that uses a continental sounding of temperature and water vapor and that includes realistic vertical wind shear.

GFDL

Studies will be made of the decay mechanism of a hurricane after its landfall.

CLIMATE

The purpose of climate-related research at GFDL is twofold: to describe, explain, and simulate climate variability on time scales from seasons to millenia; and to evaluate the impact on climate of human activities such as the release of CO_2 and other gases in the atmosphere. The phenomena that are studied include large-scale wave disturbances, with a period of a few weeks, and their role in the general circulation of the atmosphere; the seasonal cycle, which must be known before departures from the seasonal cycle (interannual variability) can be appreciated; interannual variability

associated with phenomena such as El Niño-Southern Oscillation; very long-term variability that, for example, includes the ice ages; and the meteorologies of various planets, to enhance our perspective on terrestrial meteorology and climate. Both observational and theoretical studies are necessary to achieve these goals. Available observations are analyzed to determine the physical processes that maintain the circulations of the oceans and atmospheres; mathematical models are constructed to study and simulate the ocean, the atmosphere, the coupled ocean-atmosphere-cyryosphere system, and the various planetary atmospheres.

Accomplishments FY 1982

A detailed description of the climate in the atmosphere, based on 15 years of global surface and upper-air data, has been completed. Included are global diagrams of the flow of mass, angular momentum, and energy, and a 180-mo time series of hemispheric and globally averaged climate parameters.

A description of the three-dimensional structure of temperature, salinity, oxygen, and other derived parameters of climatic importance in the World Ocean is in press. Global maps of geostrophic currents and of mixed-layer depth are included.

The nonlinear energy transfer of transient planetary waves in the middle-latitude troposphere has been explored by means of spectral analysis of results from a spectral GCM with a uniform surface.

In a GCM with limited computational domain and idealized geography, removal of snow cover in the spring is found to increase the absorption of solar radiation by continental surfaces and to enhance evaporation so that the soil is drier during the summer. The same model shows that an anomaly of soil moisture is less persistent in the tropics than in middle latitudes because of the influence of the Earth's rotation on the atmospheric circulation.

External Rossby waves are found to explain some of the low-frequency variability in a GCM with no topography and no land-sea contrast (so that the climate is zonally symmetric).

The importance of the reflection of Rossby waves from tropical easterly winds for the structure of stationary eddies in the extratropical troposphere was analyzed in idealized linear and nonlinear models. A GCM simulation is found to be deficient, compared with observations, in poleward-propagating Rossby waves, either because of the absence of reflection from tropical easterlies or because of insufficient thermal forcing of Rossby waves in low latitudes.

New diagnostic analysis techniques were developed to allow clearer interpretations of simulated atmospheric motions in the GFDL troposphere-stratosphere-mesosphere GCM (called SKYHI). These diagnostics offer important new insights into the role of waves and disturbances (eddies) in the zonal mean flow. The analysis shows that the net effect of the eddies is to slow down the midlatitude westerlies in the entire region from the middle troposphere to the mesopause. Traditional diagnostics suggest the opposite conclusion.

A theory that explains El Niño-Southern Oscillation phenomena as instabilities of the seasonal cycle is being developed. A model of the eastern tropical Pacific Ocean, where El Niño events originate, successfully simulates seasonal SST changes although currents are less intense than in reality.

The study of CO_2-induced change of climate was conducted. In a global model of the atmosphere-mixed-layer ocean system, the day-to-day variability of surface air temperature in middle latitudes is reduced particularly during winter in response to an increase of CO_2 concentration in the atmosphere.

The influence of oceanic heat transport on the magnitude of CO_2-induced change of climate was investigated by comparing the sensitivities of the climates of two models with and without the effect of ocean currents. It was found that the heat transport by ocean currents raises the surface air temperature in high latitudes, decreases the positive feedback effect of snow and sea ice, and reduces the sensitivity of climate.

The response of the ocean to abrupt changes in the climate caused by factors, such as an increase in atmospheric CO_2, was studied with a detailed three-dimensional ocean model coupled to a simplified energy balance model of the atmosphere. Oceanic convection at high latitudes was found to play the same key role in climate response as it does in the downward penetration of tracers.

A high-resolution spectral GCM was used to evaluate the range of circulations exhibited by an Earth-like planet when external parameters are altered. Some of these circulations are analogous to those of Saturn, Jupiter, Venus, and Mars.

Plans FY 1983

During 1983 the regional effects of the atmospheric branch of the hydrological and energy cycles on the salinity and temperature structure of the World Ocean will be studied.

A simple two-dimensional (latitude-longitude) climate model, in which deviations from zonal symmetry are predicted with an idealized planetary wave theory, will be constructed during the coming year.

A model to study the growth and decay of El Niño-Southern Oscillation phenomena will be developed.

Detailed studies of the interaction between upward-propagating waves (from the troposphere) and the mean flow will be conducted.

An attempt will be made to determine the transient response of the atmospheric temperature to a future increase of atmospheric CO_2. Various published scenarios of future CO_2 growth will be used for this purpose. The first stage of this study will use a coupled ocean-atmosphere model with limited computational domain and idealized geography. Then, a coupled model with global domain and realistic geography will follow.

Results from recent experiments designed to evaluate the influence of continental ice sheets on the climate of the ice ages will be extensively analyzed.

Parametric GCM studies of planetary atmospheres will concentrate on analysis of the dynamical structure of the various circulation forms. The dependence on internal parameters, and improved models for Jupiter and Saturn, will be developed later. **GFDL**

ATMOSPHERIC QUALITY

The main goal of atmospheric quality research at GFDL is to understand the formation, transport, and chemistry of atmospheric trace constituents. Such understanding requires judicious combinations of theoretical models and specialized observations. The understanding gained will be applied toward evaluating the sensitivity of the atmospheric chemical system to human activities.

Ongoing work over the next 5 years includes analyses of atmospheric nitrous oxide, reactive nitrogen (natural plus anthropogenic) and tropospheric ozone. Models will be developed to include a number of trace constituents simultaneously. This

capability will be used to run interdependent experiments involving ozone and its precursors, partitioned components of total reactive nitrogen, carbon monoxide, etc. Also, development of a dynamically active ozone photochemistry will be completed for inclusion into the GFDL troposphere-stratosphere-mesosphere GCM.

Accomplishments FY 1982

A series of three-dimensional model experiments exploring the tropospheric behavior of N_2O have now been completed. The results include new experimentally verifiable predictions on the expected distribution and variability of N_2O in and away from the boundary layer. Experiments on the stratospheric structure of N_2O have led to a requirement for additional destruction mechanisms beyond that provided by current theory. Also, these experiments have discovered a "universal" predictable structure for all sufficiently long-lived trace constituents that are removed in the stratosphere.

Model experiments evaluating the classical "no chemistry" hypothesis have yielded provocative new results on tropospheric ozone behavior. These experiments reveal that the classical hypothesis produces remarkable agreement with observed ozone behavior and that the photochemical hypothesis can only modify the transport-dominated classical picture. An important exception appears to be in relatively polluted boundary layers.

Plans FY 1983

Atmospheric quality research will include the following in FY 1983:

- Development of the capability to include multiple trace constituents simultaneously in its models.
- Completion of studies of classical ozone and anthropogenic reactive nitrogen.

MARINE QUALITY

GFDL research related to the quality of the marine environment has as its objective the simulation of oceanic conditions in coastal zones and in estuaries, and the modeling of the dispersion of geochemical tracers (tritium, radon, etc.) in the world oceans. Over the next few years two- and three-dimensional models of estuaries such as the Hudson-Raritan and Delaware Estuaries will be developed. A variety of models will be used to study the response of coastal zones to transient atmospheric storms, and the nature of upwelling processes that are of great importance to fisheries.

Accomplishments FY 1982

A two-dimensional numerical model of the Hudson-Raritan Estuary, in which rivers are included as one-dimensional channels with variable width and depth, produces currents and tidal elevations that compare well with measurements. The barotropic tidal residual current, which is induced mainly by the coastal geometry through nonlinear inertial effects and by the bottom topography, contributes significantly to the steady circulation in the estuary.

Dispersion of tritium, produced by nuclear bomb testing in the 1950's, has successfully been simulated with a numerical model of the North Atlantic. A simple isopycnal model was used to determine the time scale of ventilation of the main thermocline.

Plans FY 1983

GFDL plans related to marine quality include the following:

- Development of a three-dimensional model of estuaries and application of the model to the Delaware Estuary.
- Study of the factors that determine large-scale meridional overturning in the oceans.
- Development of a model of nutrient geochemistry in the oceans.

OCEAN SERVICE

Models that can be used for prediction of oceanic conditions are being developed at GFDL. The simpler models are capable of predicting relatively few parameters. For example, one-dimensional models of the turbulent surface layer of the ocean predict the SST and heat content of the upper ocean. More complex, three-dimensional models are being developed to study phenomena such as the time-dependent development of Gulf Stream meanders and rings, generation of the Somali Current after onset of the southwest monsoons, response of coastal zones to atmospheric storms, and development of SST anomalies such as those observed in the tropical Pacific Ocean during El Niño-Southern Oscillation.

Accomplishments FY 1982

A high-resolution model of the North Atlantic Ocean, which nonetheless uses a modest amount of computer time, was developed to study the formation of water masses, the transport of heat, and the sensitivity of the results to model parameters.

The great ice shelves of Antarctica and the pack ice in both the Arctic and southern oceans are poorly understood, but are generally considered to be important in the Earth's climate. A growing body of data obtained from satellites and field experiments provides a basis for improving the treatment of ice in climate models. A detailed mixed-layer/sea-ice model has been calibrated with measurements of the seasonal cycle in the upper ocean made in the Arctic Ice Dynamic Joint Experiment in the Beaufort Sea. This local model will be used to improve more general, three-dimensional models, such as the coupled ocean and ice pack model being developed by the U.S. Army Cold Regions Research Laboratory and GFDL. This model is the first to include ice and ocean dynamics with a realistic rheology of the pack ice. Preliminary tests demonstrate the importance of heat transport by ocean currents in determining the position of the ice edge in the Norwegian and Greenland Sea area.

The intrinsic time scale of the response of a coastal zone to variable winds was determined by studying the manner in which a coastal zone comes into equilibrium after the sudden onset of winds parallel to the shore. These results were used to calculate the effect of a transient storm on the coastal zone of the ocean. Realistic winds for a 4-yr period are being used to force a model that will permit a description of coastal upwelling as a stochastic process.

Plans FY 1983

An eddy-resolving model of the Atlantic Ocean will be used to test the experimental design of the NOAA STACS (Subtropical Atlantic Climate Studies) program.

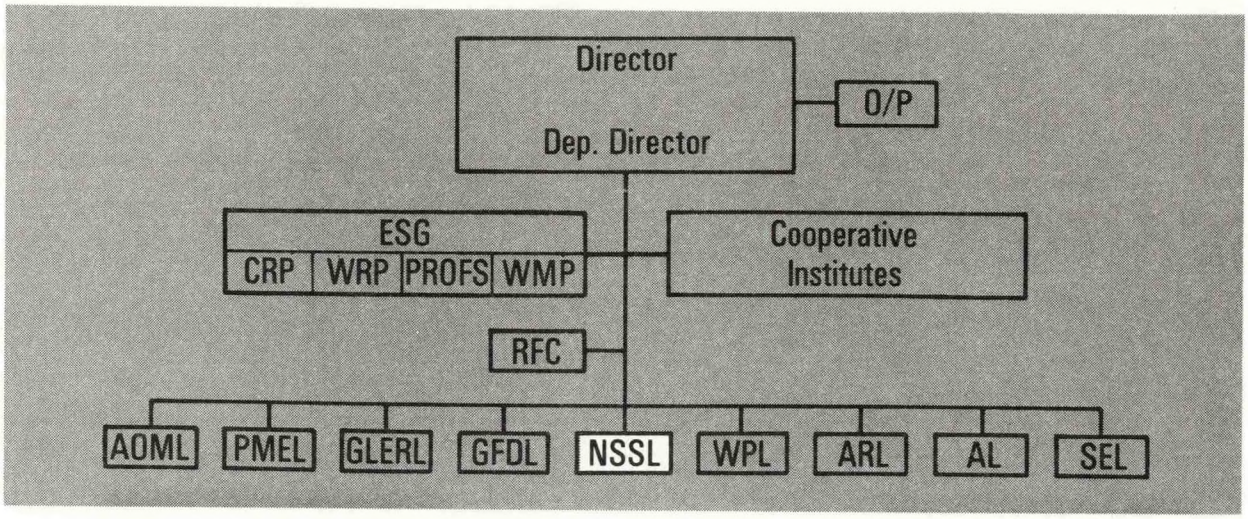
Models to simulate the seasonal cycle and interannual variability in the tropical Atlantic and Pacific Ocean will be developed with particular attention being paid to SST variations that are important in El Niño.

The effect of a realistic continental shelf on the response of coastal zones to atmospheric storms will be determined.

The parameterization of the turbulent mixing of heat and momentum in three-dimensional models of the ocean will be improved.

NATIONAL SEVERE STORMS LABORATORY
Norman, Oklahoma

Edwin Kessler
Director



The National Severe Storms Laboratory (NSSL) supports NOAA's weather observing and forecasting missions through studies of storm processes, numerical and conceptual modeling of storm phenomena, and development of improved means for observation. The NSSL mission has changed little over the years, but approaches have changed considerably in response to new technological developments, new scientific discoveries, and new requirements. Recent emphasis has been toward Doppler radar applications and studies of storm electricity.

The Laboratory maintains a 50-station capability for digital recording of surface meteorological parameters, and maintains instrumentation on the tallest tower in the United States that is equipped for recording boundary layer parameters. Two 10-cm Doppler radars on a 41-km baseline provide unique capabilities for recording atmospheric circulations in both precipitating weather systems and the optically clear boundary layer. A comprehensive range of instrumentation for recording electrical parameters has been brought to a high peak of refinement so that distributions of wind, water, and lightning can be recorded contemporaneously, and their interaction examined.

Through numerous relationships with other government agencies and universities, NSSL constitutes a resource for severe-storm data examined by researchers around the country and overseas. The Laboratory is analyzing data collected during the large field program, SESAME 1979 (Severe Environmental Storms and Mesoscale Experiment), and during other field programs, and with its outside collaborators, is applying the results to improve understanding and prediction of severe storms and to improve use of observing tools. The Laboratory is working closely with the Joint System Program Office of the Next-generation Radar (NEXRAD) program to help develop an effective national weather radar network for the late 1980's and beyond.

METEOROLOGICAL RESEARCH

The Meteorological Research Group seeks to improve thunderstorm forecast and warning capabilities by developing conceptual, numerical, and laboratory models of

major thunderstorm phenomena and of the prestorm atmosphere. Analysis and interpretation of storm flow fields expand our understanding of external and internal forcing, thermodynamics, cloud physics, and cloud dynamics, which contribute to intense thunderstorms and their attendant phenomena. Subsets of the group objective are addressed by two projects: Modeling and Dynamics, and Storm Evolution Analysis.

Accomplishments FY 1982

THEORETICAL STUDIES

A theoretical investigation on the linear effects of a turning shear vector on shallow convection in a nondiffusive fluid demonstrates that clockwise turning of the shear vector tends to produce storms with cyclonically rotating updrafts.

A physical interpretation of the diagnostic pressure equation was made to show that the dynamic component of pressure can be decomposed into two parts: deformational and rotational. The deformational (rotational) component cannot have a local minimum (maximum) in the interior of a flow domain.

An accurate theoretical approximation for adiabatic condensation temperature was obtained. The approximate solution lies within 0.01 K of the corresponding iterative solution for dewpoint depressions up to 40 K.

A review article on tornado dynamics was completed for inclusion in a comprehensive book on thunderstorms. Work on observational and theoretical aspects of tornadogenesis was completed.

Progress was made on the application of a method to retrieve pressure and temperature perturbations in convective circulations. An investigation into the effect of estimating water vapor in connection with these retrievals, and a preliminary application of the method to the convective boundary layer, were completed. Boundary layer pressure retrievals appear promising, in that continuity in time is maintained and magnitudes are in agreement with previous modeling estimates. Application of the method to a tornadic storm case where Doppler-derived winds are available is also producing quite favorable results. Analysis of the 19 May 1977 squall line utilizing both Doppler-derived winds and a two-dimensional cloud model has yielded some interesting relationships between discrete production of upward motion along the gust front and maintenance of the strong highly convective region of the squall line.

A numerical model is being developed to study mesocyclone evolution as a function of storm updraft strength and environmental wind shear. The procedure employs a kinematic iterative technique that utilizes only the three-dimensional wind field and a vertical air density profile. The model is initialized with a simulated axisymmetric updraft that suddenly is subjected to a vertically sheared ambient wind field. Response of the updraft to the winds is determined by iterating the three-dimensional wind field with time.

Work is continuing on the study of the sensitivity of hail growth to storm flow fields, determined from multiple-Doppler radar measurements, and to microphysical parameters, determined from a numerical model.

A study, which involves the use of both observations and modeling to investigate a sea-breeze-induced thunderstorm that occurred in southern Florida during the 1978 TRIP (Thunderstorm Research International Project) experiment, is near completion. A two-dimensional axisymmetric cloud model was developed and many experiments conducted using sounding data to specify initial conditions and single-Doppler radar data for comparison with modeling results. After systematic alterations of low-level environmental conditions and structure of the initial perturbation, a prototype model run was selected that produced the best match with the height and width of the observed storm.

Radial velocities were then calculated from the model velocities as though the modeled storm were being probed by Doppler radar. Good qualitative agreement was obtained in the velocity fields, and storm growth rates, evolution, and duration agreed quite well. The small amount of environmental wind shear produced significant differences in the reflectivity field, especially at later stages of storm evolution, but did not result in great changes in the radial velocity from the axisymmetric case.

OBSERVATIONAL STUDIES

Storm Data

During the past 12 months a considerable effort has been made to edit and complete preliminary analyses of dual-Doppler data sets obtained on 2 May 1979 and 19 June 1980. Data from 2 May are being used to study tornadic storm morphology and the interrelationship between tornadoes and their parental circulations. Data from 19 June are being studied statistically to determine lifetimes of storm elements and to examine the transition from multicell to supercell storms.

Storm Outflows

An investigation of severe storms that occurred on 23 May 1974 revealed interesting information on the multifaceted role of thunderstorm-produced gust fronts. Thunderstorm gust front boundaries appear to be responsible for storm initiation, propagation, and intensification. An especially interesting aspect was one storm's explosive growth and formation of a tornado near the intersection of two outflow boundaries. This study indicates that improved techniques for sensing outflow boundaries may allow better predictions of location, timing, and intensity of thunderstorm events.

Rainfall Rate Estimation

A paper discussing the utility of using radar to estimate rainfall was completed. A review of thunderstorm rainfall measurement by rain gage and radar was also completed. The principal conclusions were the following:

- Errors in radar rainfall estimates result from errors in estimating radar reflectivity factor and variation in Z-R relationships.
- Coexisting thunderstorms may have distinct radar error patterns.
- The tendency is to overestimate light rainfalls and to underestimate heavy rainfalls with radar.

Mesocyclones

NSSL Doppler radars documented portions of the life cycle of the disastrous Wichita Falls tornadic storm (10 April 1979) as it moved from 310 km southwest of Norman to 75 km southeast of Norman. Single-Doppler velocity measurements prior to the time of the Wichita Falls tornado revealed the presence of two mesocyclones about 20 km apart; the northeasternmost mesocyclone was associated with the earlier Seymour, Tex., tornado, and the second mesocyclone would produce the Wichita Falls tornado. By the time the second tornado formed, the first mesocyclone had dissipated. In general, the Wichita Falls storm followed the long-recognized supercell characteristics of motion, shape, and evolution common to tornadic storms.

A conceptual model of mesocyclone evolution is emerging from NSSL's data set of Doppler radar measurements that have been made in severe thunderstorms since 1971. Mesocyclone lifetime can be described as having three stages. In the organizing stage, the mesocyclone, which starts at storm midlevels, grows upward and downward toward the ground. During the mature stage, the mesocyclone is strongest and extends

from the ground to heights of 8-10 km. During the dissipating stage the top of the mesocyclonic circulation quickly descends to the ground as the circulation weakens.

If a mesocyclone has more than one (sequential) circulation core, subsequent cores develop much faster and remain mature for shorter periods of time. When a severe storm produces a series of sequential tornadoes, each tornado forms during the mature stage of the core circulation and decays during the dissipation stage.

It is well known that the right-moving member (looking downwind) of a splitting storm pair contains a mesocyclone with a closed counterclockwise circulation. NSSL has been successful in making single-Doppler velocity measurements in two left-moving members of a split pair. Meso-anticyclones (clockwise circulation) were found to coincide with the left-moving storm updrafts. However, the meso-anticyclone is more limited in its vertical extent and duration compared with its mesocyclone counterpart.

Tornadoes

A review article on interception of tornadoes by mobile teams has been included in a comprehensive book on thunderstorms. During the 1982 Spring Program the NSSL Tornado Intercept Team encountered six tornadoes, and in a joint effort with Oklahoma University deployed the totable tornado observatory (TOTO, described in the FY 1981 Annual Report) within 3 km of two tornadoes and under the edge of two rotating wall clouds. A pressure fall of 3 mb and a wind gust of 33 m s^{-1} were measured in association with one of the tornadoes. Descriptions of 1981 intercepts are contained in the 1981 Spring Program Summary.

NSSL Doppler radar measurements in the supercell storm that produced the unusually large Binger, Okla., tornado (22 May 1981) revealed unusual features. The Doppler velocity tornadic vortex signature (TVS) extended from the ground to within 1 km of storm top, indicating that the tornado itself existed throughout the same depth. Even more interesting is the finding that a weak echo hole coincides with the TVS. This is the first time that a marked reflectivity feature has been associated with a TVS.

GENERAL STUDIES

To provide quality data for future analysis of severe storms, programs were developed for quality control and archiving of the 1979 SESAME Stationary Automated Mesonetwork (SAM) data. Because of temperature-sensitive pressure units, pressure corrections were statically determined by using data collected from these units when subjected to varying conditions in an environmental chamber. The spatial integrity of the surface data was checked by use of a program developed to read the data archived in universal format and to analyze it objectively. All surface data for days when storms were present within the mesonetwork for 1973-1977 were archived in the universal format.

A software package was written for use on the CDC Cyber 750 to interface the NSSL plotting package with the DISSPLA plotting package residing on the 750. This eliminated the need to rewrite the NSSL graphics programs to be used on the 750 when the conversion to the 750 took place at the beginning of FY 1982. This package has benefited nearly all projects in the analysis of severe storms.

Plans FY 1983

- Theoretical and observational investigations of tornadogenesis will continue.
- The study of the 20 May 1977 storms will be completed and submitted for publication.

- The computation of severe-storm statistics from surface data for use in objective analysis and experimental design techniques will be completed.
- Techniques for the design of mesoscale field experiments will be further developed.
- Analysis and modeling of the 19 May 1977 squall line case will be completed.
- A case study of application of the thermodynamic retrieval techniques to a tornadic storm will be completed.
- A comparison of observed and numerically modeled fields within a Florida air mass storm will be completed.

DOPPLER RADAR AND STORM ELECTRICITY RESEARCH (DRASER)

DRASER develops and recommends new techniques for storm data acquisition and analysis, and relates observations to the physics of the atmosphere. The Doppler Radar Group focuses its efforts on interpretation of atmospheric phenomena with Doppler radar both for prestorm and stormy weather. The Storm Electricity Group focuses on observations of electric fields and lightning in and around thunderstorms to determine the interaction between storm processes, especially microphysical processes, and the storm's electric field.

The NSSL facility to observe electrical and kinematical processes contemporaneously with precipitation phenomena has no parallel. This program deals with the many complex aspects of lightning and other storm electricity parameters. Major objectives are to (1) determine relationships between lightning discharge processes and the dynamics and precipitation structure of thunderstorms; (2) evaluate storm electricity and Doppler radar data for indicators of thunderstorm severity; (3) develop and refine remote-sensing techniques for predicting, locating, and tracking thunderstorms and their hazards for improved warnings; (4) define lightning and kinematic characteristics of storms for inputs into engineering criteria for hazards to aircraft and ground facilities and into models used in environmental studies; (5) measure effects of electric fields and lightning on radar-derived meteorological parameters; and (6) provide ground truth and supportive data for development of a satellite-borne lightning mapper.

Accomplishments FY 1982

DOPPLER RADAR

Doppler Data Collection Program 1982

The 1982 spring data collection effort was quite fruitful in spite of the development of fewer storms in the dual-Doppler area than in the previous year. Several gust fronts passed over the surface network, which includes the LLWSAS (low-level wind sounding alert system) installed at Will Rogers Airport. Winds in excess of 60 kn were recorded. Dual-Doppler data also were recorded, and the storms are being analyzed. Several unique data sets of lightning echoes at vertical incidence were obtained, with a pulse duration of 0.25 μs and a corresponding range resolution of 37 m. This high resolution should help determine the cross section of lightning elements.

In cooperation with the Federal Aviation Administration (FAA), the evaluation experiment comparing airborne Doppler radar with NSSL's ground-based Doppler was resumed in May. By the end of June the Collins C-Band and the Bendix X-Band systems had been flown and data obtained on several storms. The Collins X-Band system test was

completed in July. The airborne systems display reflectivity and turbulence as indicated by the Doppler velocity spectrum width.

Prestorm Studies

The VVP (velocity volume processing) algorithm has been applied to prestorm radar data to obtain fields of horizontal divergence over large regions of the planetary boundary layer. The residual variance of the VVP data fit was found to be a useful criterion in accepting divergence estimates. The VVP divergence estimates were compared with those obtained using dual-Doppler radar data. To extend the comparison over larger areas, a new algorithm was developed for calculating divergence directly from radial velocity components of two Doppler radars (using Stoke's Theorem).

The effect of beam blockage at low elevations can significantly bias VVP divergence estimates, but this bias can be reduced if blockage is accounted for.

Some testing of the VVP program showed that decreasing the sector size does not appreciably improve the degree of fit to a linear wind, whereas the possible error in divergence estimation increases exponentially as the sector size is diminished. Thus, VVP resolution cannot be much better than 40°.

The VVP program was added to the Perkin Elmer (PE 3242) data processor and tested. A subroutine was developed to average radial velocities before the VVP analysis, which should reduce VVP processing time by at least 80%. The significant reduction enhances prospects for application of the VVP program in real-time processing.

Another algorithm computes vertical profiles of divergence at different ranges using the VAD (velocity-azimuth display) method. The first analysis of one case (19 June 1980) reveals a rapid development of low-level convergence about 2 hours before the development of thunderstorms in the area. The effects of beam smoothing on the vertical profiles of divergence were also examined, and a routine was developed for use on the CDC 750 to deconvolve and plot divergence and vertical velocity with height.

Some time series data were analyzed to determine the structure constant C_n^2 for the prestorm environment. Values of 10^{-14} to 10^{-15} $m^{-2/3}$ were found in the planetary boundary layer, with $C_n^2 \lesssim 10^{-15}$ for heights above about 2.3 km. Studies have begun to relate vertical profiles of reflectivity in clear air to turbulent fluxes of sensible heat and moisture. Fluxes have been computed from the KTVY-TV tower data for a few cases of coincident radar measurement. However, there appears to be considerable uncertainty in the absolute value of these fluxes.

Doppler Spectra of Tornadoes

Preliminary analysis of the spectra from the Binger tornado that occurred on 22 May 1981 was completed. Direct measurements of maximum velocities from Doppler spectra yielded values of over 90 m s^{-1} at the location of the tornado damage path. Houses were completely destroyed, and large missiles were generated at the time of the Doppler measurements.

Processing and Display of Doppler Weather Data

An algorithm has been developed to detect mesocyclones automatically. The algorithm operates on two radials of Doppler velocities at a time, and thus is suitable for real-time processing. Quantitative estimates of the location of mesocyclones or shear lines and their sizes are provided as output from the algorithm.

A color display terminal (Chromatics 7900) has been procured for use in compositing weather hazards and for aiding real-time interpretation of Doppler data.

An algorithm to estimate the mean velocity of the Doppler power spectrum from the peak of that spectrum was developed, along with a theory to estimate the probability density of the estimates. Simulated histograms at low signal-to-noise ratios indicate that the algorithm outperforms other conventional methods.

Effects of Charge and Electric Fields on the Shape of Raindrops

Closed-form theoretical solutions have been obtained that relate the eccentricity of raindrops to charge and electric fields. In the absence of an electric field, the natural oblateness of drops is enhanced by the presence of charge. This increase in eccentricity might be detected as an enhancement of the differential radar reflectivity. With increasing vertical electric field, drops elongate vertically, starting from oblate shape and passing through spherical and prolate shapes before breaking up. The role of charge in this process is to enhance preexisting oblateness or prolateness.

FAA-Related Studies

Several projects supported by the FAA have been completed. Preliminary studies were concluded on NEXRAD radar siting relative to airports for optimum weather surveillance in air terminal areas. Detailed studies on the lifetimes of storm features based on photointerpretation and computer correlation were conducted, with the final aim of using the data in arriving at an optimum scan strategy for NEXRAD. It was found that, for the storms studies, no hazardous features would have been missed by a 5-min scan cycle provided that data from all the three-moment fields (reflectivity, radial velocity, and Doppler spectrum width) at several elevations were utilized in the detection of hazardous phenomena.

Several gust fronts detected by the Norman radar were examined to build a data base on reflectivity, peak winds, height, etc. These data should help specify ground clutter canceling and the location of radar sites near airports.

Comparison between eddy dissipation rates inferred from the Doppler spectrum width and the rate measured from the spatial spectra of Doppler velocity is being made. It appears that dissipation rates inferred from the spectrum width are consistently higher.

In a related study it was shown that the residual between a least-fit linear shear and actual velocities is largest in places where the spectrum width is largest. Thus it appears that turbulent mixing at scales larger than the resolution volume creates nonlinear shear across several resolution volumes, and at these locations the cascade of energy down to the subresolution volume scales is enhanced.

Radar-Lidar Investigation of the Atmosphere

NSSL

The project became involved in a NASA contract with the aim to study the atmosphere by means of an airborne lidar, Doppler radar, and other instruments. Preliminary comparisons between instruments have been made, and spectra of turbulent velocities were obtained.

Profiling With the 10-cm Radar

A theoretical study about the feasibility of obtaining wind measurements up to tropospheric height with moderately powerful radars was completed. Ten-centimeter

radars with a 10-dB edge over the present NSSL system should be capable of measuring winds most of the time to about 12 km if the inertial subrange extends to 5-cm scales of turbulence. An experiment was designed to verify this hypothesis using a NASA radar at Wallops Island.

Book on Doppler Weather Radar

The last two chapters for the book on Doppler weather radar were completed. It is shown that two-dimensional horizontal irregularities with correlation lengths of tens of meters can explain the angular dependence of backscattered power observed at VHF frequencies.

STORM ELECTRICITY

Data acquisition with lightning-mapping sites, ELF installations, field-change and other storm electricity sensors, and the Doppler radars was closely coordinated during the 1982 thunderstorm season. Unfortunately, there were only a few storms and no tornadic storms within NSSL's nominal dual-mapping area.

A new sensor for observing extremely low frequencies (ELF) was developed and installed at NSSL and at NASA/Marshall Space Flight Center. Simultaneous data from both sites were obtained for cloud-to-ground (CG) flashes out to ranges of about 1,000 km. This ELF system will be evaluated for use in a combined ground and satellite-borne lightning mapper. The ELF system was also used to augment our ongoing research on positive cloud-to-ground (+CG) flashes. A unique data set on +CG flashes was obtained with the ELF sensors, photographic and television cameras, electric field change sensors, the VHF mapping system, and the lightning ground strike locating system. Positive CG flashes appear to be more hazardous than negative CG flashes and may also be correlated with storm severity.

We conducted several cooperative experiments with other government agencies and universities. Electrical data were used to provide real-time guidance to a NASA U-2 measuring lightning characteristics from above storms. The U-2 data are being compared with our ground-based measurements. Balloons equipped to measure vector electric fields were released into two storms. This cooperative program with the University of Mississippi demonstrated the feasibility of making such measurements in Oklahoma storms. Radar measurements of lightning were made in cooperation with the University of Oklahoma, CIMMS, and the Office of Naval Research. We also provided data acquisition support to New Mexico Institute of Mining and Technology, who simultaneously measured other lightning parameters during the U-2 overflights. Another cooperative effort with NASA/Langley and CIMMS at Wallops Island, Va., produced a significant amount of data resulting from a number of direct strikes to a NASA F106 aircraft, instrumented to study lightning hazards.

The VHF mapping instrumentation at Norman was modified to enlarge the azimuthal field of view from 60° to 120°. Our four-station, crossed-loop direction-finding network was modified to locate both +CG and -CG strike points within about 400 km of NSSL. The whole-sky television system was modified to record lightning only near the horizon for better verification of CG strikes.

Lightning activity along a squall line was studied using a 23-cm L-band radar. It was found that the IC (in cloud) to CG ratio was 76:1--an unusually high ratio.

Reflectivity, mean velocity, and Doppler spectra data were obtained for several lightning flashes. The motion of lightning channels is fixed relative to the air motion, and the Doppler-measured velocity of the channel also measures the true wind. In some cases, changes in reflectivity indicated that hydrometeors, aligned by strong electric fields, may have been reoriented with the field change caused by the lightning. Widths of the Doppler velocity of lightning channels were often less than

0.5 m s^{-1}, suggesting that shear or turbulence within the radar beam was minimal during these observations.

In summer storms the fraction of CG flashes that is positive varies diurnally from 0.03 to 0.3 and peaks later than the maximum rate of CG flashes. Our first data from tornadic storms show no obvious minimum in the CG flash rates of the storm as a whole during the time tornadoes are observed. In the Binger storm, the average number of strokes per flash increased after the tornadic stage ended, and the fraction of flashes that lowered positive charge was generally larger before and during the tornado. Within 10 km of the mesocyclone center, however, ground flash rates were lower before and during the tornado and increased after the tornadic stage of the storm ended.

Detailed analyses of VHF-mapped lightning flashes and 10-cm Doppler radar data were completed for four storms on 19 June 1980. In these storms, VHF sources from lightning processes for CG and for large IC flashes were confined to an altitude below about 10 km. The average height of VHF sources was 4-5 km for CG flashes and 5-6 km for IC flashes. Both CG and IC lightning activity were centered on the main high-reflectivity region of a storm and downwind from strong updraft regions. A new class of IC flashes was recognized that produced VHF sources to altitudes of 16 km or more in a large canopy over the main discharge region. These high-altitude IC flashes produced almost a continuum of activity centered at a height of 12-13 km. This lightning activity was centered on the main reflectivity column in the cloud and in the upper parts of the outflow region in the top of the storm. There seemed to be no temporal association between small IC flashes occurring almost continuously above about 10 km and large IC and CG flashes sporadically occurring in the lower portions of the storms.

Plans FY 1983

We will examine prestorm radar data from 17 May 1981. VVP divergence will be tested further and dual-Doppler analysis will be used extensively. Satellite data will be examined for information on low-level moisture variations, with the anticipated collaboration of researchers at Pennsylvania State University. Programs for single-Doppler estimates of wind fields may be tested in real time next spring with the possibility of a data collection program including instrumented aircraft.

The book on Doppler weather radar will be submitted to Academic Press.

Testing of the mesocyclone algorithm will be completed, and a similar algorithm to detect and measure divergence in storm tops will be developed and tested.

A study of the evolution of turbulent kinetic energy from first echo until the mature stage will be undertaken. In this process an attempt will be made to budget the storm's energy. An experiment will be conducted at Wallops Island to determine how often and to what height the turbulent fluctuations of C_n^2 are in the inertial subrange at scales of 5 cm.

NSSL

Composite display of hazardous weather will be developed and data from interlaced elevation scans will be processed to determine if there is loss of accuracy in such scans.

A study of the evolution and origin of gust fronts is continuing as a prelude to determining their predictability.

We will continue analyses of storm electricity data to determine relationships between storm electricity and the spatial and temporal factors of precipitation,

kinematics, and dynamics inferred from Doppler radar. Correlations between CG lightning and mesocyclone evolution will be made using data from several severe storms.

We will evaluate the +CG flash location capability of the modified lightning strike locating system and will analyze the unique data set on +CG flashes that was obtained in 1982.

An improved instrument site for several electric field sensors will be constructed southwest of the storm electricity building, and instrumentation for photographic and television recording of CG flashes will be upgraded. The VHF mapping system will be improved by installing new low-noise antenna couplers and other renovations.

The ELF characteristics of lightning will be determined.

One of the few new NOAA postdoctoral research scientists will be with our group. The scientist will investigate electric field profiles in severe storms using instrumented free balloons.

We expect to cooperate again with several groups including NASA/MSFC, NASA/Langley Research, University of Oklahoma, University of Mississippi, and Rice University.

COMPUTER AND ENGINEERING SUPPORT AND DEVELOPMENT

This group (CESD) develops techniques and equipment, maintains the NSSL observational facilities, and supports the observational programs associated with the meteorological research. The NSSL base facilities consist of two 10-cm meteorological Doppler radars, a WSR-57 surveillance radar, a tall tower (444 m), a 52-station (maximum) surface network, an air traffic control facility, and atmospheric electricity measurement and lightning location equipment.

Accomplishments FY 1982

As in previous years, a substantial part of the total support effort was in implementation and execution of the Spring Program of data acquisition.

The NSSL in-house computer facility capability was limited in FY 1982 with the decommissioning of the SEL 8600. Most postanalysis was transferred to the CDC 750 in Boulder, and the data quality control and monitoring was transferred to the Perkin Elmer 3242. The PE 3242 was operated as a stand-alone terminal until about midyear when it was hardwired to the Norman (NRO) Doppler radar. This computer will also be used as a real-time radar data analysis terminal.

A major step in the improvement of the Laboratory air traffic control facility was made with the completion of the design and fabrication of a color display terminal capable of mosaicking the weather radar data and the aircraft beacon data.

Development of a photovoltaic power system for use on the surface network sites continues with the receipt and testing of all components of this 52-station system.

A closely spaced dual-frequency meteorological radar was designed and implemented using the NRO radar as the test bed. The engineering and test report was submitted to and accepted by the NEXRAD Joint System Program Office (JSPO), which sponsored this work. Development of a ground clutter suppression device, which is also sponsored by NEXRAD/JSPO, continues on schedule with completion of the design and fabrication of the device.

Plans FY 1983

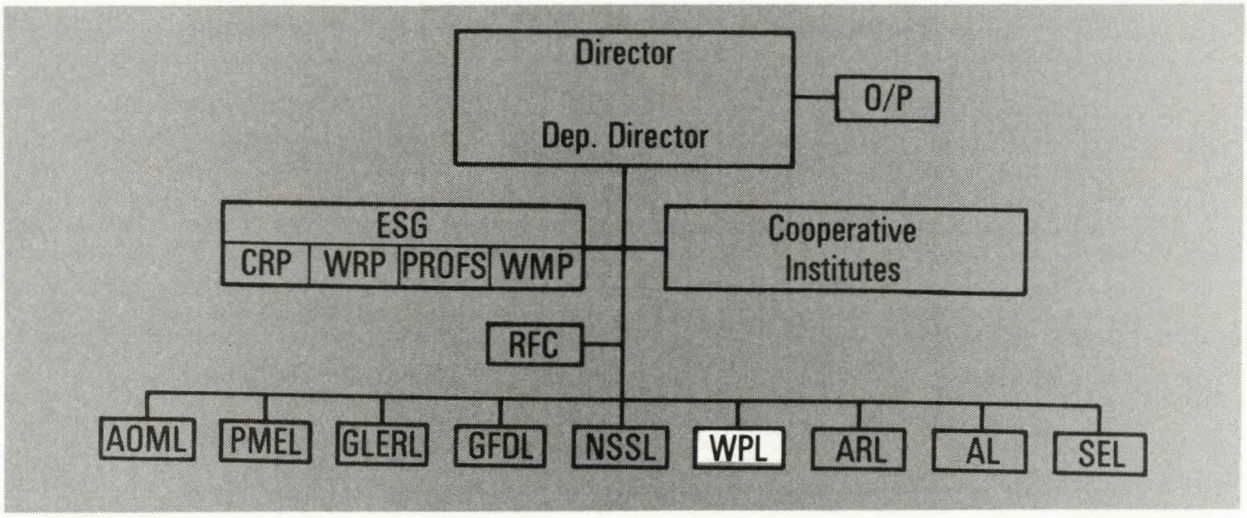
During the spring of 1983 the major NSSL facilities will be configured to support a real-time NEXRAD operational experiment for the Interim Operational Test Facility of JSPO. In particular, the NRO Doppler radar will be operated routinely and data products from this system will be transmitted to the NWS WSFO at Will Rogers and the Base Weather Station at Tinker Field for remote display and use by weather forecast personnel. In direct support of this NEXRAD work, the ground clutter suppressor for the NRO radar will be completed and the Perkin Elmer 3242 computer terminal will be expanded. The surface network and tall tower will be configured and operated specifically for support of the NEXRAD operational experiment.

The Spring Program will also include a period devoted to meteorological research. Facilities development in direct support of R&D includes the commissioning of the weather radar-aircraft beacon data display terminal for air traffic control, development of a microprocessor-based data logger and control terminal for the tall tower, and improvement in the clear-air detection capability of NRO and Cimarron (CIM) radar by use of a matched filter and slightly higher transmitter power.

Engineering developments plans include development of a fast-deployable meteorological sensor package for measurements in severe storms, development of a portable radar for use in conjunction with atmospheric electricity measurements, and evaluation of alternate power sources for the NSSL surface network.

WAVE PROPAGATION LABORATORY
Boulder, Colorado

C. Gordon Little
Director



NOAA's core mission of atmospheric and oceanic forecasts and warnings requires that it observe the present states of the atmosphere and ocean to be able to predict their future states. Since both media are three-dimensional, the observations must also be three-dimensional; moreover, the data sets must adequately resolve spatial or temporal structures at least as small as those to be forecast.

In general, the denser the observational data set in space and time, the more complete and accurate the services can be. Experience has shown that in situ measurement methods, which require that a sensor be located at each measurement location, are too expensive to be practical for anything but the largest scale phenomena. Therefore, in 1967, the Wave Propagation Laboratory (WPL) was set up to explore the possibility that remote sensors might provide the several-orders-of-magnitude improvement in space/time density of observations required to predict or warn of smaller scale phenomena.

The WPL mission is therefore to improve the Nation's geophysical research and services, through the development and application of cost-effective remote measurement systems. To achieve this goal, it must successfully perform the following functions:

- Theoretical and experimental studies of the interactions of acoustic and electromagnetic waves with the atmosphere or ocean, with particular reference to the use of such interactions for remote-sensing purposes.
- Development and experimental evaluation of new geophysical remote-sensing concepts.
- Application of the unique advantages of newly developed remote-sensing techniques to geophysical research.
- Improvement of the Nation's geophysical research, and operational forecasting and warning services, through transfer of the newly developed remote-sensing technology to others.

Because observational capability underlines essentially all geophysical research and services, WPL's research has broad impact and already contributes to four of OAR's nine programs. Where appropriate, the research tasks within each program are grouped in the text below according to meteorological scale.

In the following presentations a brief introduction giving the rationale for the research is followed by explicit statements on the FY-1982 program and FY-1983 plans.

WEATHER OBSERVATION AND PREDICTION

WPL's contributions to weather observation and prediction support NOAA's largest and most important single service, namely, weather forecasts and warnings.

Services are required on all space and time scales, and it is important to recognize that WPL's remote-sensing R&D program includes contributions on all scales, from the micrometeorological to the global.

MICROMETEOROLOGICAL AND BOUNDARY LAYER R&D

Research on micrometeorological processes in the atmospheric boundary layer is important because these processes include the turbulent fluxes of heat, moisture, and momentum that change the dynamic and thermodynamic properties of air masses. Remote sensors contribute uniquely by providing the resolution and continuity in both space and time that are required to observe, monitor, understand, and predict these important boundary layer processes. WPL has long led in the development and application of such sensors.

Accomplishments FY 1982

BOUNDARY LAYER SENSOR DEVELOPMENT

Scintillation Techniques--Theory

The small-scale temperature and humidity eddies produced by boundary layer turbulence cause optical signals propagating in the lower atmosphere to twinkle, or scintillate. Understanding the theory of these scintillations enables them to be used to monitor the nature and intensity of the meteorologically important turbulent exchange processes occurring in the boundary layer. WPL made new advances in scintillation theory during FY 1982.

The diffraction theory of optical scintillations, when applied to light sources of large angular extent, predicts that the intensity of sunlight reaching the ground will fluctuate slightly because of atmospheric irregularities. The irregularities involved have sizes on the order of meters. This solar illumination pattern on the ground drifts with the wind and has a size that is related to the altitude of the irregularities in the atmosphere. We have derived those relationships in sufficient detail to permit the design of a simple optical device to profile the optical refractivity turbulence and winds in the lowest few kilometers of the atmosphere. This theory on the use of whole-sun scintillations to measure vertical profiles of optical refractive turbulence and horizontal wind was published in FY 1982.

In essentially all optical scintillation work to date, the effect of viscosity in limiting the size of the smallest atmospheric eddies (the so-called inner scale of turbulence) has been ignored. The theory has now been extended by WPL to include the effects of viscosity. It was shown that an appropriate spatial filtering of the received scintillation pattern should permit path-averaged measurements of the inner

scale of turbulence, and hence of the vertical fluxes of heat and momentum. This recently verified theory of the inner-scale effect on the log-amplitude covariance for saturated scintillation has now been published.

Scintillation Techniques--Experimental

Early work by WPL, supported in part by the National Weather Service, led to the concept of Laser Weather Identifiers (LWI's). These instruments use scintillation rate measurements to identify the occurrence and nature of precipitation. An optimum algorithm for the LWI was developed during FY 1982. A whole-sun scintillation recorder to make vertical profiles of wind and C_n^2 was developed and tested. A detailed experimental study of saturation effects upon large-aperture optical scintillations was completed.

Improvements to the Boulder Atmospheric Observatory

The Boulder Atmospheric Observatory (BAO), with its remote sensors and a 300-m-high meteorological tower, is a unique facility for the study of the atmospheric boundary layer, and the evaluation and calibration of remote sensors. During FY 1982, the capabilities for measuring wind, temperature, and humidity gradients on the carriage were incorporated as a semipermanent feature. They augment existing turbulence-measuring capabilities on the carriage and permit precise monitoring of flux-gradient relationships in nocturnal stable layers.

The new Infrasonic Observatory was installed at BAO using specially designed noise-reducing microphone arrays to detect long-range infrasound for the Department of Energy (DOE).

BOUNDARY LAYER RESEARCH

Theoretical

New theoretical arguments were developed, relating temporal variances of temperature and vertical velocity to length scales of heat and momentum flux in the stable boundary layer. Analytical and numerical studies on vortex dynamics, oriented specifically toward aircraft wake vortices, were completed.

Experimental

An instrument intercomparison experiment for the Environmental Protection Agency (EPA) was constructed at BAO to evaluate turbulence measurements from Doppler acoustic sounders and standard in situ meteorological sensors. In another experiment, data from FM-CW radar measurements of turbulent dissipation and C_n^2 in elevated layers were compared with data from the BAO tower facility.

STABLEX (Stable Layer Experiment) 1981 studies of gravity waves and elevated-inversion-layer events at BAO were completed in collaboration with visiting scientists from the People's Republic of China. STABLEX 1982 flux and gradient measurements were collected using the new carriage instrumentation.

In collaboration with British scientists, a paper on turbulence structure in the stable boundary layer using BAO data was completed.

Studies on two downslope windstorm events in Boulder were completed. A review paper was published on sources and detection of atmospheric wind shear as it affects aircraft. The FAA and NASA participated in aircraft wave vortex studies at BAO. In a unique experiment, the ability of the WPL FM-CW radar to detect and locate wingtip vortices from large aircraft was demonstrated. Radar cross section measurements were made on 45 aircraft wakes.

BAO was operated on a 24-h basis with a data retrieval rate of better than 90%. Major air quality and upslope cloud experiments were supported by BAO staff and data systems.

Plans FY 1983

SENSOR DEVELOPMENT

An experimental test will be made of the feasibility of measuring inner scale and momentum flux using optical scintillations.

The feasibility of a lidar technique for measuring C_n^2 profiles will be examined experimentally.

BOUNDARY LAYER RESEARCH

BAO turbulence measurements will be analyzed and techniques developed for inferring stack-top and plume-level wind velocity and turbulence. These parameters are needed as input to air quality dispersion models.

The development of data sets and models of atmospheric boundary layer behavior as a function of meteorology and terrain will begin for weather forecasting and air pollution purposes.

R&D ON MESO-β AND -γ SCALES

A single ground-based radar or lidar system can remotely monitor atmospheric processes on the meso-γ (2- to 20-km) and perhaps the meso-β (20- to 200-km) scales. Such data sets are required for an extraordinarily wide range of atmospheric research problems, as well as for short-term local weather nowcasts and forecasts. WPL progress in this area assigned to the Weather Observing and Prediction program is divided into two main categories, mesoscale sensor development and mesoscale research. Specific applications of WPL's mesoscale remote sensors to air quality or to climate are covered later.

Accomplishments FY 1982

MESOSCALE SENSOR DEVELOPMENT

Microwave Doppler Radar

A method for computing planetary boundary layer stress and turbulent kinetic energy profiles from single-Doppler radar data has been implemented, and a method for correcting three-dimensional wind fields for the nonsimultaneity of the multi-station Doppler radar data is being evaluated. A calibration-independent processing algorithm was developed to detect aircraft wakes automatically.

MESOSCALE RESEARCH

Theoretical

An analytical model of coherent-lidar signal processing was developed to allow system performance simulations.

Two theoretical papers on mesoscale phenomena were published during the year. The first described the measurement of high gradients of temperature and refractive

index aloft by ground-based Doppler radars. The second proposed a model for the development of elevated layers in the marine environment near coastlines.

Experimental

During the JAWS (Joint Airport Weather Studies) field observations, sector velocity scans by the WPL IR Doppler lidar were coordinated with the NASA pulsed-Doppler lidar located 10 km south of the WPL site. This was the first time two Doppler lidars probed the same atmospheric volume. These observations included clear-air downbursts from storms detected on a number of occasions, to ranges of 15 km.

Dual-polarization radar data acquired from the major CCOPE (Cooperative Convective Precipitation Experiment) project were analyzed during the year and significant findings were reported. An analysis of the complex cross-correlation between the received polarization channels for CCOPE data indicates an apparent low degree of alignment of cloud particles in a layer just below the 0°C level and near the cloud top. An analysis of CCOPE polarization data shows a thin layer of high depolarization 400 m below the 0°C level. Above the melting layer, the circular depolarization ratio appears to respond to changes in the ice crystal form.

Plans FY 1983

MESOSCALE SENSOR DEVELOPMENT

IR Doppler Lidar

The Doppler processing system will be improved by adding a real-time signal processor and color display. Upslope observations and JAWS data will be analyzed and reported. Work will continue to improve the understanding and modeling of coherent-lidar performance.

8-mm-Wavelength Doppler Radar

A new, fast polarization switch will be implemented in the K-band radar. A color display system will be installed on the S-250 data-processing system.

3-cm-Wavelength Doppler Radar

One X-band radar will be modified to achieve dual-polarization capability.

A measurement program will be conducted with dual-polarization radars and instrumented aircraft to aid interpretation of polarization data.

A velocity-polarization board will be added to the pulse-pair processor to increase velocity and polarization data-processing rates.

FM-CW Radar

The possibility of single-antenna operation will be tested in the laboratory.

MESOSCALE RESEARCH

Mountain-Plains Circulations

The unique, clear-air Doppler lidar will be used in studies of thermally driven mountain-plains circulations that typically prevail in the Boulder area during anticyclonic conditions.

Chinook Winds, Mountain Lee Waves, and Clear-Air Turbulence

As opportunities exist, mountain lee waves, clear-air turbulence, and strong, downslope chinook winds will be studied, using the IR Doppler lidar system.

Orographic Clouds and Precipitation

Extensive data sets will be analyzed from the Boulder Upslope Cloud Observation Experiment (BUCOE) to learn more about the role of ice crystals in the formation of clouds and precipitation under upslope conditions.

R&D ON SYNOPTIC AND MESO-α SCALES

Although individual ground-based remote sensors are limited by Earth curvature to meso-β-scale applications, arrays of such sensors can be used to study atmospheric processes up to continental scale. WPL's planned contribution to this scale is the Profiler, a combined radar-radiometric system for the continuous measurement of profiles of wind, temperature, and humidity. A suitable array of such systems could continuously provide the three-dimensional fields of these parameters on the meso-α (200- to 2,000-km) and synoptic (2,000- to 10,000-km) scales for numerical weather prediction (NWP). Such a system would have major impact on NWP since the observational data could be (1) time averaged to remove aliasing of high-frequency components, (2) entered more frequently into the NWP algorithms, and (3) inserted in the form of time derivatives as well as time averages. It is also believed that the wind field data (which are critical to mesoscale NWP) would be considerably more accurate than those available from radiosondes.

Accomplishments FY 1982

Construction of the UHF triple-beam Doppler radar at the Denver WSFO was completed and initial tests performed.

Construction of the Colorado Mesoscale Profiler Network is progressing: the facilities and VHF antenna are complete at Sterling; the facilities are complete near Cortez; and the site is under preparation near Craig. Two-channel, water vapor/liquid water radiometers have been ordered; new VHF transmitters and receivers have been tested successfully at Platteville.

A versatile hub process, making implementation of algorithms and data access very efficient on the Profiler host computer at Denver, has been programed.

A diffraction study of the antenna system for the mesoscale network dual-channel radiometers has resulted in an economical design.

A mobile dual-channel microwave radiometer with steerable beam has been constructed for the Bureau of Reclamation.

Plans FY 1983

Installation of VHF wind and humidity Profilers for the Colorado Mesoscale Network will be completed about midyear.

Real-time profiles of wind from the UHF radar will be obtained and incorporated into the Profiler data stream.

Development of data-processing algorithms will be continued to improve further the quality of the profiles.

R&D ON THE GLOBAL SCALE

Weather forecasts for periods longer than a few days require global observations of winds, temperature, and water vapor. The current global weather-observing system relies heavily on the international radiosonde network over populated land areas, supplemented by satellite observations over the oceans and polar regions. This observational system has two main weaknesses. First, and most important, the present wind-measuring capabilities from satellites rely on displacements of the cloud and water vapor fields; the resultant velocity fields have limited spatial coverage, height resolution, and accuracy. Second, the accuracy of the derived temperature and humidity profiles is poorest near the ground, limiting the accuracy of the derived pressure heights and thicknesses. WPL's WINDSAT and Profiler programs are designed to remove, or greatly reduce, these limitations.

Accomplishments FY 1982

WINDSAT

A plan was developed with the National Meteorological Center (NMC) to simulate WINDSAT inputs to global weather forecasts, using a well-documented 10-day period during the First GARP Global Experiment as a reference.

A global Large Aerosol Workshop, held in Boulder in June, was attended by scientists from around the world. A NOAA Technical Memorandum summarizing the workshop and presenting recommendations for further work is in preparation.

Progress in WINDSAT planning and analyses, and the results obtained with the trailer-based lidar, were reported at the DOD Infrared Information Symposium on Laser Techniques, at the annual Optical Society of America meeting, at the DOD Optical Remote Sensing Workshop in Monterey, at the Conference on Lasers and Electro-Optics (CLEO), at the Eleventh International Laser Radar Conference, and at the NSIA-AIAA Space Systems Technology Workshop II in Albuquerque. A paper on aerosol-scattering statistics was published, showing for the first time the log-normal distribution of IR backscattering coefficient, β.

Winter β values were observed to be somewhat lower in the midtroposphere, but values near the tropopause (200 mb) are about the same, summer or winter.

PROFILER-SATELLITE COMPARISONS AND COMBINATIONS

Profiler and satellite profiles have many desirable complementary features. Orbiting satellites provide total global coverage, discontinuously in time; an array of Profilers would provide data continuously in time, but discontinuously in space. The Profiler's most accurate measurements are of the wind field and of the temperature and humidity profiles in the bottom half of the atmosphere. The satellite's most accurate measurements are of the temperature and humidity profiles in the upper half of the atmosphere. Tropopause height and cloud liquid water content are well measured by the Profiler; neither is well measured by current operational satellites. Thus, there were many reasons for believing that a composite observing system, integrating the advantages of both systems, could provide better data sets than those provided by either system alone.

The expected improved quality of combined Profiler-satellite profiles was demonstrated using data from the NOAA-6 and -7 and VAS sounders, and from radiosondes and

the Profiler; further improvements were made by including radar-measured tropopause heights.

Plans FY 1983

WINDSAT

NMC will be provided with WINDSAT computer model results of cloud-degraded wind measurement accuracies for use in its observing-system simulation studies of the impact of a WINDSAT system.

As opportunities exist, β profiles will be measured in different meteorological regimes.

PROFILER-SATELLITE COMPARISONS

The improved quality of combined Profiler-satellite profiles will continue to be demonstrated by comparing them with data from the NOAA-6 and -7 and VAS sounders, and with data from radiosondes and the Profiler.

AIR QUALITY

NOAA's weather service mission includes the provision of meteorological information and understanding relevant to air quality. WPL contributes to this program through the application of its remote sensors to the measurement of the three-dimensional fields of wind, turbulence, and aerosol in air-pollution-oriented experiments.

Accomplishments FY 1982

WPL researchers participated in the Atmospheric Studies in Complex Terrain (ASCOT) experiment at Brush Creek, Calif., by operating five solar-powered optical crosswind sensors, showing height dependence of drainage flows. A monostatic acoustic system and a tethersonde were also deployed.

Field observations showed that an ultraviolet lidar system is superior to longer wavelengths for plume-tracking experiments in which laser output is restricted to ensure eye safety. The essential components were completed for automatic scan control of the lidar, and online processing and display of data.

Analyzed lidar data from EPA's Small Hill Impaction Study #1 showed that vertical dispersion of a plume released 20-55 m above the surface in stable conditions followed a square-root growth law with distance downwind up to 1 km from the source, while horizontal dispersion was dominated by wind meander.

A lidar experiment was performed at BAO to investigate convective plume dispersion under stable conditions, using the new rapid-scan system. The experiment tested for diffusion phenomena observed in laboratory tank and computer models. The experiment involved release of oil fog and chaff from two levels on the 300-m tower, and tracking them with ground-based lidar and radar systems.

An instrument intercomparison experiment was conducted for EPA at BAO to evaluate turbulence measurements from Doppler acoustic sounders and standard in situ meteorological sensors.

A mobile observing facility for boundary layer turbulence was developed and deployed to collect sonic anemometer data during the EPA Ridge Experiment.

Plans FY 1983

Data from the EPA instrument comparison experiment will be analyzed and a report will be prepared.

BAO turbulence measurements will be analyzed and techniques will be developed for inferring stack-top and plume-level wind velocity and turbulence data, which are required for air quality dispersion models.

WPL will operate the lidar in and analyze data from EPA plume experiments. Dispersion will be studied in unstable conditions under a capping inversion layer at BAO, and plume impingement will be studied on a ridge near Farmington, N. Mex.

WPL researchers will participate in the DOE-sponsored ASCOT western-slope experiments planned for Colorado in 1983, and will analyze data collected in 1982.

CLIMATE

Studies are under way within the United States to understand the processes that determine climate. Fundamental to all of these studies is the role of the ocean; it acts like a flywheel, storing and releasing vast quantities of heat. WPL is concentrating on developing and applying an array of remote-sensing techniques to such climate studies.

Accomplishments FY 1982

WPL has begun a joint program with AOML and the Office of Ocean Technology and Engineering Services (OTES), called STACS (SubTropical Atlantic Climate Studies). On the basis of the knowledge that nearly all the oceanic heat flow into the North Atlantic is channeled through the Florida Straits (between Florida and the Bahamas), this study is developing and evaluating a number of remote-sensing techniques for observing and monitoring heat flux in these straits. Conventional, in situ oceanographic sensors are too costly by orders of magnitude to provide such data.

CODAR (Coastal Ocean Dynamics Applications Radar) was used to develop and demonstrate techniques for using single-site observations to give surface transport data from the Florida Straits for the STACS program. This was the first non-WPL use of CODAR for routine real-time monitoring applications to research and services. Operating from the Florida coast near Jupiter Inlet, the CODAR system observed the Gulf Stream maximum (surface) flow, the position of this maximum and its temporal-spatial meanderings, and total mean surface flow through the system coverage area.

Studies are under way in WPL to extend the use of CODAR to understand subsurface processes important for climate. The new hydrodynamic models derived at WPL for upper-layer mixing are the basis for such understanding. They show how energy and momentum propagate downward in the ocean by nonlinear mechanisms, beginning with the waves and surface currents. The models appear to have the capability of explaining and predicting thermocline formation and erosion. Since CODAR can observe surface wavefields and surface currents, these models are the key to the extension of CODAR observations to subsurface mixing, heat storage, and flux.

The solar-heated upper layer of the ocean is a major energy source for atmospheric dynamics. The principal modulation of solar influx to the ocean is caused by the major cloud systems over ocean areas. An experimental and theoretical study of the relation between observable (from satellites) characteristics of clouds and their effect on short- and long-wave radiation is under way as part of the EPOCS (Equatorial Pacific Ocean Climate Studies) program. The relation between the physical and optical properties of clouds has been further studied, employing optical sensors and a lidar system to define the physical boundaries of the clouds.

As part of the EPOCS program in July 1982, data from NOAA WP-3D flights have been obtained on the effect of tropical cumulus on solar flux incident on the ocean. A simple relationship between downward solar flux and total liquid water traversed has now been verified in both the Panama and California clouds.

Plans FY 1983

Final analysis of EPOCS data will include the study of the relationship between cloud microphysics and radiative properties, especially their effects on modulation of solar flux into the ocean; the study of the spectrum of radiative and microphysical inhomogeneities; and the correlation between satellite visible and infrared imagery and the modulation effects. Gust probe and radiation data will also be used to study the maintenance of stable cloud systems. With the publication of a paper on cloud optical properties in FY 1983, the WPL cloud radiation study will be complete.

The three-dimensional ocean acoustic ray-tracing program will be used by ERL researchers to aid in the interpretation of the acoustic data taken during the STACS program.

MARINE OBSERVATION AND PREDICTION

The difficulty and expense of obtaining in situ observations of ocean parameters make remote-sensing methods highly desirable. WPL is therefore active in the development of such sensors. By applying this array of new techniques to marine observations, WPL is extending predictive capabilities in coastal waters.

Accomplishments FY 1982

NEAR-COASTAL WATERS

CODAR research, development, and application have continued. A method was derived for removing current-induced distortion from the second-order CODAR Doppler spectrum before inverting to obtain the waveheight directional spectrum. Desk-based field hardware/software was developed that speeds up CODAR current processing by a factor of 5.

Accurate use of the CODAR crossed-loop antenna system for measurement of the waveheight directional spectrum at the Atlantic Remote Sensing Land Ocean Experiment (ARSLOE) was demonstrated continuously over the course of a 5-day storm.

An operational version of CODAR was constructed and demonstrated under OTES sponsorship, and will soon be available commercially.

Approximately 40% of the OTES-sponsored extensive manual-type documentation of CODAR theory, hardware, and software necessary for other users was completed.

Preliminary relationships between surface current and surface wind patterns under changing storm conditions were established.

GLOBAL WATERS

The primary tool for observing the oceans globally will be satellites. WPL has been active in the SEASAT program, interpreting the outputs of the active microwave radars, i.e., the altimeter, synthetic-aperture radar (SAR), and scatterometer. Major strides were made in quantitative explanation of the interaction of short and long ocean waves. This is important for (1) saturation of HF second-order echo energy; (2) electromagnetic bias in microwave altimeters; (3) SAR imaging of ocean waves; and (4) the dispersion relation and wave spectra of short-wave studies.

Major progress was made in understanding the mechanisms involved in imaging of ocean waves by SAR.

Various parts of the satellite microwave altimeter echo were used to map the polar sea-ice edge.

Plans FY 1983

Application of CODAR to the understanding of fundamental ocean-mixing processes will continue. In particular, CODE (Coastal Ocean Dynamics Experiment), a joint project with WPL, Scripps, and Woods Hole, will provide an extensive data base on which to develop such an understanding, by evolving and evaluating new models for coastal mixing.

Options will be identified for air-sea interaction experiments, based on WPL's atmospheric and oceanic remote-sensing systems.

Documentation of CODAR hardware and software will be completed (funding permitting).

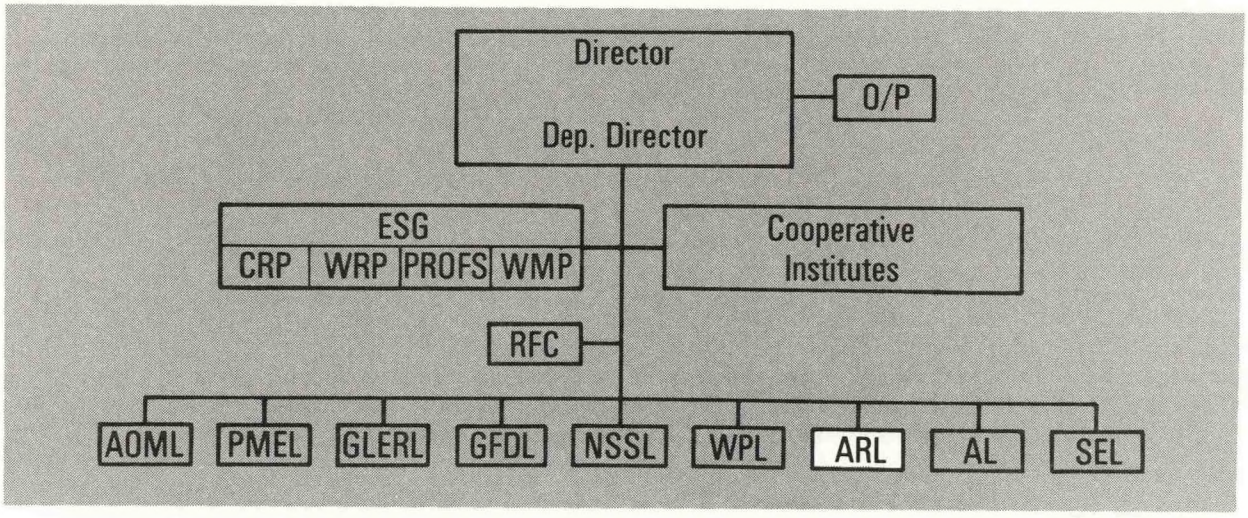
The three-dimensional ray-tracing program will be used to aid in interpretation of acoustic remote-sensing measurements such as tomography and the acoustic scintillation technique.

In cooperation with the Institute of Ocean Science, Vancouver, B.C., studies will be made of the conditions under which acoustic scintillations can be used to measure subsurface ocean currents.

Theoretical studies on upper-layer hydrodynamics will continue. The effects of wind stress at the surface and of geostrophy (i.e., Earth rotation) will be included in the theoretical models. These models will be tested with CODAR (and other) data, where possible.

AIR RESOURCES LABORATORY
Rockville, Maryland

Lester Machta
Director



The Air Resources Laboratory (ARL) includes a headquarters group in Rockville, Md.; the Field Research Division in Idaho Falls, Idaho; the Atmospheric Turbulence and Diffusion Division in Oak Ridge, Tenn.; the Meteorology Division in Research Triangle Park, N.C.,; and the Solar Radiation Facility, the Sun-Climate Staff, the Air Quality Division, and the Geophysical Monitoring for Climatic Change Division (GMCC) in Boulder, Colo., with GMCC observatories at Mauna Loa (Hawaii), Barrow (Alaska), the South Pole, and American Samoa.

ARL research is geared to user needs, which are frequently those of other Federal agencies with related missions. Funding and guidance derive from this association through interagency agreements. In some cases, the ARL unit under contract to another agency acts as its meteorological arm, providing the required meteorological guidance. Most ARL research deals with the use of meteorology to understand and predict human influence on the environment, especially with regard to the atmospheric transport and diffusion of toxic effluents. General areas of study include turbulence and diffusion in the atmosphere, atmospheric trajectories from microscales to global scales, meteorology of air pollution, CO_2 and climate, acid rain, and monitoring of atmospheric constituents for climatic change.

HEADQUARTERS GROUP

The ARL headquarters research group in Rockville develops models that simulate local, regional, and global transport and diffusion of pollutants injected into the atmosphere. Mesoscale and regional-scale versions of these models are being used extensively by the Department of Energy (DOE) to evaluate the environmental effects of various means of energy production. Air sampling programs and other field experiments are conducted to provide data for model verification. Major funding for this work is provided by the DOE Office of Health and Environmental Research (OHER) and the Environmental Protection Agency (EPA). The sources and sinks of CO_2 in the atmosphere on a global basis are being studied. Research on the sources, transport, and deposition of acidic precipitation is also being carried out.

Accomplishments FY 1982

ATMOSPHERIC TRANSPORT

A package of computer programs has been developed, incorporating National Meteorological Center (NMC) observed and forecast wind fields and ARL dispersion models, to forecast transport and dispersion for use in tracer experiments and to forecast the travel of radioactive clouds from foreign nuclear tests.

A Cross-Appalachian Trace Experiment (CAPTEX) was carried out in September 1982 as a trial run for experiments planned in 1983. CAPTEX is designed to study the dispersion of material released in the Ohio Valley and transported across the Appalachians to the east coast. The Ohio Valley is suspected of being a major pollutant source region affecting air quality and contributing to acid rain problems in New York, New England, and Canada. A special tracer gas, developed by ARL, was released near Dayton, Ohio, and automatic sequential samplers were deployed to collect the tracer at 19 National Weather Service (NWS) substation network sites from Lake Ontario to Norfolk, Va. Aircraft were flown in Ohio and New York to measure plume concentration aloft. Two new sampling systems, a high-volume airborne sampler and an inexpensive adsorption tube sampler, were field tested. Results of CAPTEX '82 will guide the design of CAPTEX '83.

Another tracer experiment is being carried out in collaboration with the DOE Savannah River Laboratory to provide long-term, regional-scale transport and diffusion data for air pollution model verification. Krypton-85 emitted routinely from the Savannah River Plant, S.C., is being sampled twice daily at five stations from 300 to 1,000 km to the northeast. Sampling began in March 1982 and will continue for at least 1 year.

CARBON DIOXIDE

NOAA, through ARL, has undertaken atmospheric measurements of many quantities important to the Earth's CO_2 budget. The four GMCC baseline stations together with 15 additional CO_2-flask stations are providing data on the geographical variations of components of the annual CO_2 cycle and gradients of CO_2 concentration as well as trends in these quantities and mean concentration. Analysis of the trend in the amplitude of the annual cycle suggests that photosynthesis in the temperate and high latitudes is probably increasing with time. This may be due to either fertilization by increasing atmospheric CO_2 or an increase in the size of forests of temperate or high latitudes. An analysis of the long-term trend of atmospheric CO_2 at Mauna Loa and the South Pole suggests that the trend is most readily accommodated by the fossil fuel CO_2 without any need for CO_2 derived from tropical deforestation.

ACID DEPOSITION

Because of continued scientific and public interest, acid deposition (acid rain) has been a very active area for ARL scientists. Activities include ARL contributions to the precipitation chemistry network planning of the World Meteorological Organization (WMO), the European long-range transport modeling, and the scientific documents for Canadian-U.S. bilateral work. Considerable time was spent on planning and implementation of U.S. Federal acid deposition activities. A National Atmospheric Deposition Assessment Plan was published with ARL participation, and other planning documents were completed during FY 1982.

In ARL, scientific research and support were increased significantly in FY 1982 because new funds were allocated in the NOAA budget for acid rain. Projects include the following:

- Studies of natural sources of acid precipitation such as biogenic sulfur components.

- Evaluation of the ARL trajectory program to interpret acid rain data.
- Full support for the Global Research Network.
- A major project to look at the North American sulfur and nitrogen budget.
- Support for the National Atmospheric Deposition Program sites at NOAA locations.
- Establishment of special research sites in three U.S. locations.

Other activities included work in dry deposition and new methods of precipitation collection.

Plans FY 1983

ATMOSPHERIC TRANSPORT

CAPTEX '83, to be conducted during September-October, has developed into a major U.S.-Canadian atmospheric dispersion experiment. Six tracer releases are planned from Dayton, Ohio, and Sudbury, Canada. Tracer measurements will be made at about 80 sites in Canada and the U.S., extending to the east coast. The experiments will provide information on mechanisms affecting long-range dispersion, and data for air pollution model evaluation. Other Federal agencies and private industry, as well as the Canadian government, are participating in CAPTEX '83 and have expressed great interest in continuing this collaboration with NOAA.

The Atlantic Coastal Unique Regional Atmospheric Tracer Experiment (ACURATE) using krypton-85 will be extended through September 1983.

Preparations will be made for a year-long Metropolitan Tracer Experiment (METREX) using perfluorocarbon tracers in the Washington, D.C., area to study plume transport and dispersion in an urban environment. Field work is expected to start late in FY 1983 or early in FY 1984.

CARBON DIOXIDE

Analysis of the network data and other data will continue with emphasis on determining the recent effects of the biosphere on atmospheric CO_2. It is also anticipated that sensitivity tests of several carbon-cycle models will be done to determine the critical components of these models.

ACID DEPOSITION

Plans for FY 1983 include further support for sulfur budget studies, more research on natural sources of acidity, and participation in planning major field studies. New studies are expected to be initiated in cooperation with outside groups.

FIELD RESEARCH DIVISION

The research of ARL's Field Research Division (ARLFRD) in Idaho is primarily sponsored by the Nuclear Regulatory Commission (NRC), DOE, and EPA. It is directed toward current and anticipated environmental problems associated with the release to the atmosphere of toxic and undesirable effluents by our industrialized society. These problems include the quantification of downwind atmospheric dispersion contributed by the meander of plumes under light wind and inversion conditions, the effect of

the land-sea interface, the effect of surface roughness and complex mountainous terrain, the measurement of the vertical as well as the horizontal profile of plume concentration, and the measurement of air trajectories. Tracer gas techniques and radar-tracked, constant-level balloon trajectories as well as standard meteorological profiles of wind and temperature are used in full-scale field experiments to address these problems and provide the necessary data for transport and diffusion model verification.

Accomplishments FY 1982

An intermediate-range field dispersion experiment to distances of 50 km from the tracer gas release point was carried out along the western coast of Lake Michigan during 28 May-8 June 1982. Nine tests were completed, each test consisting of at least a 5-h release of SF_6 tracer gas. Hourly samples were taken at about 140 locations over at least a 5-h period to determine effluent concentrations within a radius of about 16 km from the release point along the shore. Wind and temperature profiles were measured from a research vessel located offshore and from a series of 13 meteorological towers extending from the shore to a distance of 30 km inland. Meteorological and gas concentration measurements were also taken by aircraft. Plume trajectories were determined by both visible smoke plumes and radar-tracked neutrally floating balloons. The field experiment was sponsored jointly by NRC and DOE.

Plans FY 1983

A month-long transport and diffusion field experiment will be carried out in the Four Corners area of New Mexico to determine the effect of Hogback Ridge on an elevated plume passing overhead. Measurement techniques similar to those of the FY-1982 Lake Michigan study will be utilized. The research is sponsored by EPA as part of its Complex Terrain Model Development program.

ATMOSPHERIC TURBULENCE AND DIFFUSION DIVISION

The Atmospheric Turbulence and Diffusion Division (ATDD) in Oak Ridge, Tenn., is generally concerned with research and the physics of the lower atmosphere, with recent emphasis on the environmental consequences of energy production and the prediction and control of air pollution. ATDD works closely with various divisions of Oak Ridge National Laboratory (ORNL) and with atmospheric science units at other national laboratories on environmental projects of mutual concern. Major funding is from DOE/OHER's Pollutant Characterization and Safety Research Division. Additional sources of funds include EPA, NRC, U.S. Army, USGS, and various other Federal agencies and national laboratories.

The goal of the ATDD research program is to extend contemporary knowledge of the lower atmosphere to nonstationary conditions, nonsimple surfaces, and complex terrain. The work focuses on those factors that influence dispersion of pollutants, and on the exchange of momentum, heat, moisture, and mass between the lower atmosphere and underlying surfaces. This work is directed toward applied questions of pollutant dispersion and deposition. It has immediate relevance to concerns regarding acid deposition, and to the assessment of environmental impacts of particular air pollutants. It also addresses the problem of formulating the lower boundary condition for use in numerical models. The program is organized around two major areas: atmospheric transport and diffusion, and atmosphere-canopy interactions. Current research efforts include studies of flow and dispersion over nonsimple surfaces, studies of deposition of pollutants to vegetative canopies, basic studies of atmospheric diffusion parameters, investigations of canopy radiation transfer and thermal properties, and plume-rise studies. Wherever possible, studies are conducted with a coordinated program of

theoretical development, field experimentation, laboratory modeling, and numerical simulation.

Accomplishments FY 1982

PLUME TRANSPORT AND DISPERSION

Planetary Boundary Layer Studies

The program of routine documentation of the growth of the morning mixed layer was continued, with field data being obtained on the first week of every month near ATDD, in Oak Ridge. A computer model of planetary boundary layer (PBL) evolution was coded, to be used in conjunction with data obtained from the routine field observations.

Plume Dispersion Analysis

An automatic video digitization facility is being developed. Tests of the special video recording and playback system were conducted, interfacing with a desktop computer was completed, and tests of the computerized plume analysis system are being conducted. These tests will use field photographs of plume releases as well as wind tunnel experiments.

PBL Turbulence Studies

Revised procedures for estimating PBL dispersion statistics from external meteorological and surface variables were developed in a program partly supported by NRC. This work examines the way in which surface boundary layer relationships can be applied (and misapplied) when extending surface-based, height-dependent dispersion relationships into the mixed layer.

COMPLEX TOPOGRAPHY

Modeling of Drainage Flows

A two-dimensional drainage flow model of pure katabatic flow was developed. Comparisons of model results with physical modeling studies and analytical models appear quite satisfactory. The model is being modified to include the effects of a dense forest canopy and an ambient wind field.

Field Studies

ATDD staff participated in an exploratory multilaboratory experiment in the southern Piceance Basin in Colorado. A study of nocturnal flow in an idealized valley was conducted, and a regional-scale experiment was performed with about seven tethersonde-airsonde teams spread over a rough grid of 30- to 50-km spacing. Data recovery, editing, and analysis are expected to continue through October 1982.

A drainage flow study was conducted at Los Alamos on the Lone Spruce ski slope of Los Parajetos Mountain. Early analyses show that the depth of the drainage layer grew linearly with downslope distance; however, wind speeds did not change greatly.

ARL

ATMOSPHERE-CANOPY INTERACTION (FOREST METEOROLOGY)

The radiation distribution data base has been expanded, by including infrared surface temperature, to provide a more definitive test of canopy thermal emittance models. Canopy solar radiation distribution models are being tested.

Climatological monitoring and data reduction has continued. Monitoring work expanded to allow determination of bulk canopy radiative properties on a continuing basis as required for energy budget analyses.

A study of the distribution of omnidirectional wind speeds within the forest was initiated.

DRY DEPOSITION STUDIES

A field study conducted at the Walker Branch Watershed was designed to test the utility of revised eddy-correlation methods in complex terrain and to apply these new techniques to obtain measurements of the flux of nitrogen dioxide.

Work on documenting occurrences of fog and on dewfall is under way. This work is intended to provide input for assessments of acid deposition.

Plans FY 1983

PLUME TRANSPORT AND DISPERSION

Planetary Boundary Layer Studies

Analysis of the first full year of PBL evolution data will be completed, and decisions regarding the necessity for continued monitoring will then be made. It is anticipated that more than 2 years of data will be required to document seasonal variations of PBL evolution in a statistically stationary manner. Surface boundary layer data representative of the area surrounding the Oak Ridge observation site will be coupled with the PBL data set; these data will be derived from the Walker Branch meteorological monitoring stations.

Plume Dispersion Analysis

Archives of photographs of previous diffusion experiments will be searched for material suitable for automatic evaluation of dispersion characteristics from visual observations. The use of satellite or aircraft imagery (either optical of infrared) to provide dispersion data over water and in other inaccessible areas will be investigated.

PBL Turbulence Studies

Nocturnal shear dispersion will be addressed using numerical models of the lower atmosphere, and by theoretical investigations of the factors that control wind direction shear in strongly stable flow.

COMPLEX TOPOGRAPHY

Modeling of Drainage Flows

Field observations are of limited utility in testing the detailed parameterizations required for models of the kind being developed in this program. Feasibility studies will be initiated to evaluate the utility of laboratory studies, and to design apparatus to simulate two-dimensional drainage flow over a roughened, cooled surface. If preliminary tests are successful, a series of laboratory studies will begin.

Field Studies

ATDD field teams will participate in studies over complex terrain, and will also continue to conduct independent research to identify factors that influence local drainage flow in regions of strong terrain irregularity. Particular emphasis will be placed on the role of flow separation near major terrain features and on the interaction between such separation and the initiation of drainage flows.

ATMOSPHERE-CANOPY INTERACTION (FOREST METEOROLOGY)

Wind and turbulence data from within and above the deciduous forest will be analyzed to determine the effects of differing upwind topographies upon turbulence structure and upon turbulent exchange processes.

Variance and covariance flux measurement techniques (for momentum, sensible heat, latent heat, sulfur, and CO_2) will be tested and the net exchange of these quantities determined. The influence of forest phenology and physiology and of synoptic meteorological conditions upon these exchanges will be investigated.

DRY DEPOSITION STUDIES

Field measurements of pollutant dry deposition will be conducted, using equipment developed at ATDD and air chemistry sensors provided by other laboratories.

An integrated observational program of air chemistry, atmospheric particles, and micrometeorological measurements will be carried out in collaboration with Pennsylvania State University, State College, Pa., and the Argonne National Laboratory, Argonne, Ill. The field studies are designed to improve existing techniques and develop new methods for evaluating dry deposition rates of selected atmospheric pollutants, particularly acidic contaminants. The measurement program will provide, as a minimum, (1) data on sulfur and nitrogen oxides, ozone, and time-dependent particulate size distribution function; and (2) a comprehensive set of micrometeorological observations sufficient for evaluation of momentum, evaluation of heat and moisture fluxes, and determination of deposition velocities of selected atmospheric pollutants.

METEOROLOGY DIVISION

Meteorology Division (MD) support and services to EPA include theoretical and experimental studies of the physical processes affecting transport, diffusion, transformation, and deposition of air pollutants; development, evaluation, modification, and dissemination of air quality simulation models for inert and reactive pollutants on all temporal and spatial scales; studies of the effects of air pollutants on weather and climate; and studies to define the relationships between air quality and meteorological parameters.

MD provides operational support to various EPA groups in their abatement and compliance activities. This includes technical advice; applications of air quality simulation models; evaluation of the meteorological portions of state implementation plans, environmental impact statements, and requests for variances; expert testimony at public hearings and judicial proceedings; emergency field services; and preparation of technical staff reports and documents.

Accomplishments FY 1982

ARL

In the research area, major emphasis during FY 1982 continued to be on the development and evaluation of air quality simulation models, including the collection of critical data bases. Work on the problem of pollutant dispersion in complex terrain included (1) statistical testing of the Valley, Complex I, Complex II, and potential flow models using data from the Small Hill Impaction Study #1 at Cinder Cone Butte, Idaho; and (2) development and testing of two preliminary Cinder Cone Butte models to simulate very stable and slightly stable (near-neutral) flows and associated ground-level concentrations. The application of scaled physical modeling concepts, in the Fluid Modeling Facility, to the Cinder Cone Butte experiments has been summarized emphasizing the implications of the dividing streamline height on plume interactions with elevated terrain.

Two existing air quality dispersion models were modified for use in toxic exposure assessment: PAL-DS (point, area, and line source) for small scales and MPTER-DS (multiple-point source with terrain adjustment) for large scales. The models included deposition and sedimentation (DS).

Three urban-scale O_3 models--urban airshed model, Lagrangian photochemical model, and photochemical box model--were tested against RAPS (Regional Air Pollution Study) observational data, and statistical measures of the models' predictive capabilities were generated. An article was published on the application of prognostic meteorological variables to the forecasting of daily maximum 1-h ozone concentration in the northeastern United States.

Work was completed and articles published on (1) a mathematical model for multicomponent aerosol formation and growth in plumes; (2) spectral scales in the atmospheric boundary layer; (3) ground-level concentrations due to fumigation into an entraining mixed layer; and (4) UNAMAP-1A (Users Network for Applied Modeling of Air Pollution) long-term SO_2 and SO_4 air pollution model refinement of transformation and deposition mechanisms.

Users' guides were prepared for CHAVG, a program for computing averages of hourly air pollutant concentrations; for PTPLU, a simple-source Gaussian dispersion algorithm; and for a commuter exposure model for CO. Work was completed and reports published on estimating concentrations downwind from an instantaneous puff release, on a new dispersion scheme for elevated releases, on site-to-site variations in performance of plume dispersion estimation schemes, and on an analysis of two candidate screening models, Complex I and Complex II.

Plans FY 1983

Direct meteorological support to EPA will continue. Research will continue on developing and evaluating air quality simulation models for inert and reactive pollutants and the associated meteorological models, on all temporal and spatial scales. Major emphasis will be on model development, evaluation, and verification using available data bases; the use of the data base obtained during the North East Regional Oxidation Study (NEROS) field program to evaluate and modify a regional photochemical oxidant model; the conduct of the second small-hill study and preparation for a major field study in the western United States to establish a data base for the development of air quality dispersion models for areas of complex terrain; the development of long-range transport models; the development of boundary layer models; and the initiation of the study and modeling of atmospheric processes affecting acid deposition. Work will continue in the Fluid Modeling Facility, using the wind tunnels and water channel/towing tank, on the study of plume dispersion in complex terrain, in the wake of automobiles, and around buildings.

SOLAR RADIATION FACILITY

The solar radiation facility has these functions:

- To maintain standard instruments for solar radiation measurements.
- To calibrate pyranometers and pyrheliometers.
- To test specimen solar radiation instruments.
- To make radiation measurements and establish their interrelationships.

The Facility also serves as a WMO regional radiation center.

Accomplishments FY 1982

The primary standard instrument served as the reference standard for the Fifth New River Intercomparison of Absolute Cavity Radiometers held at the DSET Laboratories, Phoenix, Ariz.

Pyranometers were replaced at all 38 of the NOAA solar radiation stations, and pyrheliometers at 25 of the stations. Also, old-style pyranometers were installed at 10 of the network stations as part of a special project to relate old (before 1977) and new solar radiation data.

Progress continued in the effort to describe and understand the accuracy limitations of solar radiation instruments. Eventually each pyranometer used for network measurements will have a curve describing its variability with respect to temperature and angle of incidence of the Sun.

The Boulder measurements of direct and global radiation are being analyzed to determine the effects of the El Chichón volcanic dust cloud on solar radiation.

Plans FY 1983

Pyranometers will be replaced at all network stations, and pyrheliometers will be replaced at as many locations as time and instruments permit.

The Sixth New River Intercomparison is being planned for November 1983 as a WMO regional pyrheliometer comparison.

Data from measurements with the old- and new-style instruments will be analyzed in cooperation with the Solar Energy Research Institute.

The facility will continue working with national (ASTM) and international (ANSI) groups that are writing industry standards for solar radiation measurements.

SUN-CLIMATE STAFF

The Sun-Climate Staff of ARL conduct fundamental research on the causes and mechanisms of climatic change, on time scales of months to decades, including solar variability as a possible cause. The application is directed toward, but not limited to, understanding and predicting climatic change in the United States. The general approach is to develop understanding of climatic processes through analytical studies using climatic, oceanographic, solar radiation, ozone, and other data, principally those representative of the past century.

The Sun-Climate Staff monitor progress on a grant to the University of Arizona that began in FY 1980, the purpose of which is (1) to develop and deploy a highly accurate spectrometer and associated calibration device for ground-based measurement of the secular characteristics of solar spectral changes in the UV, visible, and near-IR portions of the electromagnetic spectrum; and (2) to study the effects on surface-based measurements of atmospheric attenuation in these regions of the electromagnetic spectrum.

Accomplishments FY 1982

Research of the Sun-Climate Staff has identified the periodic behavior of U.S. climatic data and determined the dominant periods connected with the variability of

temperature and precipitation in the United States. It has also determined how these dominant periods change during the year as well as regionally over the United States. The strongest 10- to 11-yr signal in the U.S. temperature record over the past 85 years occurred during June in the upper Midwest and the western Great Lakes states, including the Iowa-to-Ohio "corn belt"; whereas, the strongest 22-yr temperature variability was in July and August in the central Midwest. The immediate mechanism for forcing the 10- to 11-yr signal in the U.S. temperature record has been studied and is understood.

The response of U.S. climate to meteorological and oceanographic conditions in the tropical Pacific was examined with specification models, irrespective of whether the tropical forcing is solar induced. These specification models are being evaluated for their possible usefulness as a basis for experimental forecasts.

Studies with satellite-based measurement of solar variability, on time scales of interest to climatic change, indicate the principal solar variability is associated with (1) solar rotation and (2) the secular development and extent of solar active regions. Sun-Climate Staff research has concentrated on understanding and modeling the spectral and temporal characteristics of UV and integrated-spectrum (solar constant) radiation for these two characteristic time periods.

The University of Arizona has developed, in collaboration with the National Bureau of Standards, a high-accuracy calibration device for use with a ground-based solar spectrometer. An observational program of measurement of solar spectral radiance began during summer 1982 on Mt. Lemon near Tucson, Ariz., using a secondary spectrometer, while work continued on a prototype of the final design of the solar spectrometer.

Plans FY 1983

Basic research will continue on the identification of climatic variability with solar (and other) time periods and on the pursuance of causes and mechanisms for these climatic changes. The application of specification models, based on both internal and external factors, to experimental forecasts of U.S. climate on time periods of 1-18 months will continue.

Research on analysis and development of models of UV and ozone variability will continue. A rocket-flight UV spectroradiometer will be built, tested, and calibrated.

The University of Arizona will continue development of the final design of the solar spectrometer, and will continue its observational program from Mt. Lemon and Mauna Loa Observatory, unless limited by El Chichón stratospheric dust.

AIR QUALITY DIVISION

The Air Quality Division, formerly part of OWRM, conducts field and laboratory investigations into (1) the physics and chemistry of formation of natural and anthropogenic tropospheric aerosol particles; (2) the dispersion, transformation, and sinks of these aerosols; (3) the effects of aerosols and of trace gases on the formation, colloidal stability, and chemical composition of clouds; (4) the scavenging of aerosols and gases by clouds; and (5) measurements and calculations of the effects of pollution sources on the radiation budget, visibility, and atmospheric-electric processes.

Accomplishments FY 1982

Aerosol and cloud-drop spectra between 0.05- and 23.5-m particle radius were measured with PMS optical spectrometer probes on Whiteface Mountain, N.Y. The concentration of sulfates was determined by microchemical spot analysis of impactor samples. A correlation analysis of air mass trajectories and aerosol/cloud-drop properties gave the following results: polluted continental air masses have small-particle concentrations of several thousand per cubic centimeter, 90% of which are sulfates; clouds that form in those air masses have high drop concentrations, a relatively small modal radius, and a narrow drop spectrum. Maritime air masses contain small particles at concentrations that are more than one order of magnitude smaller. Consequently, the cloud-drop concentration is smaller, but the cloud-drop distribution is wider and heavily skewed toward larger drops. Nonpolluted continental air masses have aerosol and cloud-drop properties that lie in between. The percentage of sulfates in nonpolluted aerosols is half of that found in polluted air masses. The results suggest that small pollutant particles, particularly sulfate, play an important role in the cloud nucleation process. The resulting effect on the cloud colloidal stability, shown by the cloud-drop distribution data, is reflected in the precipitation rates that have been observed by an NWS station during the times the measurements were made.

Mechanisms and rates of the scavenging of small particles by cloud drops were investigated during the Boulder Upslope Cloud Observation Experiment (BUCOE) in spring 1982. The number concentration as a function of particle size at cloud base and at a point inside the cloud (measured with PMS optical spectrometer probes), the height above cloud base of the in-cloud measuring point (determined with an integrating nephelometer), and the vertical wind velocities near cloud base and near the interior point (measured by three-dimensional anemometers installed at the Boulder Atmospheric Observatory tower) served as inputs into the continuity equation for particles. Under the assumption of steady state and a linear vertical-velocity profile, the scavenging rate was found to be about 10^{-3} s^{-1}, resulting in a decrease of the small-particle concentration at equilibrium by a factor of about 20.

During the same experiment, proton-induced X-ray emission elemental analysis was used to determine the relative amounts of elements in the small-particle mode as a function of altitude and cloudiness. From this data it follows that sulfur-containing small particles are advected to the Boulder Atmospheric Observatory by long-range transport, and are preferentially scavenged by cloud droplets. In one example, an upslope cloud with a liquid water content of 5×10^{-3} g m^{-3} scavenged 52 ng m^{-3} of sulfur aerosols out of a concentration of 60 ng m^{-3} in the dry atmosphere. This depletion of 87% by mass of sulfur aerosol exceeds, for example, that of soil-derived iron, which was depleted by only 70%. Assuming the sulfur aerosol is predominantly sulfate, and the sulfate ion is combined with hydrogen ions, the minimum pH value of cloud water resulting from the scavenging of sulfate is 3.8 in the absence of neutralizing aerosols.

The 1981 data base from the Gunbarrel Hill, Colo., field site was analyzed to quantify the relationship between the atmospheric electrical conductivity and physical parameters of particles suspended in the air. The analysis established an inverse correlation between the conductivity and the fine-particle concentration, and between the conductivity and the total-particle surface area, which were both significant at better than the 99% confidence level. An expected but not previously proven result is a correlation coefficient between the conductivity and the fine-particle number density. These results add credibility to the significance of conductivity as a sensitive air pollution indicator, and strengthen the interpretations of long-term conductivity records from Gunbarrel Hill and from the research vessel CARNEGIE as showing deteriorating air quality.

Plans FY 1983

Research objectives are to obtain correlations between (1) aerosol size, composition, and origin and (2) cloud water acidity to determine useful relations for predicting the acidity of rainfall. The research strategy will consist of ground-based and airborne measurements of physical and chemical properties of aerosols and cloud water ionic composition in widely different environments and at various distances downwind from sources.

To distinguish maritime aerosol from continental aerosol contributions to cloud water ionic composition, the modifications of cloud water chemistry by both marine and continental aerosols will be investigated. This will be done in Pacific cyclones, first offshore over the ocean, and subsequently (in the same storm system if possible) at increasing distances inland. Use will be made of the predominantly zonal west-to-east flow of air masses crossing the United States in 3-6 days. Forecasting on this time scale, with respect to large-scale features, is within the state of the art.

The aircraft sampling and in situ and laboratory analysis methodology to be employed will be the same that we previously used: cloud water samples will be acquired with our airborne collectors, utilizing both the techniques of impingement and of impaction followed by freeze-out. The cloud water samples will be maintained at 4°C until ground-based analysis by ion-exchange chromatography and inductively coupled plasma analysis can be performed as soon after sampling as is practical. The water-soluble and nonsoluble ions thus determined will be compared with those found in aerosols. For this purpose, aerosols will be sampled on both Nuclepore filters and electron microscope grids mounted on various stages of an impactor. Microchemical spot techniques for sulfates and nitrates will be utilized to detect the major anions in individual particles. X-ray energy spectrometry is the proven method of choice for elemental (atomic number greater than 10) analysis of individual particles. The cloud water and aerosol filter samples will be supplemented by in situ measurements of particle size spectra, cloud-drop spectra, liquid water content, and the concentrations of various trace gases (SO_2, NO_x, O_3, and H_2O).

Data sets from simultaneous, or near-simultaneous, measurements of background aerosol and cloud water composition, taken in an air mass traversing the continental United States from offshore in the Pacific Ocean, will be examined for correlations. The results will determine the nucleation, in-cloud, and below-cloud scavenging efficiencies of clouds of various liquid water contents and droplet size distributions for aerosols as functions of aerosol size and composition. Useful output will consist of information on (1) the background acidity, and its causes, for clouds before they cross a shoreline and (2) modification of this acidity, and its causes, for the same clouds as they travel over the continent.

Under an interagency agreement with the National Park Service, wind and other meteorological data will be analyzed and used to develop a smoke management plan for the Grand Canyon National Park. The smoke is generated by the annual burning of understory (short vegetation) in the areas along the canyon rim. The goal of this project is to develop a procedure for forecasting conditions when the smoke will be transported down into the canyon and trapped there, so that burning can be curtailed during such periods. This project provides an opportunity to study the flow patterns in a narrow valley with steep slopes and complex terrain, a subject about which very little is presently known.

GEOPHYSICAL MONITORING FOR CLIMATIC CHANGE DIVISION

The Geophysical Monitoring for Climatic Change (GMCC) Division of ARL operates four observatories that measure atmospheric constituents important for climate change. The observatories are located in remote clean-air sites at Point Barrow, Alaska; Mauna

Loa, Hawaii; Cape Matatula, American Samoa; and South Pole, Antarctica. The research objective at these observatories is long-term surveillance of the atmosphere. Measurements from these sites are used to determine whether gases and particulates put into the atmosphere by human activities or by natural causes are significant enough to change climate.

Accomplishments FY 1982

AEROSOLS AND RADIATION

Monthly variations in optical thickness of stratospheric aerosol were determined from the Mauna Loa transmission data from 1963 onward. These data were used to correct Umkehr ozone profile data from seven stations. The corrected profiles reveal trends that differ from the original uncorrected data.

Lidar observations were used to deduce stratospheric aerosol optical thickness for 1980 and 1981. The mean optical thickness at 694-nm wavelength for this period was 0.005, and all values ranged between 0.002 and 0.007.

Results of a special field project at Whiteface Mountain, N.Y., show that measurements of visible light absorption of impurities found in cloud water did not differ greatly from measurements in the freely suspended aerosol. The imaginary term of the absorption refractive index was found to be on the order of 0.01, which indicates moderate absorption. A relationship between the pH of cloud water and absorption refractive index (as pH increased, absorption refractive index decreased) was seen in the collection of measurements. This suggests that the sources of acidity and darker aerosols (perhaps carbon) are related. Preliminary radiative transfer calculations show very little increase in the absorption of visible light by clouds containing the impurities sampled at the Whiteface site. More recently, light-scattering measurements of aerosols were made with a four-wavelength integrating nephelometer, in conjunction with other measurements.

Exploratory measurements of the radiative fluxes affected by Arctic haze and measurements of aerosol size distributions were obtained at Barrow in May. A theoretically based analysis of these measurements will yield information on the optical absorption of solar radiation.

Two episodes of significant stratospheric-dust concentrations were detected by the Mauna Loa lidar and atmospheric transmission measurements. The cloud detected at 18 km in January (origin unknown) was observed to have a maximum backscatter ratio (Rayleigh and Mie to Rayleigh) of 3. On 9 April, the Mauna Loa lidar detected a huge stratospheric dust layer ejected into the stratosphere at 27 km by the El Chichón eruption in Mexico. This layer was initially only a few kilometers thick and had a peak backscatter ratio of 350, which is roughly 2 orders of magnitude greater than any dust layer previously observed by the lidar. The vertical diffusion of the layer is being studied with the use of lidar observations made subsequent to the initial sighting of 9 April. The drop in atmospheric transmission following detection of the El Chichón stratospheric cloud was the largest found at Mauna Loa since measurements began 24 years ago in 1958.

A prototype automated solar radiation dome and spar were put into operation in October at Mauna Loa Observatory. Spectral narrowband and broadband irradiance measurements were initiated on an automated tracking and data acquisition system. The intent is to begin a new generation of high-quality solar irradiance measurements to detect and understand the roles of long-range tropospheric and stratospheric aerosol transport in the solar irradiance fields in the remote atmosphere.

A special solar irradiance study was conducted at the South Pole Observatory to characterize the radiation balance and heat budget of the Antarctic ice cap. Special measurements of spectral and broadband solar fluxes were made.

The relationship between the mass of the crustal elements (aluminum and manganese) observed on filter samples from the Mauna Loa Observatory, and the source region of the air masses was studied. Kinematic trajectories on isobaric surfaces, specifically the 700 mb (3.1 km) and 500 mb (5.5 km), showed that the deserts of Asia were the origin of relatively large masses of crustal material. Chemical analysis was performed by the Department of Chemistry at the University of Maryland. The trajectories were calculated using a modified version of the ARL trajectory model. The stated results were for February through June 1979.

TRACE GASES

Following the eruption of El Chichón, special measurements were initiated at Mauna Loa Observatory in May to study the effects of the El Chichón stratospheric aerosol layer on ozone and ozone measurements. A specially calibrated Dobson spectrophotometer was used to make observations for measuring true ozone and SO_2 amounts, if possible, and for assessing whether the amount of volcanic SO_2 ejected into the stratosphere was enough to interfere with regular ozone measurements. Preliminary indications are that SO_2 is being detected, but the amount is uncertain because of errors present in available SO_2 absorption coefficient data at UV wavelengths and because of possible interference by aerosols.

Dobson spectrophotometer Umkehr observations were also initiated at Mauna Loa Observatory in May 1982, primarily to study the effect of stratospheric aerosols on Umkehr-type measurements. Preliminary research had shown that Umkehr data can be erroneously biased by interfering aerosols to yield negative ozone values near 50-km altitude. Data processed by the newer "short" Umkehr method yield more realistic but low ozone amounts near 50 km.

In September 1982, a weekly program of ECC (electrochemical concentration cell) ozonesonde releases commenced at Hilo, Hawaii. These direct ozone soundings to 40-km altitude provide data that aid in interpretation of results of the indirect, Umkehr ozone vertical-distribution measurements, and may shed light on potential particle depletion of the ozone layer by volcanic aerosols.

Measurements of the vertical distribution of SO_2 in the stratosphere were made by GMCC personnel from Hilo in late September 1982 with newly developed, prototype, balloon-borne EEC SO_2 sondes to study the stratospheric sulfur budget. There is considerable uncertainty about the amount of sulfur gases emitted by the eruption of El Chichón. Preliminary analyses of the data suggest the possibility of an SO_2 layer extending from the tropopause at 14- to 30-km altitude, with a peak SO_2 mixing ratio of 0.5 ppmv occurring at 24.5 km. The results are, however, not unequivocal because of the prototype nature of the instruments. A rough estimate of the global stratospheric abundance of SO_2 yielded a value of 25 Mt. Since SO_2 possesses absorption bands in the UV and IR spectral regions and is, furthermore, a precursor of H_2SO_4 aerosols, such a large amount of SO_2, with significant stratospheric residence time, would probably have a substantial impact on the radiation balance and dynamics of the stratosphere.

Total ozone observations with Dobson ozone spectrophotometers were continued at Bismarck, N.D.; Caribou, Maine; Tutuila Island, Samoa; Mauna Loa, Hawaii; Wallops Island, Va.; Barrow, Alaska; Nashville, Tenn.; Boulder, Colo.; Tallahassee, Fla.; Huancayo, Peru; and Amundsen-Scott, Antarctica. Preliminary results have been archived at the World Ozone Data Center (WODC), Downsview, Ontario, Canada.

Total ozone measurements at the White Sands, N. Mex., Dobson station, operated and funded by the U.S. Department of Army, were terminated in January 1982. Efforts are being made to reestablish the measurement program at some new station in the southern United States.

A new Dobson station was established at the Fresno Air Terminal in Fresno, Calif., during October 1982.

In a continuing effort to upgrade the quality of ozone observations throughout the world, a program was initiated in 1982 to check on the calibration levels of Dobson spectrophotometers in use throughout the world. To achieve this goal, the global Dobson station network was divided into seven regions. A standard lamp and power supply and two calibrated standard lamps were sent to each region for performing the tests. By the end of 1982, calibration data from 54 instruments were received in Boulder.

In related work in 1982, Manila, Philippines, Dobson spectrophotometer no. 52 was received in Boulder for repair and calibration in August. At that time, a Philippine technician was trained in operation and maintenance of the instrument. Also, U.S. instrument no. 34, located in Caribou, Maine, was returned to Boulder for recalibration.

During 1982 at Boulder, GMCC first measured Dobson spectrophotometer slit functions in a continuing investigation of a possible systematic bias in Dobson total ozone measurements. Results were reported at a NASA-sponsored meeting called to study similar ozone absorption-coefficient-related biases in other ozone-measuring instruments, including satellite instrumentation.

Dobson instrument no. 61, which had been modified in 1981 to run under the control of an HP85 computer, was installed early in 1982 in an Ashdome equipment shelter at Boulder. Because the opening and closing of the shelter's shutter was also controlled by the computer, completely automatic Umkehr measurements were begun starting in February 1982. By the end of September, 114 automatic Umkehr measurements were made.

With funds from EPA, the Chemical Manufacturers Association, NOAA, and the World Meteorological Organization (WMO), work was started to automate six more Dobson spectrophotometers for Umkehr observations, and to distribute them to a global network of stations by June 1984 for accurate long-term measurements of stratospheric vertical distribution. Motivation for this project is a long-term study of possible depletion of ozone near 40-km altitude by chlorofluorocarbons. Tentative sites for the stations are Mauna Loa, Hawaii; Huancayo, Peru; Poker Flat, Alaska; Haute Province, France; and stations in Africa and Australia.

The atmospheric baseline measurements of CO_2, ozone, chlorofluorocarbons (CFC-11 and CFC-12), aerosols, and solar radiation continued at Mauna Loa Observatory (1958-1982), Barrow (1973-1982), American Samoa (1974-1982), and South Pole (1974-1981). Selected data are archived in Asheville, N.C., at the National Climatic Center.

Tests in Boulder on ECC balloon ozonesondes adapted for high altitude (to 40 km) soundings continued. Concurrently, observations with these instruments are being conducted in Boulder at a frequency of one sounding per month.

Stratospheric water vapor soundings with balloon-borne frost point hygrometers continued in Boulder at a frequency of one flight per month. An analysis of nearly 20 years of stratospheric water vapor data from Washington, D.C., and Boulder, Colo., indicates a significant quasi-biennial oscillation related to the oscillation in the tropical zonal wind. This appears to be another confirming indication that the stratospheric water vapor distribution at midlatitudes is strongly determined by air injected from the troposphere into the stratosphere at tropical latitudes.

New stations operating in the flask network in FY 1982 were Cape Meares, Ore.; Kitt Peak, Ariz.; Halley Bay, Antarctica; Christchurch, New Zealand; and Weathership M, North Atlantic. The Falkland Islands station was lost during FY 1982.

Oceanographic CO_2 programs included (1) sampling atmospheric CO_2 during the CO_2 expedition of the NOAA research vessel DISCOVERER in the northwestern Pacific, in April 1982; and (2) arranging for atmospheric CO_2 sampling during the circumpolar Antarctic expedition of the NSF expedition of the POLAR STAR, and during the Japanese Antarctic expedition of the FUJI.

An important result in FY 1982 was the convergence of the NOAA and Scripps Institution of Oceanography (SIO) standard CO_2 calibration scales. Problems of drifting standard gases have now been resolved. The NOAA standards were measured nanometrically, so that final CO_2 results since the beginning of the GMCC program are now being prepared in the 1981 mole fraction scale.

In June 1982, GMCC hired a chemist from the University of Washington to assume responsibility for the GMCC CO_2 program; he was elected a Fellow of CIRES in September 1982.

Flask-flask comparisons between GMCC and SIO for samples taken simultaneously at Barrow, Mauna Loa, Kumukahi, Samoa, and La Jolla show excellent agreement since joint sampling began in mid-1981. The sampling at SIO is reported blindly to WMO 4 times per year.

An important result from the CO_2 flask program is the latitude distribution of the secular growth of atmospheric CO_2 concentration, with a maximum of ~1.5 ppmv yr^{-1} at high northern latitudes (40°-60°N), decreasing to ~1.2 ppmv yr^{-1} at midlatitudes of the Southern Hemisphere.

GMCC participated in the Department of Energy (DOE) research conference entitled "Carbon Dioxide, Science, and Consensus," on 19-23 September in Berkeley Springs, W. Va. A brief presentation was made of the GMCC CO_2 program and recently determined global CO_2 distributions.

COOPERATIVE PROGRAMS WITH CIRES

Two GMCC staff members in the ozone research program are CIRES Research Assistants. Three members of the CO_2 program staff have CIRES research appointments. They work in the GMCC CO_2 facility doing flask analysis and data reduction.

Plans FY 1983

AEROSOLS AND RADIATION

A special series of optical remote-sensing observations from Mauna Loa and an aircraft platform will be made of the El Chichón stratospheric-dust cloud to determine the radiative properties of the cloud, which are important to studies of climate variations.

The size distribution properties of aerosols being sampled at the American Samoa Observatory will be defined.

A data base will be developed with empirical information on the relationship between the stratospheric-dust optical depth and profile, and the error to the Umkehr ozone profile. This data base will be used to verify modeled computer calculations of the correction.

GMCC will participate in the Arctic Gas and Aerosol Sampling Program (AGASP) in March and April 1983 in conjunction with investigators from universities and from other government agencies. Aircraft and surface measurements will be made of solar fluxes and aerosols to study the extent of the Arctic haze. The measurements will be

made in Arctic regions, especially around Barrow and over ocean sink regions of the Greenland-Norwegian Sea.

Trajectory studies for 1980 and 1981 will be correlated with intrusions of atmospheric aerosols, in an attempt to identify long-range transport of aerosols back to continental sources.

TRACE GASES

Analyses are planned of total ozone, ozone vertical distribution, and SO_2 data obtained in Hawaii following the eruption of El Chichón volcano in Mexico.

Completion of work in automating and installing three of six automatic Dobson spectrophotometers during 1983 is anticipated. The spectrophotometers will be located at field stations for routine observations.

The performance of high-altitude balloon-borne ECC ozonesondes will be intercompared with several other types of more sophisticated and complex instruments in June 1983 at Palestine, Tex., in a NASA-sponsored intercomparison of various types of ozone-measuring instruments.

GMCC will participate in a second round of stratospheric water vapor intercomparisons during 1983 to resolve some of the discrepancies that appeared in an earlier round of intercomparisons conducted in 1981.

A surface ozone monitor will be deployed to Iceland during the period February-May 1983 to look for strong intrusions of ozone from the stratosphere into the troposphere that may reach the surface. These measurements will be made in conjunction with AGASP aircraft measurements being made in the same area.

GMCC will participate in CO_2 marine expeditions of PMEL in the central-north Pacific (March 1983), and in the U.S.S.R.-U.S. collaborative expedition in the western Pacific (fall 1983). CO_2 will be measured in air and in surface water for determination of latitude gradients, air-sea exchange, and ocean sinks/sources.

The relative precision, accuracy, and reliability of gas chromatographic vs. (presently employed) nondispersive infrared techniques for monitoring atmospheric CO_2 at remote locations will be investigated in collaboration with a visiting scientist from the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia. This will also permit routine GMCC monitoring of methane (CH_4).

Ground-based in situ concentrations of CO_2 and other trace gases will be evaluated with respect to total atmospheric column averages determined simultaneously by high-resolution Fourier-transform infrared spectroscopy. Observations will be made at Mauna Loa in collaboration with the University of Denver, and will continue at Kitt Peak National Observatory in collaboration with Battelle Laboratories.

Plans will be made for an evaluation of the techniques to measure O_2 concentrations in the atmosphere and to collect air samples for O_2 analysis.

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A systematic study will be undertaken jointly with Scripps Institution of Oceanography scientists to determine the causes, if any, of discrepancies between the two CO_2-measuring systems on Mauna Loa. This will include comparison of the instruments themselves as well as the sampling and data reduction procedures.

The global CO_2 sampling network will be expanded to include the Galápagos Islands, Easter Island, and the Fanning-Christmas Islands in the Pacific, bringing the total number of stations to about 25. (A Brazilian Atlantic island and an Amazon site are under negotiation.)

Collaborative efforts with NCAR and CSIRO will be expanded to determine global distribution, seasonal amplitudes, and secular growth rates of CH_4 from air samples collected at GMCC sites.

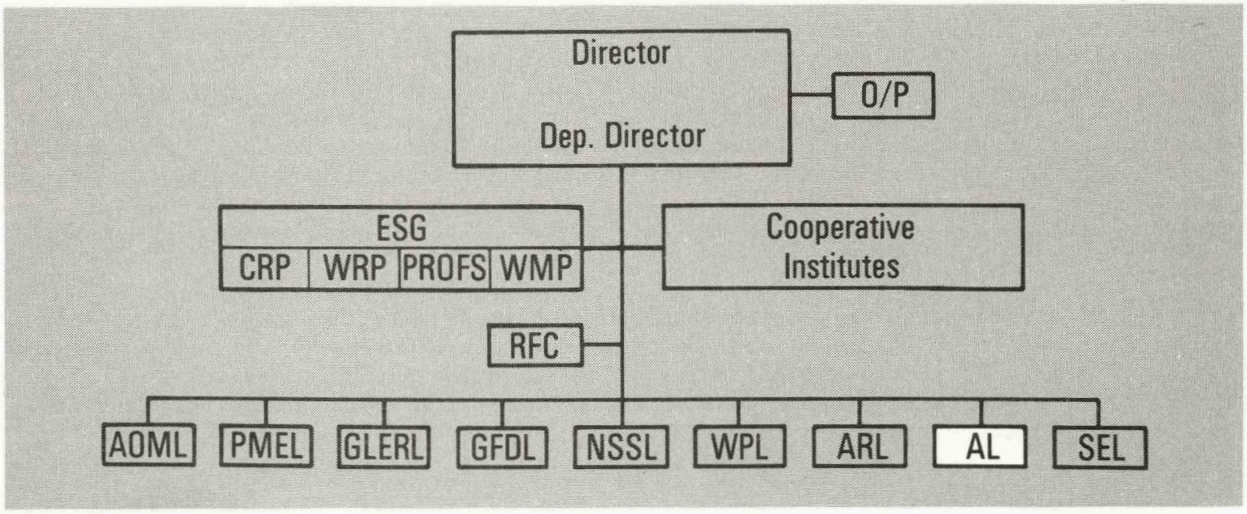
Reduction will be completed of all previous CO_2 measurements, both continuous and flask data, at GMCC sites, for release to WMO, to the DOE CO_2 Information Center, and to all interested carbon-cycle modelers, by 15 March 1983.

COOPERATIVE PROGRAMS WITH CIRES

The visiting research scientist to GMCC from CSIRO has a CIRES appointment. He will conduct his laboratory research program--gas chromatographic measurement of CO_2 and CH_4--in space provided by CIRES. The CO_2 program leader for GMCC, also a Fellow of CIRES, shares the laboratory space and has an NSF research grant through CIRES. He is co-investigator with an SIO scientist to investigate the ocean sinks for fossil fuel CO_2 using the chlorofluorohydrocarbon gases as transient tracers of ocean circulation and mixing. A field program will be conducted in February 1983 in a tropical Atlantic study of transient tracers in the ocean.

AERONOMY LABORATORY
Boulder, Colorado

Eldon E. Ferguson
Director



The Aeronomy Laboratory conducts research on chemical and physical processes of the Earth's atmosphere to advance the capability of monitoring, predicting, and controlling the quality of the atmosphere. The research concentrates on the stratospheric and tropospheric regions of the atmosphere but also involves the ionosphere as well as the atmospheres of other planets.

Research methods involve both in situ and remote measurement of critical atmospheric parameters, including chemical composition and dynamic properties such as wind velocities, turbulence, and wave motions. Theoretical programs in atmospheric photochemical modeling and in atmospheric dynamics and transport support the observation programs. An experimental laboratory chemical kinetics program supports the theoretical photochemical modeling program and also supplies input for the development of new atmospheric monitoring and measurement technology.

The research of the laboratory is accomplished by six programs that have substantial interaction: Atmospheric Chemical Kinetics, Atmospheric Dynamics, Atmospheric Sampling, Atmospheric Wave and Turbulence Theory, Optical Aeronomy, and Theoretical Aeronomy.

ATMOSPHERIC CHEMICAL KINETICS

The primary activity of the Atmospheric Chemical Kinetics program is the experimental investigation of chemical reactions that are important in the atmosphere. Neutral reactions involving atoms and free radicals dominate the chemistry of the lower atmospheric regions, the stratosphere, and the troposphere. In recent years the chemistry of the stratosphere has been of great interest because of the recognition of human potential for inadvertently affecting the ozone layer with disastrous consequences. First, the possibility of an ozone reduction from water and nitrogen oxides released in stratospheric flights of supersonic transports was considered. This brought worldwide attention to the potential for global air pollution problems. More

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recently, the use of chlorine-containing halocarbons and nitrogen fertilizers have been labeled as potential threats to stratospheric ozone. In addition to the effects of ozone loss on biological systems, climatic changes may also be precipitated by changes in the chemical composition of the atmosphere.

Most chemical reactions that take place in the troposphere and stratosphere involve free radicals. These are atoms or molecules characterized by high reactivity, which often results from having one or more unpaired electrons. These reactions are the key steps in the formation and destruction of atmospheric ozone, the oxidation of natural and anthropogenic chemicals released into the atmosphere, and the formation of acid rain. The Atmospheric Chemical Kinetics program emphasizes quantitative studies of the rates and mechanisms of the important gas phase reactions of atoms and small molecules. Studies are made over a wide range of temperatures and pressures to simulate conditions in the atmosphere.

The study of ion-molecule reactions continues to make valuable contributions to our understanding of the chemistry and composition of the atmosphere. In recent years the major effort in this area has concentrated on improving our knowledge of chemistry of the metallic elements that are deposited in the upper atmosphere by meteor ablation and on using laboratory kinetic data in conjunction with measurements of atmospheric ion composition to determine the concentration of critical trace compounds such as sulfuric acid in the stratosphere.

Accomplishments FY 1982

New data were obtained on the self reaction of hydroperoxyl (HO_2) radicals. This reaction is very important in the atmosphere as the source of hydrogen peroxide, a critical oxidant that has been implicated in several important processes including the conversion of sulfur dioxide to sulfuric acid. This study establishes a low-pressure rate constant for the hydrogen peroxide formation reaction. The new work also provides evidence that the reaction has a negligible pressure dependence at low pressures. This observation contradicts a recent study published by another research group. A by-product of the present work is the development of some new methods of generating HO_2 radicals and accurately calibrating their concentration.

A measurement of the rate constant for the reaction of hydroxyl (OH) radicals with chlorine monoxide (ClO) was obtained. This reaction is of potential importance in the stratosphere. The study was undertaken because of an apparent discrepancy in several independent studies. The new result indicates that an error of about a factor of 2 exists in two published measurements of this rate constant.

A laboratory apparatus was constructed for studying the atmospheric photochemistry of nitrate (NO_3) radicals. Major uncertainties exist in photochemical kinetic data for NO_3. This radical is very important in the atmosphere where it is primarily formed by the reaction of nitrogen dioxide with ozone. A thorough understanding of the chemistry of NO_3 is required to interpret the role of nitrogen oxides in the stratosphere and troposphere.

Studies were made of the atmospheric reactions of silicon (Si), magnesium (Mg), and iron (Fe) positive ions. These materials are deposited in the Earth's upper atmosphere by meteors, and their presence is known from rocketborne mass spectrometer experiments. Laboratory reaction rate measurements and theoretical analysis yielded an explanation for the rapid disappearance of Si^+ compared with Mg^+ and Fe^+ at altitudes below 105 km. It was found that Si^+ ions react with water vapor whereas Mg^+ and Fe^+ do not. These results were utilized to determine mesospheric H_2O concentrations from the observed ion concentrations. Detailed laboratory studies of Si negative ion reactions were carried out and their role in the atmosphere analyzed.

Reactions of a number of molecular ions were measured in the flow drift tube in different buffer gases, allowing some control of the vibrational states of the ions. In general, large effects of vibrational energy on rate constants were found. This effect was used to measure vibrational excitation and de-excitation rate constants for several molecular ions. These rate constants were found to be generally large for collisions with gases other than helium.

Plans FY 1983

The system that was developed to study NO_3 will be used to measure the NO_3 absorption cross section in the 600- to 700-nm region. A study will be made to develop a method of observing NO_3 by means of laser-induced fluorescence. This technique will be evaluated as a kinetic detection scheme. A systematic study of NO_3 kinetics will be initiated.

A new experiment for studying the atmospheric reactions of some important metal vapors will be started. It has been proposed that the metallic elements injected into the atmosphere at high altitudes by meteors may influence the ozone/chlorine chemistry of the stratosphere. This experiment will begin with some studies of reactions of sodium vapor.

A high-pressure flow tube reactor will be developed. At present a critical limitation on the use of flow tubes for kinetic studies is that they cannot be used at pressures above about 5-10 torr. High-pressure measurements are made with the flash-photolysis technique, which generally is used at pressures above about 30 torr. A new type of flow tube experiment, which will operate at pressures up to about 70 torr, is planned.

Studies of the effect of reactant ion vibrational excitation on ion-molecule reaction rate constants will be pursued. These processes can be very important in the upper atmosphere. The efficiency of molecular ion vibrational excitation and de-excitation will be measured using vibrational-state-dependent reaction rate constants as probes for the ion vibrational state.

Thermochemical parameters of some stratospheric negative ion clusters will be measured in the laboratory. These data can be used with measurements of the ion composition of the atmosphere to deduce the concentration of critical trace components such as nitric acid, sulfuric acid, and water vapor.

A flowing afterglow apparatus will be modified to be used as a chemical ionization detector for atmospheric radicals. This experiment will take advantage of the fact that radicals generally have a small ionization potential or a large electron affinity. As a first test of this method, the detection of HSO_3 radicals, which are thought to be a very important intermediate in acid precipitation chemistry, will be undertaken.

ATMOSPHERIC DYNAMICS

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The experimental research of the Atmospheric Dynamics program is based on study of the atmosphere by analysis of Doppler radar echoes from irregularities in the atmosphere. Doppler radars measure the profile of the wind, including the vertical components, and profiles of certain parameters of turbulence. Because of their rapid cadence of measurement and great altitude range, Doppler radars are well suited for studying phenomena that vary rapidly in time, such as buoyancy (internal gravity) waves and turbulence. They can, of course, also study slowly varying phenomena such as planetary waves and tides. The Doppler radar technique used for such studies is

generally called the MST (mesosphere-stratosphere-troposphere) radar technique. MST measurements should be invaluable in studying zonal and meridional tidal variations throughout the atmosphere; energy-coupling processes between the troposphere, stratosphere, and mesosphere; generation and propagation of atmospheric waves; Sun-weather relationships; atmospheric turbulence; atmospheric stability; etc.

To exploit the capabilities of the MST radar technique, the program has been following several lines of experimental research. In 1973 we started construction of the Sunset VHF pulsed-Doppler radar near Boulder, the first VHF radar designed and constructed specifically for MST studies. In 1976 we began exploring the limits of the MST technique by using a variety of radars with a wide range of frequencies, geographical locations (from near the Equator to the Arctic), sensitivities, and configurations. These studies demonstrated that the MST technique works from 40 to 1,300 MHz at all locations, and that, with a sufficiently powerful radar operating below ~70 MHz, measurements can be made at all heights, from near the ground up to about 100 km. On the basis of these studies, construction (funded by NSF) began on a large MST radar at Poker Flat, Alaska, during FY 1979. Because of its unique design, it has been possible to operate the radar almost continuously, with gradually increasing sensitivity, since construction began in February 1979.

Accomplishments FY 1982

The Poker Flat radar was brought up to full power in September 1981. Modifications to the Sunset radar to make it fully steerable in the north-south and east-west planes were completed. Two portable radar systems were constructed.

The Poker Flat data were used to study the seasonal and diurnal variations of turbulence in the troposphere and lower stratosphere, which were found to be surprisingly large. Further radar and balloon experiments were conducted with the Sunset radar to try to understand the mechanisms for these variations.

As part of the ALPEX (Alpine Experiment) program, a three-station array of portable radars was deployed in southern France in April 1982 to measure simultaneously the frequency, wavelength, and phase velocity of buoyancy waves in the troposphere and lower stratosphere.

Time series of winds observed by radar were used to compute frequency spectra as a function of altitude in the troposphere, lower stratosphere, and mesosphere. It was shown that in the lower atmosphere these spectra, as well as wind spectra versus horizontal and vertical wavenumber, tend to have a universal shape and amplitude, independent of geographical location, altitude, weather conditions, etc. It was also shown that the spectra can be fitted by a model based on the buoyancy wave dispersion relation.

Mesospheric tides were inferred from the Poker Flat data. Use of the Poker Flat radar as a meteor radar was explored to extend MST radar observations into the night, including the polar night.

In September 1982 a portable radar system was deployed at Natal, Brazil, to study artificial plasma irregularities in the ionospheric F region.

Plans FY 1983

With the completion of the construction phase of the Poker Flat MST radar and the completion of a major reconfiguration of the Sunset radar, this program area will devote efforts more to analysis than has been possible in the last few years. The following is a list of areas in which we expect to make major contributions.

Our research on turbulence has two objectives: first, to describe the statistics of occurrence of turbulence; and second, to develop physical understanding that permits us to construct a model for its occurrence. A description and a model for the morphology of occurrence of turbulence are important to the design of radio and optical propagation systems. Also, turbulence is the principal dynamical sink of energy in the free atmosphere. The dependence of the occurrence of turbulence on geographical location, including latitude and topography, and on season, time of day, synoptic weather, thunderstorm activity, buoyancy wave activity, etc., will be studied with existing radars, including our portable system. More detailed observations as described above will be used to improve our model for the occurrence of turbulence to extend its reliable application to a much wider range of atmospheric conditions.

Our previous research has shown that Fresnel reflectivity (with the radar pointed vertically) has a definite relation to the gradient of temperature, so that from observations of the reflectivity the buoyancy frequency and temperature profiles can be inferred. We will continue to explore and develop this technique, both for the determination of tropopause heights and for the retrieval of temperature profiles as a part of a combined radar-microwave radiometer Profiler system. This will require a series of careful experiments to describe the dependence of the reflectivity on the zenith angle, pulse length, wavelength, meteorological conditions, etc., which has already been initiated at the Sunset radar, utilizing a recently developed method of absolute calibration.

Buoyancy waves play an important role in atmospheric dynamics: they efficiently transport energy and momentum, both vertically and horizontally, and their breakdown into turbulence at small vertical scales results in a major energy sink in the free atmosphere. To improve our observations of discrete buoyancy waves, a four-station microbarograph array will be installed in conjunction with the Sunset radar. The ALPEX observations will be analyzed to obtain periods, horizontal and vertical wavelengths, and phase velocities, to study such factors as modal structure, vertical propagation, and interaction of waves with critical levels.

Power spectra of wind fluctuations versus period, vertical wavenumber, and horizontal wavenumber (when possible) will be computed under as wide a variety of conditions as possible, such as geographical location, altitude, season, and weather conditions, to study the degree of universality of spectral shape and amplitude. The variation of the amplitude of the spectrum with altitude will be analyzed to determine the loss of energy versus altitude and its relation to the background wind profile. These spectra will also be used to study the relative contributions of different dynamical processes, particularly buoyancy waves and two-dimensional turbulence. The relation between the buoyancy wave spectrum and our model for the occurrence of turbulence will be further refined.

We will further explore the direct measurement of synoptic-scale vertical velocities. Since these velocities have never been directly measured, it will be important to determine the potential impact of this kind of data on weather forecasting.

The continuous data set already obtained from the Poker Flat MST radar over the past 4½ years is proving to be invaluable in studying a variety of mesospheric phenomena such as zonal and meridional tidal variations, energy coupling processes between the mesosphere and the lower atmosphere, the generation and propagation of atmospheric waves, Sun-weather relationships, and atmospheric turbulence. The data serve as a base for a number of ongoing cooperative studies with the university community and other agencies, including the University of Alaska (several groups), University of Washington, Boston College, Cornell University, UCLA, CIRES, the Air Force Geophysical Laboratory, and the Control Data Corporation.

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We will continue studying the relationship between upper-mesospheric winds and heating in the lower auroral ionosphere during magnetically active periods. This study will use mesospheric data from the Poker Flat MST radar and ionospheric data from the NOAA-operated VHF auroral radar at Elmendorf AFB in Anchorage, Alaska.

The plans for research on climate variability and solar radiation are described in the Theoretical Aeronomy section.

ATMOSPHERIC SAMPLING

The research goals of the Atmospheric Sampling program are the in situ measurement of the concentrations and properties of trace atmospheric species and the use of this information to solve key problems in understanding the photochemistry and transport of the lower stratosphere and troposphere. Several key environmental issues are being addressed. All involve the potential deleterious alteration of the Earth's atmosphere by humans:

- Depletion of stratospheric ozone by chlorofluoromethane releases and by supersonic aircraft, and the resulting increase in harmful solar ultraviolet radiation that reaches the Earth's surface.

- Increase in tropospheric ozone by subsonic aircraft, and the resulting increase in the "greenhouse effect" and hence climate alteration.

- Increase in the acidity of precipitation by anthropogenic sulfur and nitrogen emissions, and the resulting aquatic, terrestrial, and material damages.

To contribute to a clarification of scientific facets of these issues, the approach taken by the Atmospheric Sampling program focuses on the in situ measurement of the concentrations and properties of the relevant trace atmospheric species. The field applications of these instruments and techniques have employed a variety of platforms: balloons, stratospheric aircraft, tropospheric aircraft, ships, vans, and semipermanent ground stations. The more recent of these investigations are summarized in additional detail in the following sections.

Accomplishments FY 1982

Tropospheric profiles of nitrogen oxide (NO) and nitrogen dioxide (NO_2) were measured with the Atmospheric Sampling program's sensitive NO chemiluminescence detector. Although limited in number thus far, these measurements show that the NO and NO_2 profiles are quite different from those assumed in previous theoretical studies. The implications of the difference are very significant. One of the more important implications is that upper-tropospheric ozone, which figures significantly in climate, may be altered by high-flying subsonic aircraft.

The program's H_2O detector was redesigned to operate in the daytime. The first application of this new design was built into an instrument that is carried aboard NASA's U-2 aircraft, which flies up to 21 km. This research platform offers several hours of flight time at many global locations. The first application was in Panama in the late summer of 1980. This mission explored tropical tropospheric-stratospheric exchange processes. The results from these flights show that tropopause-overshooting cumulonimbus clouds are able to add water to the lower stratosphere. Furthermore, the data suggest that a sizable fraction of the water that is transported into the stratosphere probably enters over Micronesia, where the cumulonimbus clouds can reach maximum heights.

A research field station was established at a remote site at the 10,000-ft level on Niwot Ridge near the Continental Divide on land administered by the Arctic and Alpine Research Institute of the University of Colorado. The location of the station

has the valuable feature that, depending on wind conditions, it can be used to examine "clean-air" or it can offer the opportunity to study the chemistry of relatively polluted air. The University of Colorado, Metropolitan State College, Colorado College, and the Cooperative Institute for Research in the Environmental Sciences are collaborating with the Aeronomy Laboratory at this research station. The remaining FY-1982 accomplishments listed here were done at the Niwot Ridge research station.

The photodissociation of NO_2 by sunlight plays a critical role in tropospheric photochemistry, and model calculations of both clean-air ozone chemistry and smog production require this rate to be accurately known. Measurements of the rate were made over a summer period using an instrument designed and constructed for that purpose. This study showed that the rate can be determined to ±7%, theoretically or experimentally, for a given site and atmospheric conditions, with most of the variation being due to clouds. The cloudy-day data identified shortcomings with the simple cloud models currently used, and the study has suggested improvements. Furthermore, two different sets of NO_2 quantum-yield data were tested in the theoretical calculation. The good agreement of one set of calculations supports the larger-valued set, which is not the most widely accepted set at present, thereby suggesting the need for further quantum-yield laboratory studies.

Nitric acid (HNO_3) is an important part of acid deposition. To test the current understanding of the photochemistry whereby HNO_3 is formed from NO and NO_2, HNO_3 and nitrate particulate (NO_3^-) measurements have been made at the Niwot Ridge site, in addition to simultaneous measurements of NO and NO_2. It is clear that, for given NO_2 levels, the summertime HNO_3 levels are higher than those in the winter. This is consistent with the expected higher OH concentrations of the summer months. Similar correlations have been made between HNO_3 and NO_3^-, the former being thought to be the precursor of the latter. There is no clear relation observed, suggesting precursors of NO_3^- other than HNO_3.

Other observations made during this Niwot Ridge study permit estimates of the seasonal dependence of the dry removal rate of HNO_3, which appears to be much faster in summer than winter. Previous to this, virtually nothing was known about this aspect of dry acidic deposition. These year-long measurements of Rocky Mountain HNO_3 levels may well serve as a benchmark to later gauge the effects of the expansion of the urban corridor along the Front Range.

Plans FY 1983

NASA will sponsor the second intercomparison of stratospheric H_2O instruments in April 1983, at the National Scientific Balloon Facility (NSBF) in Palestine, Tex. Both of the Atmospheric Sampling program's H_2O instruments will take part.

NASA will also sponsor an intercomparison of four techniques for measuring stratospheric N_2O, $CFCl_3$, and CF_2Cl_2 concentrations. These balloon-borne instruments will be launched simultaneously from NSBF in August 1983. Our grab sampler will be one of the instruments involved.

The NO-NO_2 chemiluminescence-photolysis apparatus was designed for a balloon-borne experiment. The goal of this flight series is to obtain NO and NO_2 altitude profiles at different seasons and latitudes. Such data, which are currently unavailable, will provide critical tests of the understanding of stratospheric odd-nitrogen photochemistry. Data have been obtained thus far from Palestine, Tex., and Gimli, Manitoba, Canada, both in the summer. A winter flight from Gimli is the next scheduled. The Palestine and Gimli data are currently being reduced.

AL

A cryogenic-trapping/flame-ionization gas-chromatographic system is being tested for atmospheric sulfur compounds. Laboratory tests are complete and the first field

trials are under way at the Niwot Ridge site. The initial aim of this study is to assess the clean-air and polluted levels of gas-phase sulfur in relation to levels of precipitation in the mountain area.

A state-of-the-art diode-array detector is in the process of being incorporated into a monochromator-computer system. Initial tests are in progress and the necessary changes that these have identified are being made. When this system is operational for field use, it is expected to provide absorption measurements of atmospheric species like NO_2, NO_3, and SO_2 with heretofore unobtainable quality.

As a continuation of the tropospheric NO and NO_2 study described above, a new NO-NO_2 aircraft instrument is being designed, in collaboration with the National Center for Atmospheric Research (NCAR). NASA will sponsor ground-based and flight intercomparisons of NO instruments in 1983. Participation in these intercomparisons is the first phase of a measurement program aimed at understanding the tropospheric distribution of NO and NO_2 and their roles in ozone production.

A dual-column ion chromatograph was acquired as part of a study of precipitation chemistry and gas-phase HNO_3 chemistry. The Atmospheric Sampling program's previous measurements in this regard used a single-column chromatograph at Colorado College. Now, a special laboratory has been set up for these analyses and the necessary supporting clean-area facilities were added.

The existing ultraviolet absorption ozone instrument will continue to be part of the NO-NO_2 stratospheric balloon package. Furthermore, it and the H_2O instrument will be used to provide information about the microstructure of these stratospheric species. Lastly, this ozonesonde is being compared with the chemical ozonesondes that are currently being used in ozone monitoring. Joint balloon flights have been made, and others planned, with ARL's Geophysical Monitoring for Climatic Change Division.

An ultraviolet excimer laser is being explored as a detector for hydrogen peroxide (H_2O_2), using photofragment fluorescence. H_2O_2 is thought to be a major oxidant of SO_2. Currently, there is no way to detect H_2O_2 reliably in the gas phase.

In the course of the ion chromatographic analysis of filter-collector atmospheric samples and precipitation samples, an unknown ion was observed. Further study showed the ion to be oxalate. Mixing ratios up to 50 pptv were observed in the atmosphere and 0.3 ppm in the precipitation. The relation of this acid to urban pollution is to be examined.

A new technique is being developed for the detection of a variety of atmospheric nitrogen compounds. It was discovered that carbon monoxide (CO) and a gold surface can convert many of these compounds to one that is readily detected. This method promises to afford more sensitive and more rapid measurements than were heretofore available.

ATMOSPHERIC WAVES AND TURBULENCE THEORY

This program is devoted to theoretical studies of turbulence, waves, and eddy transport in the atmosphere. These phenomena are basic to many areas of geophysics, including meteorology, climatology, pollution dispersal, oceanography, space physics, and aeronomy. The program is directed toward problems that are timely and challenging.

Wave and turbulence fluctuations are present in vast regions of the atmosphere because the natural state of the atmosphere is often locally unstable. Such fluctuations have a striking effect on transport of pollutants and have been intensively

observed over the past two decades. However, because of notorious mathematical and conceptual difficulties, there were no theories of turbulence and nonlinear wave interactions available to determine the strength of these fluctuations and how they influence pollution dispersal and meteorology. The development of such theories has become a principal concern of this program during the past decade.

Accomplishments FY 1982

The Atmospheric Waves and Turbulence program has (1) initiated a major program to develop and improve equations used for modeling turbulence in the atmosphere, and for pollution studies and other engineering applications; (2) calculated the diagonal pressure-velocity correlations needed for such models; (3) derived a formulation to predict the average energy dissipation rate in the troposphere; (4) derived a formula to predict the kinetic energy of CAT (clear-air turbulence) from measured eddy dissipation rates; (5) developed a nonlinear theory of shear instabilities in the atmosphere; (6) applied a comprehensive theory of stably stratified flows to determine turbulent diffusion in the ocean and atmosphere; and (7) developed the theory of momentum deposition and friction caused by gravity waves in the middle atmosphere.

Plans FY 1983

The following studies of turbulence in the atmosphere are planned:

- To develop a reliable turbulence model of the planetary boundary layer by applying contemporary turbulence theory from first principles. This year's goal is to calculate the influence of stable stratification on the pressure fluctuation terms, to show why the fundamental hypothesis of "return to isotropy" cannot be applied to atmospheric turbulence modeling, and to calculate the realistic deviations from isotropy.

- To explain theoretically, and to calculate, the apparently universal spectrum observed for vertical scales of fluctuations in oceans and the atmosphere.

- To determine the relations between dissipation rate, kinetic energy, and vertical diffusion for thin turbulence layers in the clear atmosphere, i.e., CAT.

- To develop a theory that explains and predicts the puzzlingly slow decay of stably stratified turbulence found in the oceans, the atmosphere, and laboratory experiments.

- To apply the pressure strain rate theory to the boundary layer model currently used by NEPRF (Naval Environmental Prediction Research Facility). The NEPRF facilities will be used to test and expand the theory. A liason has been set up with NEPRF for this purpose.

Planned studies of gravity waves include continuation of the modeling of eddy diffusion and friction from 30- to 100-km altitude, coupling of the troposphere to the mesosphere, the influence of gravity waves on the mean flow, the role of tidal waves in atmospheric diffusion, and the interaction of gravity waves with airglow and minor atmospheric constituents.

AL

In addition, new insights into the importance of gravity wave heat flux and Rayleigh friction in the middle atmosphere will be developed. The heat flux studies will be in collaboration with the Optical Aeronomy program.

OPTICAL AERONOMY

The Optical Aeronomy program uses optical measurements of the atmosphere as a tool for studying fundamental processes such as energy balance, composition, and dynamics. Major attention is now given to measurements bearing on the composition and dynamics of the lower atmosphere, principally the troposphere and stratosphere, although important problems in the upper atmosphere continue to receive some attention.

Accomplishments FY 1982

Studies of stratospheric NO_2 by absorption spectroscopy have continued, with increasing emphasis on the influence of transport. Dramatic changes in NO_2 content accompany breakdowns of the stratospheric polar vortex, such as those associated with sudden-warming events. In the summer and fall of 1982 the stratospheric dust cloud arising from a volcanic eruption in Mexico produced even more dramatic changes in stratospheric NO_2, which we continue to monitor.

A 5-yr study of stratospheric NO_3 was completed. The behavior of NO_3 presents many puzzling anomalies in both its seasonal and latitudinal variation. Our studies of NO_3 in the troposphere exhibit equally unexpected anomalies. Since NO_3 is a key intermediate species in the chemistry of nitrogen oxides, it follows that its curious behavior indicates a notable deficiency in the present understanding of this chemistry.

Stratospheric OH measurements have continued and now reveal a clear solar-cycle dependence of the abundance.

The Solar Mesosphere Explorer (SME) satellite has been returning data since the fall of 1981. Our involvement in this project is through the instrument that measures NO_2 in both the stratosphere and troposphere, and we are participating in analysis of the data. It is already clear that the global structure of stratospheric NO_2 is essentially what we found earlier using ground-based methods, but the wealth of detail now available will doubtlessly lead to many new findings.

High-resolution interferometric studies of thermospheric winds and temperature have continued. A collaborative program with the University of Alaska and the University of Michigan is now under way, providing a chain connecting middle and high latitudes. A major step forward has been the development of a powerful new interferometric technique, known as TESS (Twin Etalon Scanned Spectrometer), which greatly enhances the ability to measure weak airglow emissions at high resolution and has permitted detection of vertical motion in the thermosphere.

Plans FY 1983

The effect of the volcanic cloud upon stratospheric NO_2, NO_3, and OH will be studied both from the ground and in conjunction with the SME satellite.

Prior to the volcanic eruption, the SME satellite had secured a half year of stratospheric NO_2 measurements; we expect resumption of such measurements as the cloud dissipates. These measurements will be studied for some years to come, both for the interest in the chemistry of NO_2 as well as its role as a tracer of large-scale dynamics in the stratosphere.

Tropospheric studies will be expanded using the long-path-absorption facility at the Fritz Peak Observatory. We expect new instrumentation to extend the sensitivity of measurements to much lower levels of concentration than hitherto measurable, particularly for NO_2 and NO_3.

High-resolution measurements of winds and temperatures in the upper atmosphere will continue with a major improvement brought about by the new instrument, TESS.

THEORETICAL AERONOMY

The objective of the Theoretical Aeronomy program is to undertake theoretical studies of important atmospheric problems, to construct and utilize computer models of the chemistry and dynamics of the atmosphere, and to analyze atmospheric data collected within the Laboratory or by collaborative experiments. The ultimate goal of the program as a whole can best be described as to attain an understanding of the composition, dynamics, and energy budget of the atmosphere that is sufficiently detailed to enable accurate predictions of future trends. In recent years the principal concern has been with problems related to the minor-constituent composition of the stratosphere and mesosphere (the middle atmosphere), deriving largely from the widespread practical concern with stratospheric ozone and its potential depletion by artificial pollutants. More recently, however, the activities of the group have expanded to include investigations of the problems of tropospheric chemistry and of tropical atmospheric dynamics. These newer areas are expected to grow in future years, in parallel with corresponding growth and shifts of emphasis in the experimental programs of the Laboratory. Most of the program's projects are developed and carried out in close collaboration with the Laboratory's experimental programs, or with other atmospheric research groups outside of the Laboratory, including at present those at GFDL, NCAR, and the University of Colorado. These outside links are essential to the objectives of the program, and will be maintained and strengthened where possible in future years.

In addition to its own projects, an important function is that of providing assistance to other Laboratory programs on problems that require advanced computer programing techniques. This direct service function provides further coupling between this program and the more experimental side of the Laboratory.

Accomplishments FY 1982

Tropospheric ozone has been one of the major research subjects of the Laboratory in recent years, since it plays a vitally important role in tropospheric chemistry and is itself a direct health hazard. Determination of the relative importance of the two potential sources of tropospheric ozone--transport from the stratosphere and local photochemical production--is one of the most important challenges in this area. The Theoretical Aeronomy program is involved in three areas of tropospheric ozone research:

- Collaboration with the Atmospheric Sampling program on initiating and interpreting measurements of O_3, NO_x, HNO_3, and $SO_4^=$, with emphasis on the measurement program at Niwot Ridge.
- Collaboration with GFDL on modeling tropospheric ozone and NO_x distributions with a full three-dimensional general circulation model.
- Studies of the photochemistry of O_3, NO_x, and hydrocarbons, with a box model and a two-dimensional model.

AL

The observational evidence that supports photochemical control of tropospheric ozone was investigated, and it was shown that significant photochemical production can occur at Niwot Ridge in summer. This happens during upslope conditions when ozone precursors such as NO_x and hydrocarbons are transported to Niwot Ridge from the Denver metropolitan area. The model predicts that the ozone mixing ratio should increase with that of NO_x until the latter becomes greater than 2 ppbv. For higher NO_x mixing

ratios, the ozone production rate should decrease because of the increased destruction of OH radicals by the reaction of OH with NO_2. The observed variation is in qualitative agreement with the predictions, but the model calculations tend to underpredict the ozone abundance. This is probably due to the neglect of nonmethane hydrocarbons in the present model.

The finding that maximum O_3 occurs at about 2 ppbv of NO_x may have important implications for summer O_3 levels in rural areas. With the large emissions of NO_x in the eastern United States, NO_x mixing ratios of this magnitude may be common. Tropospheric NO_x not only plays a critical role in the photochemistry of ozone and odd hydrogen but also contributes significantly to acid deposition in the northeastern region of the continent. The oxidation rates of NO_x to HNO_3 and NO_3^- by rain and snow are important processes in acid deposition. We were able to deduce these rates by the combined use of modeling and measurements at Niwot Ridge.

The photochemistry of the stratospheric ozone layer and its possible perturbation by anthropogenic activities continue to be the center of extensive research studies. The most recent model studies show large, nonlinear column ozone perturbations with increases in stratospheric chlorine content. The present Cl_x level of about 1.5 ppbv is too low to produce a perturbation that is greater than the measurement uncertainties, but substantial depletions are expected to occur for Cl_x mixing ratios of several parts per billion by volume.

Photochemical processes in the middle atmosphere have been explored through the use of two-dimensional models of the stratosphere, mesosphere, and lower thermosphere. Two different models were employed for this purpose. The first of these had previously been used to study the production of NO in the lower thermosphere, and its transport to the mesosphere and stratosphere. The resulting NO distribution exhibits considerable seasonal and latitudinal variation. Since photoionization of NO provides the principal source of ions in the quiet D region, these variations could have important consequences to the ion composition of this region. These effects were explored in detail, and it was shown that the smooth winter anomaly in D region electron density can be simulated in our model. One of the major uncertainties in calculating thermospheric NO densities is the lack of information about the relative yield of excited nitrogen atoms from N_2 dissociation. Laboratory studies do not appear to be consistent with atmospheric observations regarding this question. The possibility has been suggested that translationally hot nitrogen atoms may play a role in this discrepancy.

We have also examined the chemistry of silicon ions in the lower thermosphere. Silicon ion abundances can be used to infer water vapor densities near 100 km, and at present this provides the only available means of estimating water vapor densities at such high altitudes. These inferred abundances were compared with model calculations, and implications for atmospheric transport were explored.

The second two-dimensional model was developed in collaboration with NCAR scientists. The model provides a numerical simulation of both the photochemical and dynamical properties of the middle atmosphere. In most stratospheric models, the net flow is the result of a partial cancellation of large eddy and mean advective terms. Eddy motions are approximated by eddy diffusion coefficients, which are not well known, and the resulting transport properties are therefore subject to considerable uncertainty. Our model uses a residual Eulerian circulation, which eliminates the need for this cancellation. Provided that wave perturbations to the zonal flow are steady and dissipationless, this is equivalent to a Lagrangian description of transport, and represents a first approximation toward a realistic representation of stratospheric transport. The model has been used to calculate the distributions of long- and short-lived stratospheric species, and the results have been compared with observations. This model also has been used to study the distribution of NO_2 in the high-latitude stratosphere, using new temperature-dependent cross sections for N_2O_5 photolysis. The use

of these photolysis rates and our residual circulation both strongly affect the calculated NO_2 distribution, which has been compared with observations of NO_2 column amount at various latitudes and seasons. Many previously unexplained features of the observed distribution, including the observation of very low NO_2 abundances at high latitudes in winter, are consistent with our model calculations.

Cooperative work with University of Colorado and NCAR scientists on the SME satellite has continued. Model distributions of O_3 in the mesosphere have been compared with the satellite observations as a function of latitude and altitude. This comparison is being used to infer information about the photochemistry of O_3, which should be applicable to both the mesosphere and stratosphere. Observations of changes in mesospheric O_3 during the solar proton event of 13 July 1982 are being compared with model calculations. This provides a test of our understanding of O_3 photochemistry under perturbed conditions.

Work has continued on investigating the influence of solar radiation on the tropical tropopause, a collaborative effort with the Atmospheric Dynamics program. Radiosonde measurements made at a number of tropical Pacific stations were analyzed for 1952-1969 and have revealed that temperatures at the base of the stratosphere (40-80 mb pressure) vary annually in antiphase with mean tropospheric temperatures as deduced from height variations of the 100-mb surface. At higher levels in the stratosphere (10-30 mb) there is a tendency for the variation to return toward the phase of the tropospheric variation. These features are also apparent in the interannual variations: years of high average tropospheric temperature tend to have low temperatures at the base of the stratosphere, and vice versa. The interannual variability is small but statistically significant, since the number of data points used is large.

This behavior is consistent with the concept of tropospheric heating through the release of latent heat in deep cumulus convection, accompanied by adiabatic cooling in the lower stratosphere forced by the same convective source. Tropospheric heating and lower stratospheric cooling thus go together, with a tendency to return toward radiative control at higher levels in the stratosphere.

Radiosonde data from the same Pacific stations have now been obtained through 1980, and analysis of the interannual variability is being extended to include the full 30-yr period, 1951-1980. This should show whether or not the apparent correlation between tropical tropopause height and the solar cycle that was evident in the earlier data has extended to recent years, and may point out other possible causes of interannual variability. The link with such other tropical ocean-atmosphere interaction phenomena as El Niño and the Southern Oscillation is being explored.

In another collaborative effort with the Atmospheric Dynamics program, a theoretical study of the influence of electric fields on the drift motions of turbulent irregularities in the upper mesosphere has been completed. Echoes from these irregularities are commonly recorded by the Poker Flat (Alaska) MST radar, and their Doppler velocities can be assumed to give the local wind vector if no other factors are involved. At these altitudes, however, the radar scatter is provided by small-scale irregularities in plasma density, and plasma motions are influenced by electric fields, which can reach substantial magnitudes near the auroral zone. The conclusion of the study is that electric-field effects on horizontal motions can generally be neglected at heights below 100 km except during intense auroral substorms, but attempts to measure the small vertical components of the wind at high latitudes may be seriously affected throughout the upper mesosphere.

AL

Plans FY 1983

Tropospheric ozone and its possible perturbation by anthropogenic activities will continue to be one of the major subjects of our research. Important problems in this

area are the photochemical production and destruction of O_3; the transport of O_3; the distribution of tropospheric NO_x, OH, and RO_2 radicals; and the effects of nonmethane hydrocarbons. We will continue to study these problems by working closely with the Atmospheric Sampling program and the Atmospheric Chemical Kinetics program. Collaboration with scientists at GFDL on three-dimensional modeling will be strengthened in both stratospheric and tropospheric modeling.

Studies of the acid deposition problem will be expanded. Emphasis will be on atmospheric transformations of SO_2 and NO_x, heterogeneous processes, and natural emissions of sulfur and nitrogen compounds. Developing a regional acid-deposition model for the Colorado Front Range is a long-range goal for this group. The model will be very useful for interpreting the data at Niwot Ridge and for designing other measurement strategies. It will consist of a mesoscale meteorological model and a photochemical model. It is clear that such a model can be readily applied to study the regional oxidant problem such as that of rural O_3. This model will be developed in collaboration with scientists at NCAR.

Our understanding of photochemistry of O_3 in the lower stratosphere is still inadequate. Possible perturbations of stratospheric O_3 by chlorofluorocarbons and NO_x emissions depend critically on what happens in the lower stratosphere. Joint efforts involving atmospheric chemical kinetics, atmospheric sampling, and modeling are essential in making progress in this area.

The ion and neutral chemistry of the middle atmosphere will continue to be a subject for theoretical study. The production and transport of NO in the thermosphere and its possible effects on stratospheric O_3 should be studied in more detail. The ion chemistry of the D region after solar proton events will also be examined. More complete photochemical, radiative, and dynamical processes should be included in the residual Eulerian two-dimensional model. These include the effects of turbulence induced by gravity and planetary wave breaking, for example. The zonally averaged fields provided by this model can also be used as convenient initial conditions for three-dimensional model studies of the transport of photochemical constituents.

Study of the interannual variations of tropical tropopause height will be continued using more recent data in collaboration with the Atmospheric Dynamics program. If possible, data from tropical locations other than the Pacific Ocean sector will be used to determine the global character of the more recent interannual variability. The Pacific data will also be compared with existing sea-surface temperature data to establish the proposed link between sea-surface temperatures, convective activity, and the height of the tropopause.

The influence of a varying tropopause temperature on the radiative balance of the Earth-atmosphere system will be investigated. Current ideas suggest that the entry of water vapor into the stratosphere is controlled by the temperature of the tropical tropopause, and that the amount of stratospheric water vapor is important for chemical and radiative balance in the middle atmosphere.

Studies of the mesospheric echoes recorded by the Poker Flat MST radar will also continue in collaboration with the Atmospheric Dynamics program. The radar data will be used to look for the predicted electric-field effects, and to attempt to determine the variability of 3-m turbulent power in the 60- to 80-km height range in the atmosphere during winter. The onset of these echoes at sunrise and their disappearance at sunset will be investigated with the use of a steady-state, one-dimensional ion chemistry model of the mesosphere. The same model will be used to study the twilight variation of polar-cap absorption recorded by high-latitude riometers during solar proton events. Riometer data from several high-latitude stations in Greenland and northern Europe during some recent solar proton events have been obtained from the Danish Meteorological Institute, and will be used in the study.

SPACE ENVIRONMENT LABORATORY
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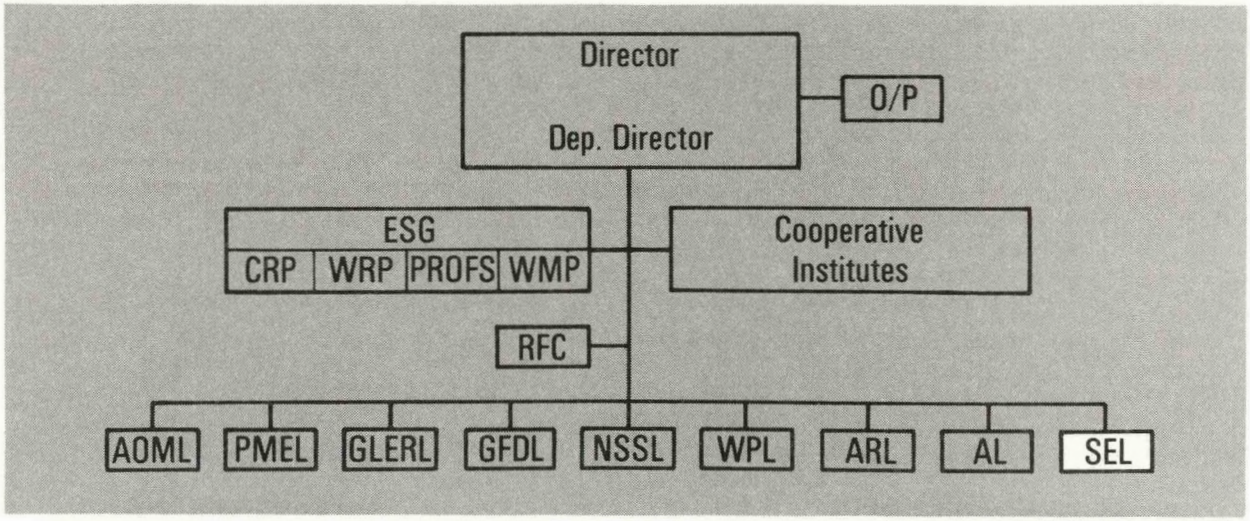

The Space Environment Laboratory provides real-time space environment monitoring and forecasting services, develops techniques for forecasting solar disturbances and their subsequent effects on the Earth's environment, and conducts research in solar-terrestrial physics in support of its services mission. The Laboratory also provides ERL with expertise and advice concerning satellite instrumentation and interface techniques in solar-terrestrial physics.

SEL had three divisions in FY 1982: Research, Support, and Services. The Research Division consisted of Sun/Interplanetary Physics, Magnetospheric Physics, and Atmospheric-Ionospheric-Magnetospheric Interactions Branches; the Support Division consisted of Numerical Analysis and Instrument Development Branches; and the Services Division consisted of the Real-Time Data Services (RTDS) and the Space Environment Services Center (SESC).

In FY 1982 a number of significant events occurred that affected the Laboratory program and presaged dramatic changes in FY 1983 and beyond. At the start of the year, the Ionospheric Research activities were terminated, and at the end of the year, the Solar UV Research group transferred from SEL to the Geophysical Monitoring for Climatic Change Division in ARL.

In the second quarter of FY 1982, Dr. Leinbach became Acting Director of SEL succeeding Dr. Williams who accepted a position at Johns Hopkins Applied Physics Laboratory. Rumors of possible budget cuts were confirmed by the annoucement on 8 February 1982 of the President's budget for FY 1983. Studies showed that the proposed budget would be inadequate to continue the essential space environment services provided by SEL, that all research would have to cease, and that the plans for updating the Space Environment Laboratory Data Acquisition and Display System (SELDADS) could not be implemented. SELDADS is the computer-based system vital for maintaining the real-time space environment data base.

Congress, in passing the Continuing Resolution for FY 1983, restored SEL funds to the FY 1982 level, forestalling the consequences of a reduced budget for a year. Consequently, SELDADS II procurement was able to proceed on schedule, and no reductions

in services were necessary. Following a request from the ERL Director, the research program in SEL was restructured to more directly support the space environment services activities in the Laboratory.

As a direct result of the proposed budget cuts, the interagency Committee on Space Environment Forecasting, of the office of the Federal Coordinator for Meteorological Services and Supporting Research, was reactivated and charged with formulating a National Plan for Space Environment Services and Supporting Research. This plan will be finished in mid-1983.

RESEARCH DIVISION

Accomplishments FY 1982

The aim of the Research Division in FY 1982 was to conduct research into phenomena that affect the solar-terrestrial environment. This involved understanding emission of radiation from the Sun, the propagation of energy through the solar wind, the interactions between the solar wind and the Earth's magnetosphere, the ionosphere, and the upper neutral atmosphere.

SUN/INTERPLANETARY PHYSICS

The principal activity in this Branch was the development of time-dependent, multidimensional models of the solar wind and interplanetary magnetic field. The near-term goal was to use these models with available real-time solar data as input and to make verifiable predictions of geomagnetic occurrence, severity, and duration.

Solar Wind Physics

As part of an extension of the magnetohydrodynamic (MHD) model to incorporate additional plasma physics, equations with higher moments were formulated for the effects of nonzero relative-flow velocities and skewing of velocity distribution functions of various species (protons, electrons, helium, etc.) in the solar wind. These effects are believed to be important in the presence of strong temporal and spatial gradients in the interplanetary medium. A paper was prepared that explicitly provides equations, based on the closure of the moment equations, for the transport properties (viscosity and thermal conduction) of the solar wind.

The nonplanar, two-dimensional, MHD solar wind model was successfully put into production on the NOAA Cyber 750 computer. Additional work was done to provide the full description of solar-flare-generated interplanetary shocks under simulated conditions of variable flare power output. It is now possible to predict the solar wind energy flux at the Earth, given a reasonable set of near-Sun observations.

The two-dimensional MHD model of coronal transients was used, together with observational X-ray inputs provided for the Solar Maximum Year/Study of Traveling Interplanetary Phenomena (SMY/STIP) event of 29 June 1980 (1821 UT) by NASA's Solar Maximum Mission (SMM), to simulate major features of the ensuing coronal transient observations. Nearly the full gamut of SMM instruments (HXIS, XRP, UVSP) was used to assess the flare pulse's temperature, density, and velocity for our mass ejection pulse. The model's temporal output was compared with Fort Davis' Type II sweep frequency record and the Mauna Loa K-coronameter's white-light observations. The comparison provided valuable insight for future flare ejection simulations that ultimately must be coupled with our interplanetary MHD model.

Solar, spacecraft, and interplanetary scintillation data were accumulated for the very active period of August 1979 when solar activity was characterized by a well-observed series of solar flares and coronal holes. These data will be used as a case history for testing the capabilities of the MHD models to predict solar wind and geomagnetic variations.

Fundamental work was also done to elucidate the hydromagnetic forces that act on a flux tube immersed in the solar atmosphere. The new theory developed will shed some light on the mechanism for filament disappearance, which is a class of important occurrences in the experience of SEL/SESC and is empirically used to alert to the possibility of geomagnetic disturbances.

A new method of solving MHD equations (using Schrodinger equation formalism) was applied to models of sunspots, prominences, coronal transients, coronal loops, and the global structure of magnetic fields in the solar system. The most important physical results appear as relations between the magnetic structure and thermodynamical parameters such as temperature, gas pressure, and density. For transients, self-similar, time-dependent MHD solutions are obtained.

The global steady coronal structure was successfully modeled with a new numerical simulation allowing a considerably more flexible survey of the parametric dependences than ever before. This work shows how to incorporate a realistic description of energy transfer in the corona. Utilizing this analysis, the model was then employed to study the damping effects of energy transfer on coronal motions.

The Laboratory has arranged with the Stanford Solar Observatory to transmit raw solar magnetic field data by telephone daily and to plot these data in formats of potential use for real-time operations. For example, false color plots have been made showing the global distribution of magnetic fields on the Sun.

About 200 ISEE-3 (International Sun-Earth Explorer) data pool tapes were compressed onto 7 archive tapes, to make them available for verification of model forecasts (hindcasts) of solar wind conditions at the Earth. These tapes will also be used in comparative studies of sudden-commencement-occurrence versus shock observations in front of the Earth, and to analyze the most useful energy input parameter derived from the solar wind for the purposes of SESC users.

A program in connection with the proposed X-ray imager instrument was developed to construct synthetic images using the diode array point response function that has been measured in the Laboratory. This will permit an analysis of observational limits for coronal holes and other features during flares and erupting filaments.

Solar Soft X-ray and UV Radiation

An analysis of nearly 5 years (1977-1981) of soft X-ray data indicates that daily background X-ray flux is an excellent index for intermediate and long-term solar variability (i.e., 3-6 months and 11 years).

Work to corroborate the UV enhancement observed by Nimbus-7 in late 1979 has centered on acquisition and processing of ground-based, UV measurements since the study began in July 1982. Data from the South Pole (ARL/GMCC measurements at Amundsen-Scott Station) and from five New York sites (New York Department of Environmental Conservation sites at Poughkeepsie, Whiteface Mountain, Rochester, Scottsville, Eisenhower Park, Schenectady, and Mamaroneck) have been obtained for the period of interest, and are in the process of being analyzed.

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A model of the solar spectral irradiance, which used ground-based observations of the CaII K chromospheric emission, was developed for UV wavelengths between 140 and

200 nm and for the Lyman alpha emission at 121.6 nm. In this model, the active regions that are bright in CaII K emission (plage) are assumed to be also regions of enhanced UV emission. Recently, the model was extended to the middle UV wavelengths between 200 and 300 nm. The solar backscattered ultraviolet (SBUV) experiment on the Nimbus-7 satellite has observed a definite 27-day variability at these wavelengths, and the model has been used to predict, from these short-term data, the variability over the 11-yr solar cycle.

MAGNETOSPHERIC PHYSICS

Studies in magnetospheric physics included experimental and theoretical investigations of the geomagnetic field and the several particle populations within the magnetosphere, and the dynamics of the complex electromagnetic processes by which the particles interact. This involved analyses of satellite data sets obtained both from research and operational satellites.

Among the significant changes that were made, as part of the program of reevaluation and redirection of the Laboratory, is that the Laboratory will no longer be involved with the NASA-sponsored OPEN (Origin of Plasmas in the Earth's Neighborhood) multisatellite program, and that all involvement with the program was transferred out of NOAA. Consistent with that same de-emphasis of scientific satellite research, a concomitant reduction was made in research associated with the highly successful ISEE (International Sun-Earth Explorer) program. Previous reports had elaborated on some of the substantial scientific achievements resulting from that program. Two years of reduced, high-quality ISEE magnetospheric particle data will remain in the Laboratory as a companion resource to currently acquired operational data.

The Magnetospheric Physics Branch conducted experimental and theoretical investigations comprising studies of the geomagnetic field and the several particle populations within it, and the dynamics of the complex electromagnetic processes by which the particles interact. Emphasis was placed on analysis of satellite instrumentation data sets, obtained from both operational and research satellites.

Multisatellite studies of magnetospheric processes continued with initial efforts directed toward an exploitation of particle data from the NOAA/TIROS (Television and Infrared Observation Satellite) series of low-altitude, polar-orbiting operational satellites. Preliminary studies have shown that polar cap precipitation events are closely associated with the arrival near the Earth of interplanetary shocks propagated from the Sun. These shocks are responsible for producing geomagnetic disturbances at the Earth. This association of polar cap precipitation and consequent geomagnetic storms raises an exciting potential for monitoring and possibly forecasting an impending geomagnetic disturbance from the TIROS platform. This potential will be evaluated. Further, although the present solar cycle has not produced major solar cosmic ray events, a sufficient number of events have occurred during the last several years of data acquisition in which initial studies of the latitude dependence of geomagnetic cutoffs have been possible. The magnetic field of the Earth serves to shield the lower latitudes of the Earth and its atmosphere from the total impact of energetic particle radiation produced sporadically in solar active regions. The importance of determining cosmic ray cutoffs is that they define the latitude range and extent of radiation hazard to satellite instrumentation and to crewed space activity during larger solar cosmic ray events.

Effort was also initiated toward better organizing and addressing the issue of quality control and verification of the operational data provided to SESC in this Laboratory. A task group was formed with the responsibility of systematizing and documenting procedures to enhance and certify the quality of the GOES (Geostationary Operational Environmental Satellite) particle, X-ray, and magnetic field data that constitute an important part of the SESC data base and output.

Theoretical supporting research on magnetospheric dynamics continued to be aggressively pursued. Energy transfer from the solar wind into the magnetospheric system was one of the principal questions addressed. Through imaginative modeling, Laboratory scientists have determined for the first time a process by which solar wind energy is electrodynamically transferred to particle populations in the interior of the magnetosphere. This process appears to extract about 2%-10% of the energy of the solar wind impinging on the magnetosphere, which is of the order of magnitude of the energy required to maintain the magnetospheric system, and may therefore represent the principal means of energy transport into the system. The resulting energized-particle population may then also form the primary source of the ring current, which is responsible for global geomagnetic variability.

Other studies were concerned with defining the morphology and composition of resident magnetospheric populations, to help establish a baseline or reference magnetosphere for providing a context or reference within which to better recognize disturbances and departures from "normalcy" and to understand the geophysical consequences of these departures.

ATMOSPHERIC-IONOSPHERIC-MAGNETOSPHERIC INTERACTIONS

The objectives of research in the Atmospheric-Ionospheric-Magnetospheric (A-I-M) Interactions Branch were to understand the transfer of energy (in the form of both electrical and mechanical) from the Earth's magnetosphere into the upper atmosphere and to understand and characterize the various consequences that may arise in the Earth's ionosphere, atmosphere, and sea level environment because of this energy input.

A major effort during 1982 continued to be the analysis of the total energy flux observations made by the Space Environment Monitor (SEM) flown on board the NOAA/TIROS series of polar-orbiting spacecraft. The total energy detector (TED) on the SEM monitors on a regular basis the energy flux carried into the polar atmosphere by incident auroral particles (both electrons and protons) over the energy range up to 20 keV.

The objectives for performing these measurements were twofold. First, measurements of the magnitude, location, and extent of the auroral particle energy influxes provide an excellent guide to the general level of geophysical activity, which is of immediate use to SESC. These measurements may also be used as inputs to calculations of parameters, such as atmospheric densities, which may be of direct use to the customers of SESC's services. Second, because the energy input to the atmosphere above 90 km by auroral particles is a major source of energy to that region, and thus dominates the dynamics of the polar upper atmosphere, it was believed that long-term, continuous measurements of this parameter would be of great value in the study of the response of the upper atmosphere to this energy input.

At the present time, 6 years of energy flux measurements obtained from three satellites have been assembled into a condensed and easily accessible data base. This data base has been used both in statistical studies of the pattern of the auroral energy input and in the development of techniques and algorithms for use in SESC. The data base was used to prepare maps of the local energy flux into the atmosphere as a function of magnetic latitude and magnetic local time for four levels of magnetic activity (quiet, unsettled, active, and storm conditions). These maps, each of which contains data from as many as 15,000 individual satellite passes, confirm and quantify the increasing magnitudes and physical extent of the energy input as well as the systematic equatorward shift of the boundary of the energy input with increasing magnetic activity. The NOAA/TIROS satellites sample the auroral regions differently during the course of the universal day so that the energy observations display a daily variation even during periods of a constant level of magnetic activity. The existence of these

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statistical maps, which cover virtually the entire polar region, have allowed the determination of empirical normalizing factors that can be used to remove (on a statistical basis) the universal time and interhemispherical dependences in the total energy flux observations.

In particular, this technique removes these dependences from the calculation of the estimated hemispherical power input to the atmosphere, which has been proposed as a polar activity index to be calculated by SESC as the observational data arrive in near-real time. Preliminary work by SESC personnel has shown that the hemispherical power input index correlates extremely well on a daily basis with the magnetic AE index (derived using data from auroral zone magnetometer stations), which has hitherto been accepted as the best available polar activity index. If the correlation is equally good on a short time scale, it will be possible for SESC to provide an AE-like activity index in near-real time rather than with the 2- to 3-yr delay that now exists in the compilation of that index.

The data base was also used to develop an algorithm that identified the location of the equatorward boundary of auroral precipitation and, through a look-up table, inferred a corresponding numerical Q-activity index from that location. SESC has adapted the algorithm to operate on NOAA/TIROS data as they are received at SELDADS and to compute the Q-activity index, which is then forwarded to the Air Force (Global Weather Central) for use as an input for their ionospheric model.

A-I-M personnel participated in the "Satellite Drag Workshop" that was held in Boulder. This meeting brought together scientists in the atmospheric community, SESC personnel, and those responsible for the day-to-day operation of satellites that are sensitive to variable atmospheric drag. This meeting led to preliminary work directed toward an algorithm that would manipulate the NOAA/TIROS TED data to give a characterization of satellite drag effects during periods of magnetic activity that is better than that given by the K and A magnetic indices currently used. The results of the preliminary work were encouraging.

In addition to the above research, which to a large extent was driven by a desire to ensure that NOAA/TIROS data were useful to the Services Division of SEL, a number of collaborative research projects, which involved these data, were pursued with scientists from other institutions. Throughout the first 6 months of FY 1982, NOAA/TIROS data were routinely extracted and sent to Stanford Research International to facilitate comparisons with data obtained by its incoherent scatter radar at Chatanika, Alaska. This radar was closed down in March and transferred to a site at Søndre Strømfjord, Greenland. When the radar becomes operational at the new site, routine extraction of the satellite data will begin anew.

Other scientific collaborations involved the study of specific events or short periods of time. NOAA/TIROS data were exchanged with groups at the University of Munster, Germany (analyzing the results of the energy-budget rocket program conducted in Scandinavia in 1980), the University of Bergen, Norway (researching the origin of stable auroral red arcs), the University of Alaska (modeling the effects upon the atmosphere of the great magnetic storm of 12 April 1982), Lockheed Research Laboratory (conducting a specific intercomparison with data from other spacecraft), NCAR (modeling the effects in the atmosphere of auroral energy deposition), Utah State University (researching the data to extract characterizations of auroral activity of use to SESC), Goddard Space Flight Center (comparing with data obtained from a series of rocket flights), and many others including the Aeronomy Laboratory of ERL. One of the more interesting results of such collaborations came about from a correlation between NOAA/TIROS total energy flux observations and atmospheric observations made by the Laboratory for Atmospheric and Space Physics (University of Colorado) using the Solar Mesospheric Explorer satellite. These comparisons showed that on a daily basis there was a one-to-one correspondence between the observed density of nitric oxide (NO) at

high altitude in the polar regions and the amount of energy deposited into the atmosphere as measured by the NOAA/TIROS SEM. Because NO enters into a catalytic chemical reaction that results in the destruction of ozone, the correlation is potentially important in understanding the interplay between ozone concentration and atmospheric behavior.

During the past year several new results were obtained from an analysis of ground-based magnetometer observations. A new mathematical formalism was developed for determining the spatial patterns of geomagnetic variations, which was based upon measurements from arrays of magnetometer stations. This formalism permits maps of the geomagnetic disturbance to be drawn by computer and also allows the separation of the magnetic disturbance vector into two components: one associated with the electrical current system in the ionosphere, and the other associated with induced currents flowing in the solid Earth. Unlike any previous technique, this method gives quantitative error estimates for the results, and furthermore, minimizes the magnitude of these errors.

This formalism is being applied to data gathered by a magnetometer chain in Scandinavia (in collaboration with German scientists) to obtain the detailed, time-dependent pattern of the ionospheric current system and its connection to the dynamo region located in the magnetosphere. The work is being extended to study the pattern of Earth currents induced during periods of magnetic activity as well.

Other studies were conducted, using data from magnetometers distributed over the entire Northern Hemisphere, to obtain a global pattern of ionospheric current flow and the connection with the outer magnetosphere. Analysis of these patterns is yielding estimates of the ionospheric electric fields at high latitudes and of the electrical heating of the upper atmosphere during geomagnetic disturbances. The experience gained from these studies is being put to use in a project designed to improve magnetic activity monitoring and forecasting at SESC.

Plans FY 1983

In the fourth quarter of FY 1982, SEL research was redirected to more closely support improvement in the solar-terrestrial services. The objectives of the research program are to investigate those aspects of the solar-terrestrial environment that affect the services provided by the Laboratory to customers using systems that are impacted adversely by solar-terrestrial disturbances. Such systems include, for example, satellite operations, ionospheric radio communications, geomagnetic prospecting, and power distribution networks. The following lines of research will be followed in FY 1983.

SOLAR PHYSICS

(1) Complete the study of the prototype solar X-ray imager and its operational advantages to Services. An operational solar X-ray imager on future GOES satellites could significantly improve the ability to assess solar activity.

(2) Develop an empirical model of coronal production of solar wind, using the Stanford Solar Observatory magnetograms and other operational solar data. This is required to provide solar wind models for analytical forecasting models.

(3) Estimate the shock velocity in the solar corona using operational solar radio data from the Air Force Weather Observatories. Solar radio data provide the best measure currently available in real time for assessing coronal disturbances and energetic particle acceleration at the Sun.

(4) Develop procedures for making long-range (27-day) forecasts of solar activity using synoptic maps of solar activity.

INTERPLANETARY PHYSICS

(1) Investigate the potential of a theoretical model for solar filaments in predicting the eruption of filaments. Mounting statistical evidence points to the clear association of some magnetic storms with erupting filaments on the Sun.

(2) Demonstrate the utility of quantitative MHD models for prediction of effects of solar activity at the Earth. Models of the interplanetary propagation of shock waves have been developed in SEL, with demonstrated capability of forecasting propagation time and shock magnitude, given the input parameters at the Sun. Proposed tests would demonstrate the utility of the model for operational purposes.

MAGNETOSPHERE

(1) Develop techniques for assessing geomagnetic activity using real-time GOES magnetometer data; correlate magnetic disturbances at GOES with ground-level magnetic disturbances; and correlate GOES magnetometer data with ISEE-3 data to study the relation of solar wind disturbances and geomagnetic activity. GOES magnetic data appear to have great potential for assessing and predicting magnetic storm activity. These capabilities remain to be tested for real-time forecasting use.

(2) Analyze polar cap energetic electron precipitation data from the NOAA/TIROS satellite in relation to long-lived perturbations of the OMEGA VLF navigation system. These perturbations can persist for several days, and there is currently no adequate understanding of the source of this anomaly.

(3) Conduct a "proof of concept" study of the potential value of energetic particle data from over the polar caps as a predictor of impending magnetic activity.

(4) Use NOAA/TIROS satellite energetic particle data to establish reliable estimates of the global "cutoff" latitude contours for energetic particles. Cutoff latitudes give a useful measure of the geographical extent of the effects of solar proton events, and are also related to the extent of auroral zone disturbances.

ATMOSPHERIC EFFECTS OF ENERGY DEPOSITION

(1) Implement techniques for generating and displaying maps of auroral zone energy input based on the NOAA/TIROS satellite total energy detector. These are required for quantitative assessment of disturbances in the auroral zones.

(2) Compare NOAA/TIROS satellite energy flux measurements with global magnetic activity. Operational satellite data offer an alternate way to assess the impacts of geomagnetic storms on power distribution systems, communications, and satellite navigation systems. Many users now rely on the conventional geomagnetic indices as input to their models for impact of disturbances. The addition of the satellite energy flux data may lead to an improved description of the disturbances.

SUPPORT DIVISION

The Support Division assists all Laboratory projects in using computers for acquiring and analyzing data through the Analysis Branch and in developing instrument hardware, engineering software, and data systems design through the Instrument Development Branch. Typical contributions to laboratory services are the development of satellite and ground-based instrumentation for SESC data collection and the analysis of data for Services Division products and operational research.

ANALYSIS

The Analysis Branch provides computer programing support to the Laboratory. Members of the Branch combine experience and training in physics, engineering, and mathematics with expertise in the use of computer systems. They provide assistance and advice in these areas to all other Laboratory programs.

Accomplishments FY 1982

The Analysis Branch supported the solar flux and UV radiation research projects by providing computer access to Nimbus-4 and -7 solar flux data, and ground-based solar flux broadband data. The Nimbus-7 data are being analyzed for solar cycle and solar rotation dependencies. Because of missing data, a technique using autocorrelation after quadratic detrending has been developed that has so far proved very successful. It is now being applied to a larger data set.

Archive production began on the NOAA GOES soft-burst X-ray project. Production finished for the solar X-ray summary and continues for the IMS satellite.

Archiving of ISEE-2 satellite, charged-particle data has continued through Day 339, 1981, with copies of the archive tapes being sent to co-investigators in Lindau and Kiel, Germany. A full set of ISEE-1 pitch angle plots was generated on microfilm. Various color displays of ISEE data were made on request. Other cooperating groups were provided copies of the ISEE-1 archive tapes; pitch angle plots; flux, magnetic, and spectral plots (both microfilm and hardcopy); and the documentation. Archiving of IMP-J data has continued into data for 22 February 1982.

The general-purpose compositor (text-formatting) program originally written in SNOBOL was converted to FORTRAN 77 for the Cyber system, and several new features and improvements were incorporated. A new manual was completed. The program was used by SEL to complete the documentation on the new HF radar software and is used by several other groups in ERL for test formatting. The FORTRAN Concordance program was supplied to NCAR where it was used successfully to increase the efficiency of a large climate model program.

Assistance was provided to the Glaciology World Data Center in converting their data base from the OUTFOL (SEL) system on the Cyber to System 2000 on the Rockville Univac. General assistance continues to be provided to the ERL Central Computer Facility. SEL staff routinely assist with the calibration and adjustment of the FR80 microfilm system, and with problems associated with tape systems. An electronic mail program was written for the Cyber and made available for general use.

The terminal equipment available to Support Division staff was upgraded during the year by the addition of six 132-column CRT terminals, three of which also support Plot 10 Graphics. Three of the systems have local dot-matrix printers, making it possible to obtain small amounts of hardcopy conveniently. These systems have proved very successful and have substantially improved our efficiency.

The support of the SEL HF radar system has been completed. The phase-2 software and documentation package will be distributed to all users in October 1982.

The Branch supported the FY-1982 computer procurement by assembling, testing, and distributing benchmark software tapes. It has also supported the SELDADS II request for proposal (RFP) preparation by participation in the Technical Review Committee and Source Evaluation Board activities.

Plans FY 1983

The Branch plans to increase its direct participation in the analysis and archiving of data from the operational SEM aboard the NOAA/TIROS spacecraft. It will continue to support the main SELDADS II RFP and will provide programing assistance to RTDS for the preprocessor system.

INSTRUMENT DEVELOPMENT

The Instrument Development Branch (IDB) provides general support to the Laboratory with instrument hardware, engineering software, and data system design. This support includes involvement throughout the lifetime of a Laboratory program, often beginning with system conceptual development and proposal writing, and continuing through design, fabrication, and test phases. IDB supports in-field deployment or launch operations, which often involves continuing evaluation and consultation during data reduction and analysis. Program management and technical supervision of contractors are provided for larger programs.

Accomplishments FY 1982

OPERATIONAL SPACE ENVIRONMENT MONITORS

In July NASA approved the SEL proposal to fabricate an additional High Energy Proton and Alpha Detector (HEPAD) instrument for the GOES program. Although the group does not normally fabricate instruments for the operational program, in this case there is a substantial government-owned inventory of parts from a previous contract fabrication program. Assembly and testing of one instrument by SEL represents a substantial cost savings over the alternative approaches examined by NASA. The HEPAD instrument is used to provide radiation hazard warnings for high-altitude aircraft during very large, high-energy solar events.

No new launches of GOES or TIROS satellites occurred during the year. Instrument repair facilities have been maintained, and one instrument was repaired during the year.

Support was provided to SEL, NESS, and GSFC on the GOES NEXT specifications for SEM systems. These will be the systems that will support SESC in the period after the present-generation spacecraft are phased out.

SOLAR X-RAY IMAGER FEASIBILITY DEMONSTRATION

A study was made of the critical features of a new instrument for GOES NEXT, which would provide important new information for SESC on the structure of solar activity.

The practical work on this program was completed with the overall optical and X-ray testing of the combined mirror and charge coupled device (CCD) detector system in SEL and at the Marshall Space Flight Center X-ray test facility. In general, the results confirm the design study predictions. The final report is written and will be ready for publication in early FY 1983.

HF RADAR

A small amount of general support was provided to the Brighton-Bootlake facility. The major contribution was completion of the serial data interface system. This

allows the radar computer to switch antenna relays or control other devices at distances up to 1 km. The technical manual is also complete. Negatives are available for all printed circuit boards to permit other groups to copy the system if they wish.

GALILEO ENERGETIC PARTICLE DETECTOR

The time-of-flight (TOF) electronics were completed and supplied to the Applied Physics Laboratory of Johns Hopkins University on schedule. In response to SEL program changes and staff changes, the Branch has withdrawn from any further participation in this program. The delivery of the TOF unit completes our obligations.

SOLAR UV SPECTRORADIOMETER

The Branch provided the Solar UV program with an outline performance analysis and specifications for the electronics of a proposed rocket UV spectroradiometer experiment.

MICROPROCESSOR SUPPORT SYSTEM

During the year the Branch wrote specifications for a set of general-purpose microprocessor systems, which will be used in the Laboratory for scientific and administrative support. These are expected to be delivered in early FY 1983.

Plans FY 1983

OPERATIONAL SPACE ENVIRONMENT MONITORS

The Branch expects to complete most of the fabrication of the HEPAD instrument during FY 1983. Instrument repair and integration support will be continued for the present GOES and TIROS programs. Support will also be provided as required for GOES NEXT program.

SOLAR X-RAY IMAGER, SEL SPECTROHELIOGRAPH, AND SESC IMAGING

Support will be provided as required to the proposals for flight of the X-ray imager. The experience gained with digital image display and CCD technology will be applied to providing a digital image output from the SEL spectroheliograph to make it more useful as an operational tool, and also applied to a general study of SESC image handling.

MICROPROCESSOR SUPPORT SYSTEM

The Branch will provide assistance with program installation and customization. Automation of some Laboratory administrative accounting and recordkeeping functions using DBMS software is planned. If resources are available, the system will be interconnected to a central hard-disk file system.

SERVICES DIVISION

The Services Division provides a variety of services to a growing national and international community of users concerned with the effects of solar activity on the environment. The Space Environment Services Center (SESC) and the Real-Time Data Service (RTDS) jointly constitute the major activity of the United States in solar-terrestrial monitoring, forecasting, and real-time data collection and dissemination. Many of the services are joint activities of NOAA and the U.S. Air Force.

The theme of the year in the Division was to maintain a high level of service to a growing number of users while making major changes to improve efficiency in the use of personnel, to increase the utility and reliability of equipment used in the services operation, and to continue to prioritize services to meet user requirements.

Work on planning and procurement for a new data acquisition and display system, SELDADS II, was a major activity. Both SESC and RTDS personnel developed requirements, served on (and chaired) the Technical Review Committee to draft the major RFP for the system, established benchmarks for system requirements, and defined and procured a preprocessor system that will improve the data going into SELDADS in terms of volume, reliability, and data quality. A major problem that had to be addressed is that the current SELDADS was developed primarily as a data collection and storage system. Significant display capability was added only after the fact, and little user planning or analysis of user requirements went into the current user software. A major effort in planning SELDADS II has been in establishing user requirements and providing for them in a systematic way.

The definition of SELDADS II user requirements has been complicated by SESC being a relatively new operation that has grown rapidly in terms of users, data sources, and products. Until this year, no system had been established for documenting or standardizing the operation. Much of the basis for the operation was passed from forecaster to forecaster as a kind of folklore. Planning begun the previous year culminated in 1982 in adoption of a product review process as a management tool to gradually, but systematically, impose order on the present operation. The process, adapted from developments in the data processing world, prescribes an orderly review process where users, providers (e.g., scientists developing improved services), and management agree on a service objective and the associated requirements for technical development, documentation, testing, and implementation in the Services operation. The review process identifies the resources necessary to complete a project and assists management in controlling the allocation of those resources. Products, e.g., new data sources, displays, indices, and improved techniques for solar flare forecasting, are the outcome of the review process and are defined in broadest terms. One of the first products in the review process has been a set of documentation guidelines for Services operation.

SPACE ENVIRONMENT SERVICES CENTER

SESC (a joint operation of NOAA and the USAF Air Weather Service) continued to provide predictions, alerts, and data for a variety of users who have systems that are affected by disturbances in the space environment or who are conducting scientific experiments to improve understanding of that environment. Predictions and summaries of activity are distributed daily to users throughout the United States and the world. Customers using the services included DOD, NASA, DOT, DOE, universities, research foundations, and industrial and commercial users.

Accomplishments FY 1982

Increased emphasis was placed on surveys of users, their priorities for services, and the importance of the services to those users. Lists of products and the results of these immediate user surveys were made available to the Office of the Federal Coordinator for Meteorological Services and Supporting Research and to the Subcommittee for Space Environment Forecasting (SC/SEF). Other agency representatives to the SC/SEF established priorities for the products according to their own uses. In addition to being used by the Office of the Federal Coordinator to develop options for long-term planning of space environment services, the priorities have been used by SESC as a basis for internal allocation of resources.

Personnel assignments in SESC were redefined in response to evolving operational requirements. Teletype communications were once the mainstay of data collection and product distribution of the Center, and the staff included four fulltime and one half-time teletype operators. SELDADS as an automated data handling and distribution system was established later and did not become fully integrated into the operation until about 1978. In 1983, the last teletype machine will be phased out, whereas the maintenance of the real-time data base has expanded to a 24-h task.

A reorganization in progress effectively converts the teletype operators to technicians responsible for the real-time data flow into and out of SELDADS. Some of the senior professional forecaster staff who had been increasingly diverted to the SELDADS task will be assigned responsibilities in the SELDADS II effort or in the development of improved analysis and forecasting techniques. A core of professional forecasters will be retained to provide the analysis and forecasts produced by SESC.

FORECAST CENTER

In the Forecast Center in Boulder, data are collected within and supplementary to SELDADS. Real-time quality control is performed on the data. Analyses and summaries are compiled and indices extracted as the observations flow in. Predictions for a standard set of parameters are made and alerts are issued for major disturbances.

In addition to standard users, special projects using support during the year included the Space Transportation System, the International Upper Atmospheric Energy Budget Campaign, and approximately 15 rocket launches. Increasing numbers of requests were received from users concerned with the effects of geomagnetic field variation on biological and technological systems.

COMMUNICATIONS CENTER

Though many of its functions were automated, the Communications Center continued to operate. A contractor provides telegraphic service to the Boulder Laboratories on a cost-reimbursable basis.

OBSERVATORIES

The Air Force Solar Optical Observing Network (SOON) provides a basic solar optical flare and radio patrol. Data from SOON are supplemented by synoptic observations from Kitt Peak Observatory, Marshall Space Flight Center, and Culgoora, Mt. Wilson, Ottawa, and other solar observatories.

The Boulder Observatory provided basic solar images for use in forecasting. Inadequate regular staff was a continuing problem in the local observatory this year.

Satellite observations came from Space Environment Monitors on the GOES and NOAA/TIROS satellites and from the ISEE-3 satellite.

Geomagnetic data are provided by NOAA, USAF, USGS, and NSF observatories.

SESC functions as the World Warning Agency for the International Ursigram and World Days Service. In this role, it exchanges solar, geomagnetic, and ionospheric data with regional warning centers throughout the world and issues a consensus international forecast for disturbances.

TECHNIQUE DEVELOPMENT

Technique development work aimed at improved services was concentrated in a few areas where current services are weakest and potential payoffs to users are high.

Studies of techniques for predicting the terrestrial effects of eruptive solar filaments continued. Geomagnetic forecasts 1-3 days in advance are one of the highest priority services to users and among the most inaccurate forecasts made by SESC. Sources of the largest geomagnetic disturbances during the present 11-yr cycle have been from erupting solar filaments that were not associated with big, energetic flares.

Another especially weak area in the services is the prediction of overall levels of solar activity 3-27 days in advance. To strengthen this area, development of techniques continued for monitoring and evaluating large-scale mass motions on the Sun, based on identification of these features in solar synoptic maps. These studies have promise for predicting the appearance and growth of solar-active regions before they are identified by current techniques.

Development of the use of magnetograms that measure the shear within solar-active regions was carried out in cooperation with the Air Force. The work is aimed at identifying the storage of energy in the period of a few hours to a day or so before solar flares occur.

After NASA announced reduction of its program to predict solar cycles several years in advance, a number of satellite programs, which use the predictions to plan launch dates and orbital parameters, were referred to SESC. A review of the prediction techniques that could be used to predict the next 11-yr cycle was made, and a combined prediction was issued.

Work to improve the geomagnetic field indices and related services to make them more useful, especially to geophysical users, was carried out.

As part of an ongoing program to bring users and service providers together, a workshop on measuring and predicting the solar variables that affect the level of atmospheric drag on satellites was organized by the Division. Whereas an earlier workshop in 1979 had covered the entire range of solar-terrestrial predictions, the 1982 "Satellite Drag Workshop" concentrated on a few users and a narrow range of problems. The narrow, focused approach was successful and will be used again in the future.

Plans FY 1983

Maintenance of services, as prioritized from user surveys, will be continued to the extent provided by 1983 allocations. Planning and implementation of user requirements for SELDADS will continue. Requirements for application software must be developed for the new system.

A centralized documentation system is planned for the Division to maintain the growing documentation for the various aspects of SELDADS I and II.

The forecaster staff will be involved in the implementation of a new Laboratory research plan, including direct participation in some of the research, liaison to assist in defining research to meet service requirements, and providing a user viewpoint for research product reviews.

REAL-TIME DATA SERVICES

RTDS operates systems that provide data from various solar and geophysical sensors for supporting SESC operations. RTDS has three operational components: (1) the Data Display System (DDS) in the Radio Building at Boulder, Colo.; (2) the Table Mountain Observatorv (TMO) near Boulder, Colo.; and (3) the High-Latitude Monitoring Station (HLMS) at Anchorage, Alaska. Systems at the three sites operate 24 hours per

day, 7 days per week. The sites are staffed during normal working hours; at other times personnel are on call for problems.

The efforts of RTDS fall into three primary types of activities: (1) operating the system to provide solar geophysical data; (2) dealing with frequent contingencies that arise in a far-flung, diverse system with so many disparate components; and (3) planning, designing, and implementing upgrades and replacements to the components before they suffer catastrophic failure.

Accomplishments FY 1982

SELDADS consists of facilities to acquire, process, and display a wide range of solar geophysical data for use by the SESC forecaster. The data are also used by a number of industrial, governmental, and scientific groups who dial up the system from their own terminals. Data are provided over dedicated lines to the USAF Air Weather Service at Offutt Air Force Base, Neb., and to the Naval Ocean Systems Laboratory, San Diego. The following systems provided data to SELDADS during the year.

Communications networks operated by the Defense Communications Agency provided worldwide data from the International Ursigram and World Days Service network and from Regional Warning Centers operated by major countries in Europe, Asia, and Australia.

The Astrogeophysical Teletype Network (ATN), operated by the Air Weather Service, supplied data from observatories around the world, including the High-Latitude Monitoring Station (HLMS) in Anchorage, Alaska. These data are decoded in SELDADS and stored for retrieval and display in SESC.

Data from the SEM's on the GOES satellites were routinely received and sent to SELDADS where they were processed, displayed, and archived.

Data from NOAA-6 and -7 polar-orbiting satellites are received at Boulder from NESS. The data are stored in a data base, displayed by SESC, archived, and sent to the Global Weather Center (GWC) at Offutt Air Force Base.

SELDADS receives, processes, displays, and archives magnetometer data from a U.S. magnetometer network via a satellite communications link. Because the data are received at SELDADS, there is a considerable amount of system monitoring and communication with the USGS, University of Alaska, UCLA, and State University of New York, which maintain the magnetometer sites. The real-time magnetometer network is designated as the Real-Time Geophysical Observatory Network (RGON).

Data from the ISEE-3 electric field, solar wind, X-ray, and magnetometer sensors are received at Table Mountain. The data are processed, and 1-min summaries are sent to SELDADS and displayed in real time by SESC. A solar wind "shock" alarm was implemented using the electron solar wind velocity.

SELDADS was operational in excess of 98% of the time despite intervals of serious disk storage failures. As a result of the failures, new disk drives were purchased to maintain operational capability over the next year or so. Software modifications were made to (1) speed up the operating system in some of the processors; (2) meet new needs for data displays from users such as NASA (the Shuttle program) and the Air Force; (3) provide new real-time monitoring displays for SESC; (4) handle new GOES SEM data formats; (5) generate online teletype messages in place of those originally produced manually; and (6) generate new user products from the TED on the NOAA satellites. Experience has shown that about 20%-30% of the user and data stream software becomes obsolete every year with an approximately 100% turnover in 5 years.

TABLE MOUNTAIN OBSERVATORY

TMO, 13 mi north of Boulder, consists of ground stations for direct receipt of GOES SEM data, a magnetometer, a total electron content detector, and other sensors and equipment for receiving, processing, and relaying the data into SELDADS. Computer capacity at TMO is used to supplement the backup processing done in the primary SELDADS in Boulder. As usual, most of the work at TMO in FY 1982 was concerned with operation and maintenance of the types of equipment used in converting original sensor data into digital streams for computer processing, as well as with the vagaries of high-technology, field site operation in a high-wind, wildlife-infested area along the Front Range.

HIGH-LATITUDE MONITORING STATION

HLMS acquires, processes, displays, and archives geophysical data observed from local and remote ground-based sensors located across Alaska and at Thule, Greenland. The site is jointly operated with the Air Force Air Weather Service (AF/AWS). A local HF propagation and magnetic forecast is prepared along with special products for AF/AWS needs. Data summaries are sent out every 15 minutes on the Astrogeophysical Teletype Network; also, a daily telephone call transfers a synoptic summary to SESC.

HLMS maintained its daily operation during FY 1982. As with Table Mountain, major efforts went into repair and refurbishing of the data collection system and interfaces with the central Boulder location. In both locations, the high level of continuous operation that is maintained is due to the efforts of a few dedicated personnel who are highly adept at solving disparate problems.

SELDADS II

RTDS provided the chairmanship for the Technical Review Committee for the primary SELDADS II upgrade. The initial version of the RFP was completed in March and submitted to the Source Evaluation Board.

The basic functions to be upgraded or replaced in SELDADS II include (1) data base management (both automated and technician interface); (2) SESC user display and analysis capability; (3) external user interface and management; (4) incoming data stream decoding, filtering, and other initial processing; and (5) event detection. Function 4 and portions of functions 2, 3, and 5 will be handled by a series of microprocessors operating individually on each of the incoming data streams. An Invitation for Bid (IFB) was completed, bids solicited, and an order issued for the preprocessor portions of SELDADS II.

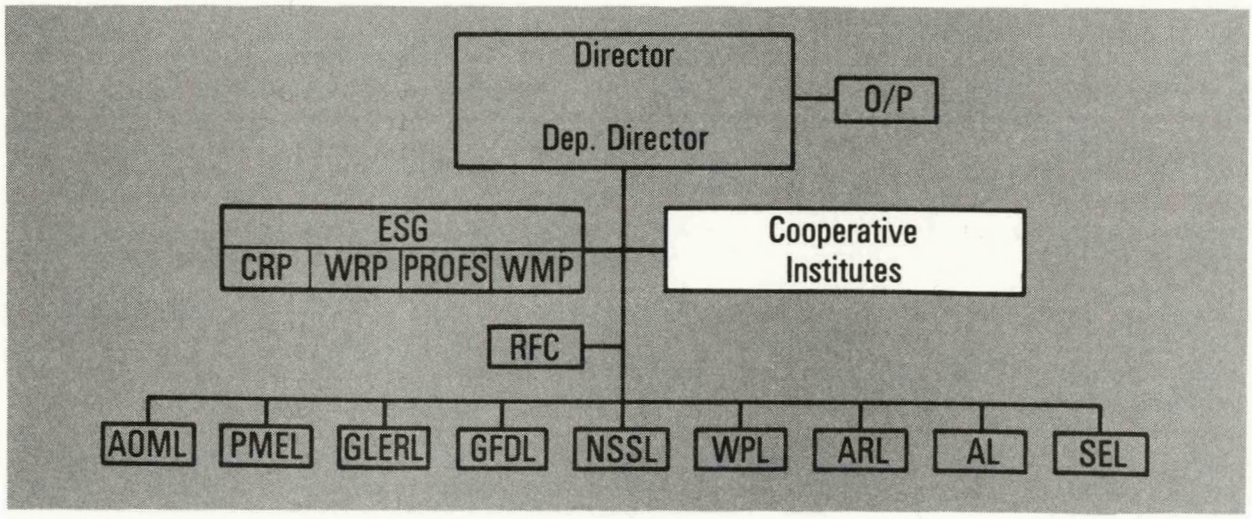
Alternative plans for various configurations of SELDADS II purchases were derived as a means of planning for various funding contingencies. Some of these are now in their second and third generation.

Plans FY 1983

Maintaining the operation of data systems essential to meet the high-priority SESC users will be the first order. Participating in completion of the RFP, planning, and initial installation of the preprocessors will also be carried out.

Reprograming necessary to complete the conversion from the earlier International Magnetospheric Study to the new Real-Time Geophysical Observatory Network will be completed. Pending the completion of a new SELDADS, existing software and displays will have to be modified to account for changing data sources such as new energy ranges in replacement sensors, implementation of new user requirements, and solutions to yet-undiscovered problems.

COOPERATIVE INSTITUTES



Several Environmental Research Laboratories interact with the university community through NOAA/university cooperative institutes. These institutes provide a mechanism for research collaboration and training in areas of mutual interest to NOAA and the academic community. There are six of these institutes at universities in Colorado, Washington, Hawaii, Oklahoma, and Florida. Each institute is closely associated with one or more of NOAA's Environmental Research Laboratories.

CIMAS

The Cooperative Institute for Marine and Atmospheric Studies (CIMAS) was formed in 1977 through an agreement between NOAA and the Rosenstiel School of Marine and Atmospheric Science (RSMAS) at the University of Miami, with the objective of enhancing research cooperation between the University and those NOAA units located in Miami. Initially focused on climate-related problem areas, its programmatic objectives were extended in FY 1980 to encompass work in coastal sediment dynamics and in fisheries ecology, the latter in cooperation with the National Marine Fisheries Service, Southeast Region.

CIMAS supports NOAA activities in part by directly engaging CIMAS research associates in activities within the local NOAA units (six Ph. D.-level individuals during FY 1982), by arranging for extended visits of scientists in areas of mutual interest (three U.S. and three foreign nationals during FY 1982), and by conducting specific research programs and workshops in areas of common interest.

Accomplishments FY 1982

The direct contributions of CIMAS research associates to activities within local NOAA units is accounted for within those units. CIMAS personnel were engaged in theoretical studies related to EPOCS (Equatorial Pacific Ocean Climate Studies), focusing on advective aspects of ocean mixed-layer dynamics. Cold-water advection in the Ekman drift was found to cause a significant enhancement of cold-water entrainment at the bottom of the mixed layer, with an associated tendency to frontogenesis in the surface

thermal field; cross-equatorial potential vorticity advection was suggested by CIMAS researchers as a mechanism for the generation of subsurface recirculation domains along the Equator, including the so-called Tsuchiya jets found in the equatorial Pacific.

Interpretation of chemical tracer data, particularly the decadal-time-scale transient spreading of the radioactive hydrogen isotope (tritium) was shown to suggest a quite symmetric upwelling pattern along the Pacific Equator, strongly limited in the density of its source waters to sigma-t levels lighter than 26.2. A significant cross-equatorial diffusion of tritium at somewhat higher density levels was also suggested. This work was based in part on sampling undertaken on EPOCS cruises, and in part on NSF-supported work under the NORPAX (North Pacific Experiment) and PEQUOD (Pacific Equatorial Ocean Dynamics) programs. Large-scale, climate-oriented tracer transport diagnostics and modeling of deep-ocean geochemical balances were also pursued with NSF support.

In the fisheries ecology area, the major effort during FY 1982 was the organization of a workshop on fisheries recruitment problems, with 40 participants from government and private-sector institutions. Aimed at an assessment of new interdisciplinary avenues toward research in fish stock recruitment processes, the report from this workshop is expected to become a major part of the U.S. position documentation in international program negotiations. The main research effort was devoted to the study of predator pressure effects on reef fish diversity by comparison of protected and unprotected reefs in the Florida Keys, and to the development of a scientifically based management plan for the local coral reef sanctuaries.

Plans FY 1983

Continued work in support of EPOCS objectives is planned, with an emphasis on modeling integral heat exchange anomalies associated with the equatorial and South American coastal-upwelling zones. Preliminary studies for the establishment of climate-oriented data bases in the subtropical Atlantic and Caribbean-Mexican Gulf regions in support of STACS (Subtropical Atlantic Climate Studies) objectives will continue, in cooperation with CIRES and NCAR in Boulder. Proposals are pending at NSF for extension of funding for (1) ocean-climate-oriented research through thermohaline circulation modeling to establish principles for monitoring climate transients and (2) research on the use of oceanic tracer diagnostics to extend our understanding of the water mass transformation processes associated with oceanic heat transport.

The sediment dynamics program has been deemphasized following a significant cutback at AOML, and it may be terminated.

The fisheries ecology program is expected to undergo a significantly enhanced research effort based on the imminent appointment of a new fisheries-science-oriented faculty member at RSMAS, complemented by one or two Postdoctoral Research Associates in CIMAS. A substantial number of applications for the latter have been received, leading to the expectation that appointments can be made for early 1983.

Most important for future CIMAS program development is appointment of a new permanent Director for CIMAS. This is expected by the beginning of 1983.

CIMMS

The Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) is a joint venture of the University of Oklahoma (OU) and ERL through the National Severe Storms

Laboratory. CIMMS received first funding in late FY 1978 and began major efforts during FY 1979. The program objectives and activities of CIMMS complement and supplement those of NSSL and the University through research conducted by Visiting Fellows, NOAA and University staff, and student appointees.

CIMMS was first led by Interim Director Rex L. Inman, then Head of the Department of Meteorology at OU. During 1980, Dr. Yoshi K. Sasaki was appointed Acting Director and subsequently Director. During 1982, Dr. Peter Ray of NSSL was appointed Associate Director of CIMMS, and OU provided funds for an Administrative Assistant position. The present Council of Fellows, which helps formulate policy, includes two members from NSSL, both of whom hold adjunct professorial appointments at OU, and two members from OU. The Advisory Council, which includes representatives from OU, NOAA, and outside organizations, meets annually.

During 1982, CIMMS activities expanded substantially. CIMMS hosted researchers from Japan, France, and Canada, who undertook studies at CIMMS in radar meteorology and mesoscale dynamics, for periods from 3 months to a year, with principal financial support from their universities or governments. A Postdoctoral Fellow represented CIMMS in the ALPEX field program during March and April 1982. Another Postdoctoral Fellow is engaged in investigations on lightning. Three Postdoctoral Fellows on multiyear appointments work in areas of boundary layer dynamics and mesoscale numerical modeling. Approximately 10 students employed by CIMMS are engaged in research studies toward advanced degrees; 5 undergraduate students are variously employed; and a Research Associate works in the NEXRAD program. Most of these are associated with both NSSL and the OU Department of Meteorology.

Approximately 10 reports and publications authored or coauthored by CIMMS personnel appeared during FY 1982.

The CIMMS symposium on mesoscale modeling was held during 1-2 June and was followed by the UCAR/NAS workshop on the National Storms Program during 3-4 June 1982; nearly 200 attended these meetings on the University of Oklahoma campus. During 22-24 September, CIMMS sponsored the "NEXRAD Doppler Radar Symposium/Workshop," with approximately 100 attendees. The CIMMS Director was a member of the International Organizing Committee of the "4th International Symposium on Finite Element Methods in Flow Problems," held in Tokyo during 26-29 July with more than 400 scientists and engineers in attendance.

Base funding for CIMMS is provided through NSSL; additional funds are also provided through NSSL, principally to support employment of students. Although the base funds from NOAA have not kept pace with inflation, CIMMS has received contracts and grants from other agencies, and additional subsidization from the University. This funding has enabled CIMMS to obtain some significant computer facilities and to expand its activities to a scale that is probably large enough to be self sustaining. CIMMS is a center of excellence and a vital administrative component of the triad that includes the OU Department of Meteorology and NSSL.

Although there have been some financial shocks to plans for building a new Energy Center at the University of Oklahoma, these have resulted only in scaling down projections. Construction of new facilities for CIMMS and the Department of Meteorology in the College of Geosciences is scheduled to start during Spring 1983.

Prominent in future plans is the "Symposium on Mesoscale Modeling," scheduled for 31 May-3 June 1983 at Norman, to be jointly sponsored by CIMMS and the American Meteorological Society. During 1985, the "Symposium on Variational Methods in Geosciences" is planned at Norman, to be jointly sponsored by CIMMS and the University of Clermont, France.

CIRA

The Cooperative Institute for Research in the Atmosphere (CIRA), established September 1980, is jointly sponsored by Colorado State University (CSU) and NOAA, and has close relationships with ERL in Boulder and NESDIS in Suitland. The Institute's research has concentrated on global climate dynamics, local-area weather forecasting, weather modification, the application of satellite observations, and air quality. Air quality, a new theme, is currently addressed through an alliance with the National Park Service.

The result of locating the NOAA/NESDIS/RAMM (Regional Mesoscale and Meteorology Branch) at CIRA has been an emphasis on development of meteorological satellite data for research purposes and environmental applications. Locally and nationally, CIRA is involved with satellite studies including participation in PROFS and other mesoscale research. Internationally, the involvement is with the satellite cloud climatology project. A pending research proposal in cooperation with the World Meteorological Organization and United Nations Environmental Program is to assist the Indian Meteorological Department with developing a sector processing center for their INSAT (Indian Satellite) groundstation; this research should begin in early spring and fit within the U.S.-India bilateral arrangements recently announced by President Reagan.

The CSU departments currently engaged in CIRA research with NOAA scientists are Atmospheric Science, Economics, Statistics, Psychology, Civil Engineering, Electrical Engineering, and Recreation Resources. Twenty-seven separate research projects have been funded through CIRA, including an IPA (Intergovernmental Personnel Act) with the National Weather Service. CIRA personnel comprise 12 Fellows, 4 Visiting Fellows, 8 Research Associates, 3 Visiting Scientists, and a Director. Since the inception of CIRA, two Ph. D. and four M.S. degrees have been awarded. Each year the Visiting Fellow program provides the opportunity for at least two scientists to perform independent research at CSU.

In July 1982 CIRA cosponsored the "Training Workshop on Satellite Meteorology" with NASA/Marshall Space Flight Center. A three-volume set of materials was made available to participants. In September 1983 CIRA will sponsor a workshop entitled "Applied Meteorology at CSU."

Plans include continued collaboration of NOAA and CSU scientists and students in research related to NOAA's mission, yet within the special themes of CIRA; increasing the Visiting Fellow program; and continual development of research involving NOAA and CSU scientists with other government agencies, such as the National Park Service.

JIMAR

The Joint Institute for Marine and Atmospheric Research (JIMAR) is located at the University of Hawaii. JIMAR was formed in FY 1978 in association with the University and PMEL. The principal research interests of JIMAR are tsunamis, climate, and equatorial oceanography.

Accomplishments FY 1982

Work continued on a finite-element model for tsunami propagation over irregular topography, development of a shallow-water digital tsunami gage, and establishment of

a tsunami-monitoring capability in Hawaii. A manual on post-tsunami surveys was written.

In climate research, a series of 58 tornado events during 1976-1981 was examined, and it was found that 82% of the events were associated with cirrus surges over the eastern Pacific Ocean 24 hours prior to the outbreak of tornado activity. An empirical orthogonal function (EOF) analysis of Hawaiian rainfall distributions was completed. A study of secular changes in carbon dioxide concentrations at Mauna Loa in relation to the atmospheric circulation was completed and published. Marine deck data were studied to determine their usefulness for detecting secular changes in the wind. It was concluded that changes in observational techniques and changes in ship routes probably preclude the possibility of gaining information on long-term changes in wind speed and direction from this data set.

In the area of equatorial oceanography, JIMAR participated in the Line Islands profiling project as part of the Pacific Equatorial Ocean Dynamics (PEQUOD) program. This project involves making a series of current profiles from the surface to the seafloor every 0.5° of latitude from 3°N and 3°S at the longitude of the Line Islands. A 3-mo preliminary effort was carried out in the fall of 1981, and a 13-mo series was begun in February 1982. This data set will be extremely valuable, not only for documenting the time variability of deep equatorial jets, but also for studying the oceanic dynamics of the 1982 El Niño event.

Analysis of the hydrographic and current meter data from the NORPAX Hawaii-Tahiti shuttle experiment showed evidence of a vertically propagating Rossby wave. The vertical propagation of momentum was studied in a theoretical model for Kelvin wave spin-up in a continuously stratified fluid. In addition, it was concluded that the mean equatorial undercurrent is in geostrophic balance, even at the Equator.

Analysis of Pacific sea-level variations and their relationship to El Niño events continued.

Plans FY 1983

Work on tsunamis will continue: development of the tsunami propagation model, development of the tsunami gage, and establishment of a tsunami-monitoring capability in Hawaii.

A post-event survey of Hurricane Iwa will be conducted to determine whether there was a storm surge associated with the hurricane.

In the climate area, activities planned for 1983 include a continuation of the study of equatorial Pacific cloud surges, an investigation of the reality of the secular changes suggested by the marine deck data, a study of the climatic singularity of 1963, and a study of synoptic climatology of the eastern Pacific near the Equatorial Convergence Zone.

Equatorial oceanography activities will include the following: conclusion of field work for the Line Islands profiling project; continued analysis of the Rossby wave data, the dynamics of undercurrent, and Kelvin wave events of the type reported earlier; extension of the results from the study of vertical propagation of momentum to Rossby wave spin-up; continued investigation of the effect of coastal geometry on equatorial wave reflection; and development of an El Niño rapid-response capability to enable us to survey in detail the next El Niño event as soon as possible after detection of onset.

CIRA
JIMAR

JISAO

The Joint Institute for Study of the Atmosphere and Ocean (JISAO) was formed in FY 1977. JISAO is located at the University of Washington and has a strong association with PMEL. The main areas of emphasis within JISAO continue to be climate dynamics, estuarine processes, and environmental chemistry, with climate dynamics continuing to be dominant.

Accomplishments FY 1982

Research in climate dynamics during FY 1982 involved a variety of topics, including the nature and causes of sea-surface temperature anomalies in the equatorial Pacific Ocean, seasonal variability in the equatorial Atlantic, studies of mesoscale oceanic eddies based on the motions of quasi-Lagrangian floats, sudden stratospheric warmings, and recurrent "weather regimes" in a simplified model of the atmospheric circulation.

Activities sponsored, fully or in part, by JISAO included 23 visits by distinguished scientists with accompanying seminars on climate-related topics, and 8 visits with accompanying seminars on pollution-related topics. Additionally five scientists with 1- to 2-yr appointments collaborated on climate-related topics.

Plans FY 1983

JISAO expects the arrival of two Research Associates (postdoctoral): a physical oceanographer who will be studying ocean circulation and air-sea interaction processes in the tropical Pacific, and an environmental chemist who proposes to study the adsorption of metals and metalloids onto oxides in natural systems. The Institute is also making available funds to offer a 1-yr appointment to a scientist, from the Marine Physical Laboratory at Scripps, who is studying estuarine processes and ocean general circulation.

CIRES

The Cooperative Institute for Research in Environmental Sciences (CIRES) is jointly sponsored by the University of Colorado (CU) and NOAA. Additional support comes from other public and private sources. Current research in CIRES falls into five broad areas: Atmospheric Chemistry, Atmospheric Physics, Climate Dynamics, Environmental Biochemistry and Geochemistry, and Solid Earth Geophysics. CIRES research on these subjects was reported in approximately 80 publications in 1982.

Since 1980, research activities in CIRES have undergone considerable restructuring that reflects changing membership of CIRES and expanded relationships between the Institute and NOAA. Academic affiliations of CIRES Fellows now include the departments of Astrogeophysics and Electrical Engineering, and the Museum, in addition to continuing links with Chemistry, Chemical Engineering, Geography, Mechanical Engineering, and Physics. There are also formal links with the National Environmental Satellite Data and Information Service of NOAA through geophysics appointments in CIRES from the National Geophysical Data Center (NGDC) and through the continual operation of World Data Center-A for Glaciology (Snow and Ice) (WDC-A) by CIRES. A National Snow and Ice Data Center, designated by NOAA in March 1982, is colocated with WDC-A.

ATMOSPHERIC CHEMISTRY AND PHYSICS

Chemical processes involving trace constituents in the atmosphere are being studied in the field and in the laboratory. These processes are of major significance to problems such as acid rain and snow, ozone depletion in the stratosphere, and anthropogenic impacts on air quality resulting from the exploitation of Western energy resources. Research emphases are on the reactions that regulate the distribution and quantity of stratospheric ozone; gas chromatography and mass spectrometry of tropospheric "clean" and urban air to determine organic species; the kinetics and thermochemistry of ion clusters; and ion reactions in the ionosphere and magnetosphere.

Field measurements are being conducted at CU's Mountain Research Station "clean air" site on Niwot Ridge. Experimental and theoretical studies involve a collaborative effort between scientists, faculty, and students in the NOAA Aeronomy Laboratory and the CU Chemistry Department. New analytical methods have been developed that permit more sensitive and accurate analyses of the constituents of ambient air. These have been described in several papers by NOAA and CU chemists. New methods for separation and analysis of terpenes and other organic compounds and nitric acid in ambient air have been developed and published. New studies of microcomputer-interfaced instrumentation have begun in collaboration with the Electrical Engineering Department. A major expansion of surface science activities is under way. The role of biogenic ice nucleation sites is being examined in a multidisciplinary study involving atmospheric physicists, physical chemists, and molecular biologists. These fundamental studies may eventually lead to such practical advances as the control of frost damage to crops, or the augmentation of snowfall by seeding with biogenic nucleating agents.

Fundamental properties of atmospheric flow and evolution are being studied through modeling of turbulence phenomena and mesoscale modeling of the planetary boundary layer. Finite-element techniques capable of treating flow over inhomogeneous terrain are receiving special attention. Such models have important applications in problems of pollutant transport and dispersal and in siting studies for potential wind power developments.

CLIMATE DYNAMICS

The climate group is focusing its research in three areas: the role of the oceans in the climate system, cryosphere-climate interactions on synoptic-to-interannual time scales, and climatic regimes associated with ice-sheet growth and decay. An ocean climate data set from 1860 to the present is being compiled to establish a fuller picture of the climatic conditions over 70% of the Earth's surface. Preliminary work has identified important "breaks" in regime around 1875, 1900, 1917, 1940, and 1963. Short-term fluctuations related to the El Niño phenomenon and the Southern Oscillation in the Pacific are receiving detailed attention in terms of possible teleconnections. In a separate project, an atlas of ocean cloud climatology is being prepared.

Satellite remote-sensing data are being used to determine the spatial and temporal characteristics of sea ice and snow cover in the Arctic and their interaction with cyclonic systems and general cloudiness. Work is in progress on the discrimination of cloud and snow cover and on the assessment of ice-albedo feedback models incorporating arbitrary cloud distributions. A new project has begun on lake freezeup/breakup statistics as a possible detector of CO_2-induced warming effects.

A project on the physical characteristics of the Greenland ice sheet is nearing completion. Ice flow and temperature fields have been reconstructed for the first time, and basal zones of melting ice have been determined using a computer model. The calculations will be of value in paleoclimatic studies from ice cores.

JISAO
CIRES

The data management and analysis activities of WDC-A complement and support several programs within the climate group. The results of the "Workshop on Radio Glaciology" held in conjunction with the "Third International Symposium on Antarctic Glaciology" were published in "Glaciological Data Report ED-13."

ENVIRONMENTAL CHEMISTRY

One aim of this new program area is the study of the pollutants in water. A specific application concerns the treatment and disposal of oil-shale retort waters and other energy-related wastes that are heavily polluted with organo-nitrogen compounds such as alkylpyridines, alkylquinolines, and aniline derivatives. The program is linked with geochemical studies of groundwater in oil shale development areas, which are seeking ways to minimize mobilization of toxic wastes (that may contaminate aquatic systems) arising from mining and energy-related activities. The effect of organic pollutants in wastewater (held, treated, and disposed of by spreading on the surface) on air quality is being studied by laboratory simulation of co-disposal of waste materials from synfuels extraction.

SOLID EARTH GEOPHYSICS

Observational and theoretical seismology, engineering seismology, and rock mechanics are the major concerns of this group. Geophysical networks are operated in the Aleutian Islands, California, and Greece to investigate earthquake precursors and problems of tectonics and geodynamics near active plate boundaries. Seismographs, laser ranging, and tiltmeters are used in these networks, and a network of specially designed deep borehole tiltmeters is being operated in Yellowstone National Park. Seismic monitoring in the Hellenic Arc may make possible detection of the foreshocks of an expected large rupture. Research in engineering seismology is confined to the studies of ground motion amplification due to local geology and seismic response of large underground structures (pipelines, tunnels, storage facilities, etc.). Research in rock mechanics focuses on the processes of deformation and failure under varying environmental conditions; various test modes are used.

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