Environmental Research Laboratories

Programs & Plans

FY1981 Programs

FY1982 Plans

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

Environmental Research Laboratories. Office of Programs.

Programs and Plans 1981 1982

December 1981

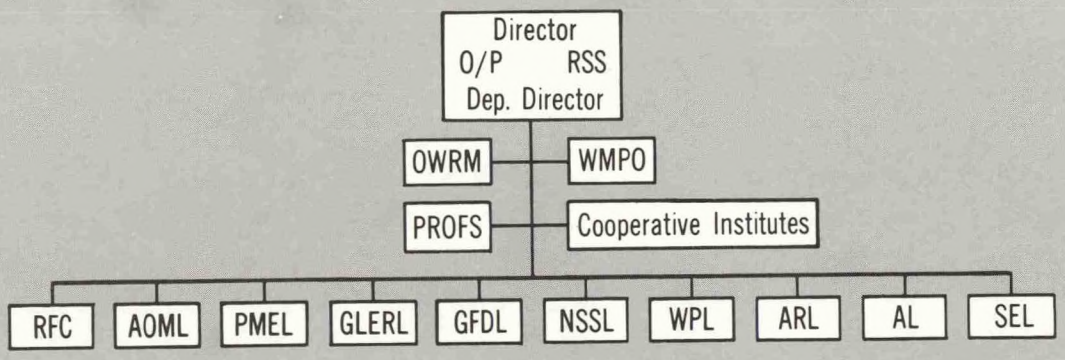
U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Environmental Research Laboratories
George H. Ludwig, Director

NOTICE

Mention of a commercial company or product does not constitute an endorsement by NOAA Environmental Research Laboratories. Use for publicity or advertising purposes of information from this publication concerning proprietary products or the tests of such products is not authorized.

Document available in Office of Programs, ERL, Boulder, Colorado

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.

CONTENTS

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), Research Facilities Center (RFC), Space Environment (SEL), and Wave Propagation (WPL); the program offices are the Office of Weather Research and Modification (OWRM), the Weather Modification Program Office (WMPO), and the Prototype Regional Observing and Forecasting Service (PROFS). In addition to these laboratories and program offices, joint institutes in various universities undertake research for ERL. 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
- 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, OWRM, 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 Flats, Alaska, to measure these parameters continuously throughout the lowest 100 kilometers of the atmosphere. A second radar system at Platteville, Colo., is being phased into the Prototype Regional Observing and Forecasting Service (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 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 the National Weather Service), 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 in order 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 analysis of severe-storm data includes the analysis of the 1979 SESAME (Severe Environmental Storms and Mesoscale Experiment) data set. SESAME '79 was a cooperative multi-agency, multi-university program during a 2½-month observing period in the areas in and around Oklahoma where tornadoes are prevalent. Many of the data have been processed, reduced, and published by the SESAME Project Office (now a part of OWRM).

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 Research Facilities Center 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. A notable project is HAMEC (Hawaii Mesoscale Energy and Climate Project), a field project to gather meteorological data to initialize and validate a mesoscale numerical model in Hawaii. 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 kilometers) 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 the National Weather Service (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 PUFFS (Prediction and Understanding of Flash Flood Storms) program 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 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 field exercise is planned during 1982 to examine the forecasts and warnings of severe thunderstorms in the Denver/Boulder, Colo., region.

WEATHER MODIFICATION RESEARCH AND DEVELOPMENT

Weather modification research and development includes research at AOML, OWRM, RFC, WMPO, WPL, and joint institutes. This program area interacts 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 are 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 have been 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 results will be published during 1982. Although the central approach of FACE was statistical, peripheral studies are 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 are under investigation. These studies have 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 new Cumulus Dynamics and Microphysics Program aims (1) to provide the basic understanding of cloud dynamics and microphysics needed to validate the dynamic seeding hypothesis, and (2) to examine cloud development in response to environmental forcing, with emphasis on effects of cloud merger.

Project Stormfury is a research program directed toward the reduction of the peak winds in hurricanes through dynamic seeding and artificial growth stimulation of convective clouds in rainbands just radially outward from the hurricane. 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. These data are essential to the experiment, since seeding is aimed at altering the microphysical and convective structure of the storm's inner core. 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 multi-wavelength (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 and Utah 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 and atmospheric effects of volcanic eruptions; 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, sulfur dioxide, aerosol concentrations, total atmospheric ozone, freons, 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 whether gases and particulates put into the atmosphere by human activities or by natural causes are significant enough to 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. Most work is carried out by balloon-borne instruments, and measurements are made by a variety of methods including 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 fluorochlorocarbons, 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 oil shale development 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. 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 C-13 to C-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, the Research Facilities Center, 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.

Ocean-atmosphere studies are the major focus of the EPOCS (Equatorial Pacific Ocean Climate Study) program. Projects in EPOCS are investigating the interannual climatic impact of anomalously warm sea surface temperatures in the equatorial Pacific. 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. In addition to EPOCS, 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 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--one tropical and one high-latitude in each hemisphere--(Alaska, Hawaii, Samoa, and South Pole) 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 two Laboratories and one joint institute. 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 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. The Space Environment Services Center (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 kilometers) 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 degrees.

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 to 20 feet 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 the sea. 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-month 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 to 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, GLERL, PMEL, and joint institutes. Much of the work supports programs managed by NOAA's Office of Marine Pollution Assessment (OMPA). 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 is designed to assess the extent of petroleum--based pollution in the Gulf of Mexico and the Straits of Florida and to identify sources and fates of this pollution. Studies of pollutant stress have been implemented to improve laboratory bioassay systems for determining the effects of continuous inputs of hydrocarbons to planktonic lower-trophic-level systems and to characterize the lethal and sublethal effects of chronic hydrocarbon pollution on multispecies phytoplankton-zooplankton systems. 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.

Marine assessment research also includes investigations of internal wave propagations and interactions between oceanic and coastal waters. These studies attempt to determine the processes by which deep ocean currents influence the dynamics of coastal and oceanic surface waters. The acoustical studies project develops and applies acoustical techniques to study oceanic processes including turbulence, internal waves, and particle transport processes.

The regional studies are multidisciplinary investigations in selected coastal regions including the New York Bight, Puget Sound, Gulf of Mexico, the Alaskan coast, and the Great Lakes. 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.

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.

In the Bering Sea, transport processes are studied in order to determine the roles played by major hydrographic fronts on the Bering Sea shelf. In Cook Inlet and Norton Sound studies are in progress to identify regions of active sedimentation of fine-grained materials and to determine sediment accumulation rates. Other Alaskan studies chemically characterize the sources of suspended matter and establish its transport pathways; and identify and quantify the natural and anthropogenic sources of alkanes, alkenes, and low-molecular-weight aromatics.

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 research in the Great Lakes is subdivided into water movements and temperature, particle dynamics, cycling of toxic organics, planktonic succession, eutrophication and nutrient cycling, environmental information services, and environmental engineering models and applications. The water movement and temperature project 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.

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 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; to educate and train the specialized personnel needed to develop and manage 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 six elements: marine resource development, marine technology development, marine environmental research, marine socio-economic and legal research, marine education and training, and marine advisory services.

The resource development element is directed toward discovering and developing both living and nonliving marine resources. Primary research areas are aquaculture, fisheries biology and ecology, marine pathology, mineral resource development, and marine natural products. In aquaculture, a major study area is the development of commercial closed systems for aquaculture of shellfish, especially oysters, shrimp, prawns, and lobsters. The fisheries program determines population characteristics of commercial or potential commercial species, develops new management and assessment techniques, and studies marine food chains. Mineral resource development consists of studies relating to discovery, availability, recovery, and processing techniques, and legal implications of offshore mining of sand, gravel, manganese nodules, 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.

Technology development carries advanced marine technology and new concepts to the point of practical or commercial application in order to develop our marine resources efficiently. Activities include developing new and improved gear for specialized fisheries, finding uses for waste materials from seafood processing, improving techniques for underwater welding and cutting, and exploring new methods for preventing internal decay of wooden waterfront structures.

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.

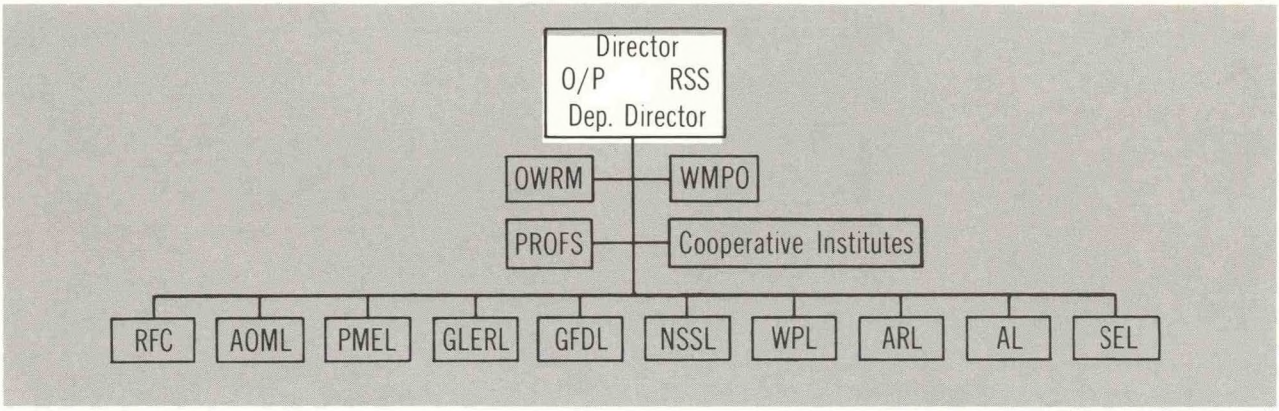
Socio-economic and legal research focuses on organizing and analyzing the many existing Federal and State laws and local ordinances by which marine businesses must operate. Many promising new commercial developments are not undertaken or fail because information on the economy, the laws and regulations, and public opinion is lacking. The rapidly changing marine and coastal zone laws are being monitored and interpreted by the university and law communities, with present emphasis on the impact on fishermen of the international adoption of a 200-mile economic zone.

The program element concerning marine education and training attempts to increase and improve the quality of personnel needed to develop, utilize, and manage marine resources more effectively. The addition of advanced marine studies to existing university programs is encouraged to provide trained personnel for marine industries. Efforts are also directed towards strengthening course offerings in fields such as ocean engineering, ocean law, ocean management, and marine affairs. Training programs are supported in oceanography and biology in cooperation with other Federal agencies.

The marine advisory services are provided by 300 marine advisors whose functions 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

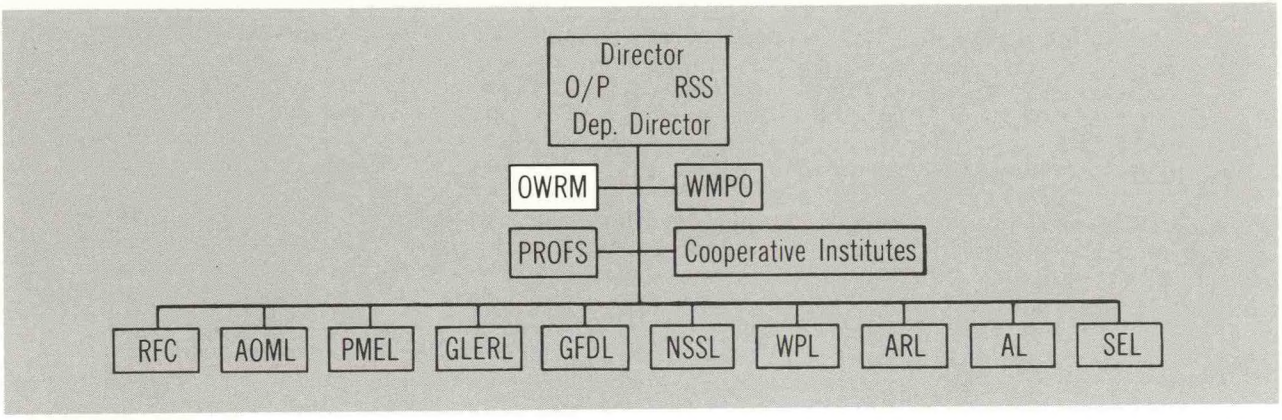
George H. Ludwig, Director
Vernon E. Derr, Deputy Director



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, two staff groups, Office of Programs and Office of Research Support Services, provide advice and services to the Director as well as to the laboratories and program offices. 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. The Office of Research Support Services (RSS) provides administrative and technical services, including budget, computer, library, management analysis, personnel, publications, and plant and property services. RSS groups serve all Department of Commerce agencies in Boulder and all ERL agencies throughout the United States.

OFFICE OF WEATHER RESEARCH AND MODIFICATION
Boulder, Colorado

Charles F. Chappell
Director



The Office of Weather Research and Modification (OWRM) conducts a program of basic and applied research to improve short-range weather predictions and warnings, and to identify and test hypotheses for beneficially modifying weather processes. The office plans, coordinates, and contributes to the execution of meteorological field experiments to investigate mesoscale weather processes and to develop and evaluate weather modification technologies. The office disseminates research results and transfers promising techniques and technologies to users.

The OWRM research effort is conducted within four organizational components: the Air Quality Program, the Boundary Layer Dynamics Program, the Cumulus Dynamics and Microphysics Program, and the Mesometeorology Division. In addition, OWRM research is scientifically and technically supported by the Research Support Group of the Director's Office.

AIR QUALITY PROGRAM

The Air Quality Program studies the effects of naturally occurring gases and aerosols and of anthropogenic pollutants on the physical, chemical, and optical properties of clouds. To accomplish this mission, the program investigates (1) the distribution of natural and anthropogenic aerosols, especially cloud and ice nuclei, (2) the effects of natural and anthropogenic trace constituents on the physical, chemical, optical, electrical, and thermal states of the atmosphere, and (3) the mechanisms of formation and growth of aerosols in polluted air.

Accomplishments FY 1981

Temperature measurements by aircraft between 1.6 and 3.1 kilometers above MSL in the polluted Four Corners area, during a period when the region was dominated by a high-pressure system centered in north-central Utah, showed a temperature profile consistently higher by several degrees and with stronger elevated temperature inversions than clear-air profiles from three surrounding National Weather Service radiosonde stations. Measurements in the 8- to 14-μm bands and calculations in the 4- to 1000-μm spectral bands of the radiative balance, around the Four Corners powerplant plume and in clear air, showed a cooling rate that was affected by the plume and the attendant persistent haze. This infrared cooling is counteracted by solar (0.3- to 3.0-μm) daytime warming. The latter was estimated by calculating the optical thickness for absorption and scattering for particle size data obtained with optical aerosol spectrometers on board the aircraft, using Mie theory and recently published imaginary refractive indices.

Profiles were made of the plumes from the Four Corners and San Juan powerplants, and the wave motions of the Four Corners plume as it crossed a terrain barrier were documented photographically. This work on November 5, 6, and 8, 1980, accomplished during conditions of calculated Froude number values of 1-2, showed that the Hogback barrier produced downward mixing of the plumes, thus bringing the effluents into contact with the ground through-

out the San Juan River valley west of the Hogback. The Hogback elevation where the Four Corners plume crossed is about 100 meters above plant site elevation; effective plume height was 100 to 500 meters above the plant site elevation. The lengths of the lee waves produced were 1.1 to 1.3 kilometers and sometimes appeared to terminate in a mild hydraulic jump; amplitude was 40 to 110 meters. The succeeding waves appeared to be lengthened by factors of 2 to 3, while amplitudes were reduced; plumes of effective height equal to the Hogback elevation were seen to form on ascending waves immediately upwind of the Hogback, thus possibly preventing contact with the Hogback. The lengths and amplitudes of the ascending waves were similar to those of the lee waves. These low-level waves could not be observed beyond the first lee wave, but appeared to disintegrate in a hydraulic jump or in rotors.

In situ measurements of aerosol surface area using airborne optical particle spectrometers, and elemental composition analysis, using X-ray energy dispersive analysis, of samples collected in the plume of the Four Corners powerplant provided evidence of a selective accumulation of sulfate on the surface of about half the fly ash particles. The amount of sulfate thus formed, however, is only about 2% of the total aerosol mass. Hence, fly ash has little catalytic effect on the heterogeneous conversion of SO_2 to SO_4 above currently accepted total rates of 1% per hour. Homogeneous nucleation at low rates is more important for the generation of small sulfate particles that are subject to long-range transport.

The 1980 electrical conductivity data at Gunbarrel Hill outside Boulder, Colo., indicated that the rural Boulder County environment was the cleanest since 1976 with respect to fine-particle pollution. This improved air quality reverses a general trend existing since the measurements began in 1967. The improvement is probably due not to the reduced emission of pollutants, but rather to the increased frequency of cleansing downslope winds and meteorological conditions unfavorable to inversion-type air pollution episodes. A period of increased particulate pollution appears more frequently in the winter evening hours and is attributed to the increasing use of wood-burning stoves and fireplaces in Boulder County.

Plans FY 1982

Field and laboratory research to elucidate the effects of air pollutants on clouds, precipitation, and radiative transfer will continue. Activities will consist of the following:

- Regional measurements of the upward and downward infrared and visible radiative fluxes to evaluate the effects of anthropogenic haze on the temperature structure of the atmosphere. Solutions of the radiative transfer equation based on measured particle size distributions will support the radiation measurements.

- An analysis of past rawinsonde temperature soundings during pollution episodes in Los Angeles, Salt Lake City, and Denver. The results will be compared with those of clean-air soundings in order to show the magnitude and the geographic extent of a thermal modification of the atmosphere by pollution.

- The use of precision infrared radiometry to detect an effect of the seasonal variability of CO_2 on the longwave terrestrial emissivity.

- An investigation of the contribution of natural and anthropogenic gases and particles to the drop-size spectra and to the acidity or alkalinity of clouds in the vicinity of their apparent sources.

- Continued aerosol studies at the Gunbarrel Hill Air Quality Research Site. The particulate size range under investigation will be expanded to 40-μm diameter for complete documentation of aerosol conditions during wind storms or "brown cloud" episodes.

All these activities relate to effects of fossil fuel combustion, especially coal and coal-derived products, and make the information OWRM gathers increasingly valuable as national and international energy production increasingly affects weather and climate.

BOUNDARY LAYER DYNAMICS PROGRAM

The Boundary Layer Dynamics Program consists of theoretical and experimental studies of the turbulent transfer of atmospheric properties and constituents. A main goal of many of

these studies is to understand and evaluate boundary layer scales of motion and the turbulent transfer of water vapor, i.e., the latent heat that drives weather systems on scales ranging from small cumuli to hurricanes. Other studies relate to air-sea interaction and air quality.

Accomplishments FY 1981

In anticipation of the modification of air quality on Colorado's western slope associated with the coming synfuel development, several data collection missions were flown for baseline data concerning air quality. The plane was fully instrumented, including the turbulence measurement systems and the Knollenberg particle probe. The area of interest included not only the coal-fired powerplants in the Craig-Hayden area, but also coal-mining regions, potential oil shale reduction areas, Dinosaur National Monument, active oil fields, and the "flat top" region. The Knollenberg probe permits us to determine present rates of production of pollutants and deposition rates in both clear and affected regions. The data are now available for future users.

Several important data bases were created for use in evaluating the mechanics of the dispersion, transport, and transformation of pollution. Airborne measurements were obtained in the Cumberland Valley of Tennessee, the Northeast corridor in Pennsylvania, and the Ohio Valley. These data are now available from EPA sources. From these data, a study of the turbulent transport of ozone in the boundary layer over Philadelphia was completed. Large downward fluxes of ozone were observed over the urban core, along with large vertical gradients of ozone concentration due to the destruction of ozone at the surface by NO/NO_x. Large fluxes and concentrations of ozone were observed on well-developed clouds over the urban center, indicating that clouds there play an important role in the transport of ozone into and out of the urban boundary layer.

Personnel participated in the Storm Transfer and Response Experiment (STREX), a multi-agency effort in the Gulf of Alaska studying offshore storms. The STREX objective was to describe the cyclonic storm's modification of the structure of the planetary boundary layer and of the sea-air interaction. The results are archived at the University of Washington.

The Tradewind Trajectory Experiment was flown as part of the Equatorial Pacific Ocean Climate Study (EPOCS). The objective was to determine the partitioning of energy between sea, air, and clouds as a function of distance along the trade winds. Measurements were taken above and below the semipermanent stratus cloud deck, which is accompanied by a strong temperature inversion above the clouds.

A detailed analysis of aircraft turbulence measurements made during GATE (GARP Atlantic Tropical Experiment) was completed and published in Boundary Layer Meteorology.

Plans FY 1982

Personnel will participate in three field programs: CYCLES (Cyclonic Extratropical Storms) in the Gulf of Alaska, MIZEX (Marginal Ice Zone Experiment) in the Bering Sea, and ALPEX (Alpine Experiment) in southern Europe.

Studies of the atmospheric boundary layer over the tropical ocean will continue. The dependence of the fluxes of latent and sensible heat and momentum on rapid changes in sea surface temperatures and atmospheric stability will be studied for data obtained over the eastern tropical Pacific.

An extension of the study of updrafts and downdrafts in EPOCS data will be accomplished to investigate the dependence of the statistical properties of updrafts and downdrafts on height of the boundary layer.

A study will be conducted of the cloud transport of ozone and latent and sensible heat into and out of urban and suburban boundary layers using cloud penetration data from NEROS (North East Regional Oxidant Studies).

Analyses of the STATE (Sulfur Transport and Transformation in the Environment) data will continue. A paper reporting the effect on plume dispersion of atmospheric random thermal heating by the Earth's surface will be completed.

CUMULUS DYNAMICS AND MICROPHYSICS PROGRAM

The Cumulus Dynamics and Microphysics Program (CDMP), a 10-yr program begun in 1981, is a basic weather modification research effort that seeks to understand the genesis and development of deep convective clouds, their interaction with the environment, and the physical processes underlying the growth and modification of convective precipitation. CDMP emphasizes interactive numerical modeling, laboratory studies, and observations.

Accomplishments FY 1981

During FY 1981, planning for the 1983 CDMP experiment in Florida was started. A Program Development Plan was published and a meeting of the CDMP Study Group was held to define the attainable goals of this experiment. The scientific community was informed of the start of CDMP by publication of a prospectus and the first Progress Report for the wide spectrum of individuals and agencies involved.

FACE-2 DATA SETS

The processing of data sets from FACE-2 (Florida Area Cumulus Experiment) continued. Reduction and analysis of six programs crucial to FACE-2 data which must be completed prior to disclosure of the treatment decisions, were performed on schedule. The six kinds of data are (1) gage rainfall, (2) confirmatory radar rainfall and covariate data sets, (3) S- and C-band radar observations, (4) microphysical data analyses of seeded vs. unseeded cumulus towers, (5) satellite-estimated rainfall from a geostationary satellite, and (6) cloud-to-ground lightning data.

CUMULUS DYNAMICS

The analysis of the FACE-2 data relating to the physical basis of the dynamic seeding hypothesis also progressed as scheduled. Preliminary physical results have already been obtained. In particular, C- and S-band radar observations in Florida have revealed that maximum echo top height is strongly correlated with the area of the echo and its total rain production, rain rate, and duration. These findings strongly support the FACE physical hypothesis so that increasing the vertical growth of the cloud (as with dynamic seeding) will result in a larger, longer lasting cloud that produces more rainfall. In general, the emphasis of the physical studies has been to provide a background characterization of cumulus cloud fields and convective cloud processes in south Florida prior to the CDMP Florida experiment in 1983. In addition, this work attempts to clarify the diurnal variations of convection in the FACE area, and the effect of synoptic and regional circulations on the amount of convective activity present on different types of days. The ultimate goal of these efforts is to account for the natural variability of convection so that the seeding effect can be better isolated.

Another study, completed and submitted for formal publication, used data collected as part of the FACE-1975 field program to investigate the interactions between mesoscale convective systems and the surface boundary layer. One of the conclusions from the study is that pressure perturbations (lows), induced by developing convective elements within the system, increase the surface convergence into the system, which causes additional convection to develop. Another finding shows that the depth of the moist layer in the near environment decreased with time, possibly forced by subsidence around the mesoscale system. It is hypothesized that this acts to weaken the interactions between the developing convection and the boundary layer (through pressure perturbations) that cause the convective system to evolve from the mature to the dissipating stage.

Data from the FACE-1975 surface mesonetwork and Doppler radars were also used to investigate the response of convective clouds to dynamic seeding. One of the conclusions so far indicates that there is a strong positive feedback between vertical development within the cloud, decrease of pressure at the surface below and in the near vicinity of the cloud, and an increase in the surface convergence into the cloud region. There also appears to be a larger scale feedback between the developing convection and the boundary layer, again through the surface pressure field, which increased the convergence into the entire area, and not just within the storm. This case study is also being simulated on the three-dimensional Colorado State University cloud model for these investigations:

(1) Intercomparison of the model findings with observations.
(2) Search for additional thermodynamic and dynamic response following seeding that cannot be analyzed from observational data.

Research on the convergence-rainfall relationships from FACE 1975 was documented in an internal series and then submitted for journal publication. The strong relationship between amount of surface convergence and amount of rainfall from the same convective event was quantified under different synoptic wind and moisture regimes. Studies were also made of the influence of variable station spacing on the above result, of precipitation efficiency, visible cloud response to convergence, cloud merger, and cloud evolution related to merger. Research with the 1979 VIN (Universities of Virginia and Illinois, and NOAA) surface mesonetwork data for Illinois continued, and preliminary results indicate a good relationship between convergence and rainfall, although somewhat less well defined than in Florida.

South Florida cloud-to-ground lightning was categorized by height of the radar echo top that produced the lightning. The minimum height producing cloud-to-ground lightning was 7.8 kilometers, and some cloud tops of 25 kilometers had no lightning associated with them. From these observations, it is evident that echo height alone is not a good indicator of the presence of cloud-to-ground lightning.

CLOUD MICROPHYSICS

Analyses of FACE-2 cloud microphysics data were performed. These analyses have focused primarily on relationships between liquid water and cumulus cloud motions, ice multiplication, rates of dispersion of seeding material and ice crystals, and resulting rates of cloud glaciation.

Formvar replicas of cloud particles were selected from the FACE-2 data sample in coordination with personnel of the Desert Research Institute. The replicas are to be examined with a scanning electron microscope to determine the proportions of cloud drops to ice crystals.

Considerable effort was devoted to further planning for work under the FY-1982 Ice Crystal Processes initiative, and a preliminary implementation plan was written.

Plans FY 1982

OWRM

Commitments and plans for the main components of the 1983 CDMP experiment will be nearly completed by the end of FY 1982. A series of meetings during December and January with participants of the CDMP division and of the CDMP Study Group will determine the scope, priorities, and major elements of the 1983 program. The first Operations Plan will be written in April. Preliminary site surveys for radars, aircraft operations, and the control center will be made by June, and subsequent planning will result from the survey. Further research on CDMP-related topics will continue through the year at OWRM, other NOAA and Federal agencies, and at the universities and private organizations participating in CDMP, such that important results based on FACE studies can be applied optimally to planning for 1983.

FACE-2

Assessment of treatment effects in FACE-2 will be the focus of CDMP research during FY 1982. Results of the analysis of the crucial data sets of FACE-2 will be published in six NOAA Technical Memoranda. Once the crucial analyses have been completed, documentary manuscripts will be sent to key people in the scientific community. Simultaneously, three papers will be sent to the Journal of Applied Meteorology for publication. Then the FACE-2 treatment decisions will be disclosed, and assessment of treatment effects can begin. Preliminary results will be available by 1 January 1982, and these will be provided to individuals in leadership positions within and outside NOAA to facilitate the planning of CDMP. Papers detailing the results of FACE-2 will probably be submitted for formal publication dur ing the spring and summer of 1982. Once this has been done, final preparation for the CDMP investigation of the dynamic seeding hypothesis will be made.

CUMULUS DYNAMICS

The analyses of FACE data related to the physical basis of the dynamic seeding hypothesis are to be continued in FY 1982. It is expected that the majority of these studies will be finished and several papers will be submitted for publication during the year. The projected papers are as follows:

(1) Radar characteristics of Florida clouds.
(2) Diurnal development of South Florida convection.
(3) Growth and development of cloud systems.
(4) Synoptic-scale influences on Florida convection.
(5) Relationships between cloud height and rainfall.
(6) Relationship between echo cover and rainfall.
(7) Surface effects on the development of cumulus convection.

An additional case study day from FACE will be selected to investigate the response of convective clouds to dynamic seeding, as determined from observations and the Colorado State University three-dimensional model. Intercomparisons will be made between observations and numerical model results. The surface and in-cloud data for a number of days from FACE-1975 will also be analyzed to investigate the feedback mechanisms between developing convection and the surface boundary layer. This study is intended to verify the indication, from several earlier case studies, that the faster the vertical growth of a convective system is, the larger is the resulting boundary layer convergence beneath and around the convective system. This relationship is thought to occur through the effects of surface pressure perturbations.

The relationship between convergence and rainfall will continue to be studied with VIN 1979 Illinois data. The data will be stratified according to windspeed, shear, humidity, stability, and other parameters, to improve definition of the relationship. Attention will be given to the vertical profile of convergence in the lower few kilometers, obtained from balloon sounding. The data will be examined to determine whether the somewhat less well-defined convergence-rainfall relation from Illinois, compared with that of Florida (determined from surface data), is due to wind patterns aloft. Studies of a major outflow interaction and mesoscale storm formation in the VIN network in 1979 will be made in collaboration with the Illinois State Water Survey and the University of Virginia.

Cloud-to-ground lightning will continue to be related to FACE radar data, in studies of the relationships between cloud-to-ground lightning and cloud height, rise rate, size, intensity, and stage of cloud life cycle.

CLOUD MICROPHYSICS

The cloud physics analyses of FACE-2 are expected to be completed during FY 1982 and FY 1983. Further studies will seek to evaluate seeding on the basis of the cloud physics data. Additional studies of cloud liquid water, vertical continuity of cloud processes, and cloud entrainment are also anticipated. Formvar replicas of cloud particles will be examined with a scanning electron microscope to determine the proportions of cloud drops and ice crystals for the samples collected before and after seeding. An X-ray energy spectrometer will be used to detect any silver and/or iodine in the ice nuclei at the center of the ice crystals.

BOUNDARY LAYER

A detailed plan will be devised for aircraft boundary layer studies to be incorporated into the overall operations plan for CDMP in 1983. In the subcloud layer, the studies will be aimed at understanding the influence of surface heating and associated land use patterns of surface moisture on turbulent motion, updrafts and downdrafts, and the fluxes of heat and momentum. The development of the spectra of the turbulent parameters and the properties of updrafts and downdrafts in seeded and unseeded conditions will be determined in order to explore the influence of seeding on the microphysical processes involved in cloud growth.

MESOMETEOROLOGY DIVISION

The Mesometeorology Division seeks to advance understanding of mesoscale weather phenomena and develops aids and techniques that improve forecasting skills and warning

procedures for weather events that significantly affect human activities. As part of the national effort to improve short-range weather forecasts and services, the division develops and transfers fundamental meteorological diagnostic and modeling technology to the operational services.

Accomplishments FY 1981

MESOSCALE CONVECTIVE COMPLEXES

The life cycles of mesoscale convective complexes (MCC) as viewed from satellite images were documented, and the synptic conditions associated with MCC development and demise were established as forecasting aids. Typical conditions include a pronounced low-level southerly jet over the region in early evening, large low-level moisture content (more than 10 grams per kilogram), and quasi-geostrophically forced upward motion (warm air advection), usually in advance of a weak shortwave trough. The airmasses in which the storms develop are usually very unstable. The contribution of MCC precipitation to warm-season rainfall in the United States was evaluated and estimated to be as much as 60%.

FLASH FLOODS

A study of flash floods in Texas revealed the complicated interplay of several focusing mechanisms that impinged upon a region of elevated terrain: a pool of cold surface air; a narrow wedge of tropical air with very high moisture content feeding northward from the Gulf; a middle layer of dry air intruding from the southeast; a shortwave trough approaching from the southwest.

A climatological study of flash flood events in a six-state area centered on the Tulsa River Forecast District has been undertaken in support of the National Weather Service's Flash Flood Program. Data have been assembled and tabulated, and significant events have been selected. The study is scheduled for completion in FY 1982.

Continuing interactions with NWS include courses taught at the Kansas City Training Center and seminars at the National Meteorological Center's Central, Southern, and Western Region Headquarters.

SATELLITE APPLICATIONS

OWRM

The Griffith/Woodley satellite rainfall estimation technique is being adapted for use over the grain belt of the United States in cooperation with the AgRISTARS (Agricultural Resources Inventory Surveys through Atmospheric Remote Sensing) program. Model adjustment factors, which improve estimates based on tropical (South Florida) to middle latitude atmospheric conditions, were calculated on the basis of a one-dimensional cloud model at 34 sounding sites over the central United States for August 1979. Assessment of the revised technique is in progress.

Hourly satellite rainfall estimations for the Wolf Basin, Tenn., flood of 1979 were used to initialize a hydrological model, producing results comparable with those using other initialization data sources. Absolute accuracy of the estimates was within 1% of ground truth. However, for a wintertime convective precipitation event over the same basin, satellite estimates were low by 46%. This was in line with expectations, since the necessary development work adapting the technique to winter precipitation has not yet been accomplished (see Plans FY 1982).

Satellite rainfall estimations for 49 of the FACE-2 GO days (1978-1980) were evaluated and will provide a basis for analyzing the extra-area effects of seeding.

A standard verification for rainfall estimation from remote platforms was developed. A preliminary assessment of the accuracy of the Griffith/Woodley satellite rainfall technique using FACE rain gage network data indicates that estimates are systematically high by 15% when made for longer periods. Work is in progress to isolate errors due to density of rain gages and determine their contribution to overall error.

NUMERICAL MODELING

Two numerical simulations were made using the Fritsch 20-level mesoscale convection model to determine the relative contribution of the direct incorporation of cold air to

the production of mesohighs in the vicinity of the tropopause. The results suggest that direct cooling by overshooting cloud tops plays only a secondary role in the production of mesohighs aloft. The cooling was accomplished primarily by adiabatic expansion in response to the mesoscale lifting induced by the convection.

A new mixed-phase version of the OWRM terrain model accomplishes the explicit prediction of both the mixing ratio and number concentration of mixed-phase particles as well as rain drops and three types of ice. Freezing of rain drops and melting of ice crystals are included as physical processes.

The warm-rain version of the OWRM model was modified to run with the terrain surrounding the Alsace plain on the French-German border. The experiment simulated the orographically induced precipitation that was apparently enhanced by "natural seeding" when large rain drops from an upper cloud layer fell and grew by coalescence in the lower cloud layer resting on the summit of the Black Forest. The maximum model-predicted rainfall agreed with observations both in magnitude and location. However, the observed rainfall over the plain was not simulated since the model does not yet incorporate the effects of larger scale (synoptic) vertical motions.

A surface radiation and energy budget package has been incorporated into the warm-rain model, and initial testing has begun in preparation for HAMEC (Hawaiian Mesoscale Energy and Climate Project) model runs.

HAMEC

The HAMEC Data User's Guide and RFC WP-3 aircraft data sets were printed and distributed to participating investigators, and a workshop on the data and preliminary results was sponsored by OWRM.

A study of WP-3 wind data revealed vortices downwind of the Island of Hawaii, in agreement with numerical simulations of the lower tropospheric flow.

NASA (LEWIS) PROJECT

NASA-Lewis is involved in a project to assess the utility of in-flight recorded and transmitted winds for analyzing the upper tropospheric flow along Atlantic air routes for the eventual purpose of selecting fuel-efficient routes. OWRM developed an objective analysis and display technique, which we applied to several test data sets provided by NASA.

EPOCS

Hourly satellite data for August 1979 have been processed to produce estimates of rainfall over the Central Pacific.

PROFS

In preparation for the PROFS 1981 ongoing forecasting evaluation tests, OWRM developed and presented a 2-wk seminar on forecasting severe thunderstorms in Colorado. An OWRM Technical Memorandum summarizes some of the course material, which included climatological aspects, reanalysis techniques for facsimile products, satellite data interpretation, and NWS Denver operations during severe-weather events.

Three OWRM forecasters participated in the PROFS displaced real-time forecast and warning exercises, and will provide evaluations of the PROFS Exploratory Development Facility's data-processing systems during the first month of FY 1982.

A study of the PROFS surface network data suggests that the information is useful for 1- to 3-h forecasts, but not much beyond.

SESAME

The SESAME Office assists researchers in acquiring information concerning the 1979 field experiment and its data sets. Toward this end, preliminary analyses were presented and discussed at a workshop cosponsored by NASA; in addition, several reports were printed and distributed, including the SESAME Data User's Guide, and SESAME news (in the Bulletin of the American Meteorological Society) served to keep researchers abreast of progress in

several subprogram areas. A study of surface pressure measurements at supplementary rawinsonde stations revealed that several calibration corrections are necessary, and graphics display software was developed for the AVE (Atmospheric Variability Experiment)/ SESAME sounding data to be used for assessing the quality of the data sets. A study of surface patterns observed during the 10 April 1979 tornadic storms suggests that several interwoven causal mechanisms were at play in initiating the storms. The SESAME steering committee has been replaced by a smaller working group known as the SESAME Council whose principal function is to promote analysis and modeling of the SESAME 1979 data and application of the research results.

OTHER MESOSCALE STUDIES

A diagnostic study of the Denver tornadoes (3 June 1981) indicated that (1) ambient conditions typical of Colorado severe-weather events preceded the storms, (2) first convection developed over the continental divide west of Denver, (3) later convection developed over a preexisting zone of convergence, and cyclonic vorticity lay in the South Platte River valley along the path the storms eventually took, and (4) the vorticity source for the tornadoes was probably this zone since upper-level shear was not strong. The South Platte convergence zone has been noted on several occasions since the PROFS data became available in early 1981, and it is hypothesized that this flow feature may explain the relative climatological maximum of Colorado tornadoes and funnel clouds that occurs just northeast of Denver.

High-based thunderstorms that produce strong downdraft winds at the surface (in excess of 20 meters per second) were investigated in another study. The ambient surface is typically characterized by an elevated moisture layer, a dry, adiabatic mixed layer extending from the surface to about 500 millibars, and only moderate instability above the level of free convection. On the basis of the study and a considerable amount of less quantifiable information, it is hypothesized that the weaker updrafts associated with this category of severe thunderstorm produce precipitation in the form of small rimed snowflakes, rather than graupel and hail, which are associated with stronger updrafts, and that this ice mass evaporates rapidly to produce the chilling necessary to start the downdraft toward the surface. The hypothesis is to be tested in a simple one-dimensional model.

A review of severe-thunderstorm forecasting based upon conventional products determined that the techniques applied during the last 30 years work well with strongly baroclinic, intense synoptic settings, but that potentially dangerous thunderstorms also occur within considerably more benign and subtle environments. An apparently dominant trigger mechanism common in the development of the latter-type storm is very pronounced, lower tropospheric warm-air advection. The general criteria for forecasting severe thunderstorms in "benign" synoptic conditions are under investigation. **OWRM**

Several studies of the affect of severe thunderstorms on general aviation were undertaken and will be completed in FY 1982.

Studies of airborne-infrared-radiometer data showed that the radiometer detects clear-air turbulence 2 to 9 minutes in advance of an encounter and has a very low false-alarm rate. The feasibility of using a similar instrument for detecting low-level wind shear (horizontal temperature gradients along gust fronts) during glide path approaches to airports was demonstrated theoretically.

Plans FY 1982

The principal activities in FY 1982 will continue to be concentrated in three areas: diagnostic studies of convective precipitation events and processes; development and refinement of the satellite rainfall estimation technique; development, refinement, and testing of mesoscale numerical weather simulation models.

Surface features associated with MCC's will be described. We also plan to begin an in-depth study of an MCC occurrence during the SESAME 1979 field experiment.

The climatology of central U.S. flash flood events for the past 10 years will be completed, and typical synoptic conditions associated with the major events and suggested forecasting guidelines will be described.

The study of model adjustment factors for rainfall estimation in temperate climates will be completed. A conceptual model for estimation of wintertime precipitation will be developed

and tested in conjunction with the AgRISTARS program. Using the EPOCS oceanic data sets, sensitivity tests utilizing satellite data degraded in both time and space will determine the minimum resolution necessary for accurate precipitation estimations compared with other estimation techniques. Extra-area effects of cloud seeding on 49 FACE-2 GO days will be evaluated from satellite-derived rainfall estimates. Rainfall estimates are being supplied to several other projects through informal agreements.

Advances in mesoscale numerical weather simulations are expected to include incorporation of a Fritsch/Chappell convective parameterization, more finely tuned mixed-phase microphysics, constituent conservation equations, and a beginning look at incorporating "live" boundary and initial conditions. The model code will be simplified through incorporation of a more efficient time-filtering scheme. A model version including the surface radiation and convective parameterization packages will be run for a Florida sea breeze case with mesoscale forcing that is relatively simple and well defined. Warm-rain model runs will be accomplished on the HAMEC data sets. Division personnel will participate in WATREX (Western Atlantic Tropical Rain Experiment) to collect additional data for model testing.

Dry thunderstorm downdrafts and their effect on airport operations will be studied with a view toward improving forecasting skill.

A study of dying tropical storms over land is expected to provide insights into the mechanisms that focus heavy precipitation in some areas.

Selected studies of Colorado tornadoes and downslope windstorms are expected to provide further understanding of the forecasting problems associated with these events.

We will continue our interactions with NWS operational units, providing training courses, seminars, and cooperative research and development. We also expect to continue to be involved in the NWS Flash Flood Program, although the nature of this interaction is yet to be determined.

Our participation and interaction with the PROFS program will continue with OWRM-provided training and evaluations. The details of other interactions are still under discussion.

During FY 1982, the SESAME Office expects to support analysis workshops, monitor the status of the various data sets, and continue providing news of interest to investigators.

The division will continue to support and operate the OWRM Weather Station, which provides current weather forecasts to several ERL activities, to NCAR, and occasionally to nongovernment interests. We are seeking the means to make this operation more efficient and cost effective through tie-ins with better data taps and interactive communications.

In an effort to coordinate mesoscale research and application activities among experts at various local organizations (e.g., NCAR, CSU, PROFS), OWRM will sponsor with NCAR a series of workshops to explore mechanisms for developing such interactions.

COOPERATIVE AGREEMENTS

The informal working relationship between the OWRM modeling group and the University of Clermont-Ferrand, France, will continue with assignment of a graduate student to Boulder to assist in developing the constituent conservation algorithm that will expand the applicability of the model to such problems as acid rain and pollutant transport.

RESEARCH SUPPORT GROUP

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

Accomplishments FY 1981

Surface and air temperatures inferred from infrared radiation measurements taken during the HAMEC project were evaluated. Discrepancies between the actual surface temperature and the temperature of the surface implied from the infrared radiometer measurements led to extensive reevaluation of the instrument. Laboratory tests, in which the radiometer was subjected to simulated aircraft conditions, showed that cooling of the outermost optical element of the radiometer caused an error in the indicated temperature. This instrument error, which can be as large as several degrees, is dependent on the material from which the optical element is made as well as the configuration of the instrument mount on the aircraft. A second error in the radiometric measurement of surface temperature from the aircraft is due to the absorption of the water vapor between the surface and the measuring aircraft. This error, determined from the sophisticated radiation model FASCOD, can be as large as 15°C if the temperature of a hot surface is being measured through a cool, humid atmosphere. For more typical atmospheric conditions, errors of ~5°C should be expected for measurements made from altitudes above 1 kilometer.

Plans FY 1982

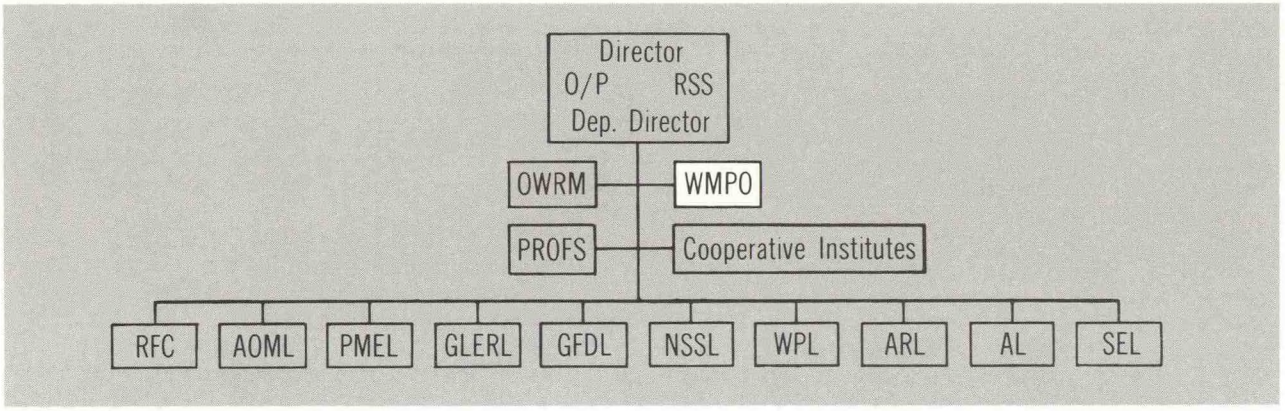
Infrared measurements of surface and air temperature will be important to future OWRM field programs. RSG will continue its efforts to understand the atmospheric effects on these measurements and improve the calibration stability of infrared radiometers used on research aircraft.

In particular, analysis of surface radiation measurements will continue. Although the errors due to the cooling of the radiometer lens by air in its immediate vicinity are understood, the relationship between the temperature of this air and the temperature of the undisturbed environmental air is not known. This relation will be determined by flight tests of radiometers mounted in several configurations on various aircraft. Corrections due to water vapor absorption will be computed with several models. The goal is to determine whether a sufficiently accurate correction can be made by a model simple enough to be run on a microcomputer. If this is possible, an instrument system can be built in which indicated surface temperatures can be corrected in real time to give accurate surface temperature.

A more accurate, fast-response infrared radiometer designed in FY 1981 will be assembled and tested. It is expected that the combination of a cryogenically cooled detector and a narrow filter will allow mapping, on a scale of several hundred meters, of temperatures along a flight path both in and out of clouds.

WEATHER MODIFICATION PROGRAM OFFICE
Boulder, Colorado

Merlin Williams
Director



The Weather Modification Program Office (WMPO) is responsible for coordinating ERL weather modification activities, including international aspects, developing new concepts, and transferring weather modification technologies to users. WMPO also evaluates the social, legal, and economic aspects of ERL weather modification programs. It provides technical advice to the Director of ERL on weather modification research activities in ERL, and it provides advisory services on weather modification applications to U.S. Government agencies and foreign governments.

Accomplishments FY 1981

The airborne Doppler was tested in the Muskegon, Mich., area with the assistance of CHILL ground-based Doppler radar. Both vertical- and horizontal-pointing types were tested. Analysis of the data showed a fault with the Doppler radar. Data when corrected for the radar fault showed strong correlation with the ground-based Doppler radar. The final report on the Doppler was published in August 1981 as a NOAA Technical Memorandum. Responsibility for the continued development and test has been given to RFC.

WM

The Weather Modification Program Office (WMPO) supported two CIRES Fellows and one contract activity with CIRA during FY 1981. The two CIRES Fellows were engaged primarily in research activities directed toward estimation of natural precipitation efficiency. These activities involved estimates of water vapor differences on the mesoscale and observation of snowfall characteristics on the microscale. The CIRA contract provided support for activities by outside scientists to develop a long-range plan for weather modification research. Publications for both of these activities are pending.

Plans FY 1982

WMPO will conduct a series of six small-scale studies designed to contribute to long-range planning for mesoscale research activities. The first of these is a cooperative effort with CIRA to study factors involved in precipitation efficiency of winter orographic storms. These activities will utilize techniques previously developed in WMPO for estimating mesoscale precipitation efficiency. There will also be a detailed snowfall analysis to predict precipitation efficiency for various cloud conditions and to provide comparisons with more direct physical measures made by cooperating groups. In addition, remote-sensing equipment will be employed to supplement detailed measurements by other groups.

Support will be given to RFC when the radar is tested during the CYCLES project and when the radar is lent to NCAR for installation on its Kingair aircraft for use during the JAWS project.

A second activity is under way to assess the requirements for and suitability of various types of remote-sensing equipment, for use in meteorological investigations. Included in these instruments are Doppler radar, Doppler lidar, dual-channel radiometer, and acoustic

sounders. It is anticipated that we shall produce specifications that can be used for guidelines in future instrument development.

Transfer of meteorological instrumentation by means of the ADDS technology to the Air Force hurricane reconnaissance program is continuing. This program consists of the design, specification, testing, procurement, and installation of data systems for use by the Air Force for routine collection of hurricane information. It is expected that this system will become operational in FY 1982.

The monitoring and administration of the Federal-State cooperative activities with North Dakota and Utah will continue during FY 1982. Analysis of the data collected during FY 1981 by the appropriate contractors and WMPO will constitute the major portion of the activity. Data archiving and management will be conducted by WMPO.

Activities will continue in the planning and development of background information for a major initiative to organize atmospheric studies in the energy-developing areas of the Rocky Mountain region. These studies will concentrate on atmospheric transport and diffusion processes in complex terrain, and are expected to provide the basis for a capability to predict air quality. The studies will aim to facilitate development of energy resources with the least possible environmental impact.

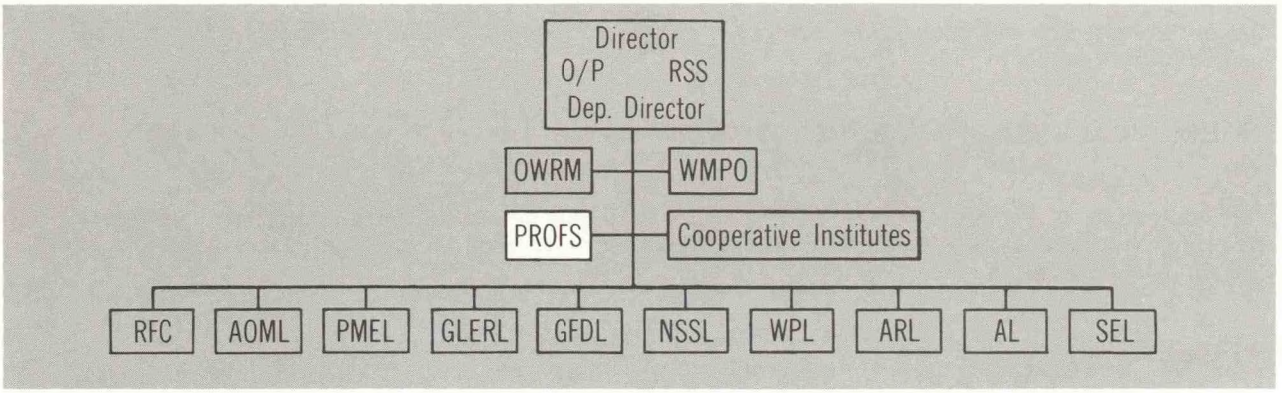
WMPO will continue its activities through CIRA to develop a long-range plan for weather modification research. These studies were initiated in FY 1981 and are expected to continue through FY 1982. The resulting plan will serve as a basis for planning NOAA's overall weather modification effort.

It is anticipated that support for the two CIRES Fellows will continue in FY 1982 and will emphasize cooperative efforts with CIRA. These efforts are designed to test and verify the precipitation efficiency studies conducted in FY 1981. The contractual support to CIRA for long-range planning is expected to continue with completion by the end of the fiscal year.

PROTOTYPE REGIONAL OBSERVING AND FORECASTING SERVICE PROGRAM OFFICE

Boulder, Colorado

Donald W. Beran
Director



The Prototype Regional Observing and Forecasting Service (PROFS) Program Office works to improve local weather services through the introduction of new technologies into weather service operations. PROFS is an Environmental Research Laboratory program, but it also receives guidance and review from the National Weather Service (NWS) and National Earth Satellite Service. NWS has assigned two senior people, a meteorologist and a systems engineer, to the Management staff of PROFS. They work closely with the PROFS Director and strive to maintain a balance between the research and operational communities within PROFS.

Accomplishments FY 1981

The major achievement was completion of the first two stages of a summer convective-storm exercise. These stages concentrated on collecting and archiving data from four sources: a surface mesonetwork of 20 automated weather stations, radar, satellite, and NWS's national data lines. The exercise was the first demonstration of the capability in the PROFS Exploratory Development Facility (EDF). PROFS can now acquire, interactively manipulate, and display data from many sources. This provides a new capability for technology evaluation, system design, and advanced system demonstration within NOAA.

The third stage of the exercise (to begin in October 1981) will bring operational forecasters to PROFS to participate in displaced real-time testing of forecasting techniques and workstation configurations. The forecasters will use the data sets collected during the summer of 1981.

A promising dissemination technique, Automated Warning Dissemination Systems (AWADS), is under development. By the use of a display screen, a light pen, and computer files of emergency telephone numbers, a severe-storm warning can be sent rapidly to all appropriate individuals and agencies in the affected area. This system can potentially reduce severe-storm warning time by several minutes.

Plans FY 1982

(1) Enhance EDF through the addition of real-time hardware and software capability, Doppler radar and Profiler (developed by the Wave Propagation Laboratory) data, and by increasing the ingest rates of conventional satellite and radar data.

(2) Conduct real-time operational exercises at the Denver NWS Forecast Office and the Longmont FAA Regional Air Traffic Control Center.

(3) Collect additional meteorological data sets that include Doppler radar and Profiler information for use in more complex, displaced real-time testing.

(4) Continue displaced real-time evaluations, using more complex meteorological data sets to extend our knowledge beyond workstation environment and into an examination of specific sensor performance, forecasting techniques, and integrated systems.

(5) Complete the preliminary functional design specifications for our Phase I objective, to improve severe-storm watches and warnings through a recommended design for the improvement of NWS field offices.

SYSTEM ANALYSIS AND DESIGN (SA&D)

This group is responsible for the analysis and design of weather information systems. It provides detailed system design of EDF, backup studies for future system elements, and conceptual operational system designs.

Accomplishments FY 1981

The group completed plans for the 1981 exercise and did the detailed designs for the three stages of the PROFS internal test series. It also completed top-level design of the FY-1982 test configuration.

Plans FY 1982

The group will complete the detailed system design of EDF and implement the 1982 phase of the design to support real-time and displaced real-time evaluation. It is beginning to work with NWS on a cost/benefit analysis of system elements and will complete conceptual system design for the NWS System II follow-on to AFOS.

EXPLORATORY DEVELOPMENT FACILITY (EDF)

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

Accomplishments FY 1981

The full complement of three computers for data acquisition, processing, and meteorological product distribution was acquired and placed in operation. Digital data lines and computerized interface equipment have been developed and implemented to acquire NWS weather radar data from Limon, Colo., and Cheyenne, Wyo. EDF successfully ingested and recorded satellite, radar, and mesoscale surface network data during the summer convective storm exercise. Automated collection of data continued for the remainder of the year. Archiving of the 20-station PROFS mesonetwork data has been initiated by the State Climatologist at Colorado State University. A portion of EDF was reconfigured to support the generation of displaced real-time display products and their evaluation for selected 1981 severe-weather events.

Plans FY 1982

In cooperation with NCAR, EDF will acquire Doppler radar data and will participate in the development of a joint satellite receiving facility in Boulder. Ingest of the national weather data base will be accomplished through the FAA 604 line and AFOS. Lightning data and Denver's Urban Drainage and Flood Control District stream gage and precipitation data will be acquired.

Sophisticated interactive real-time display systems will be developed and deployed at EDF and at the Denver NWS Forecast Office. An intensive data collection effort will be undertaken during the 1982 convective-storm season for real-time and displaced real-time work.

EXPLORATORY DEVELOPMENT GROUP (EDG)

This group selects, tailors, and evaluates new technologies for use in advanced system design.

Accomplishments FY 1981

The major accomplishments of EDG related to meteorological aspects of the summer convective-storm exercise. EDG took the lead in planning a displaced real-time test in which meteorologists used the PROFS workstation in systematic tests of requirements. EDG developed application programs that manipulate and combine satellite, radar, and conventional data, and display them on sophisticated computer image devices.

Plans FY 1982

EDG will work in four areas:

(1) Identification of meteorological and technological elements suitable for technology transfer.

(2) Testing of elements identified for transfer. This year Doppler radar wind measurement techniques, Profiler capabilities, and VAS mesoscale satellite sounding techniques will be among the elements tested.

(3) Displaced real-time testing (DRT). This is the major test series to be conducted on canned data sets. This year's DRT tests will concentrate on the update interval of data required for warnings. Satellite, radar, and mesonet data will be tested for data update intervals of 3 to 30 minutes.

(4) Real-time testing. The PROFS 1982 real-time test will occur in the PROFS Forecast Office and at the Denver Forecast Office of NWS. It will include radar, mesonet, and other data at 5-min update intervals and satellite data at 30-min update intervals. It will provide a set of workstation capabilities very similar to those developed for the PROFS 1981 displaced real-time test.

TEST AND EVALUATION (T&E)

The group is responsible for the following:

(1) Verifying system performance (dependability and accuracy) of all functions of EDF (data acquisition, data quality control, timeliness of system response).

(2) Validating overall system performance for subsystems of EDF that are implemented within the Denver Forecast Office of NWS or any other organization external to PROFS.

(3) Conducting objective evaluation tests to determine the degree of improvement attained in nowcasts and forecasts as a result of the technique evaluation exercises conducted by EDG.

Accomplishments FY 1981

The Test and Evaluation group was created, and it accomplished two major tasks:

(1) During the 1981 convective storm exercise T&E assessed the reliability of all sources of data (surface mesonetwork, radar, satellite, AFOS) that came into EDF.

(2) After the 1981 exercise the group began to study the quality of the surface mesonetwork parameters (temperature, dewpoint, windspeed and wind direction, etc.) as a continuing data quality control function.

Plans FY 1982

T&E's task for the coming year is to develop a plan for implementing and evaluating that portion of the real-time operational 1982 exercise which will take place at the NWS Forecast Office in Denver. The plan must address the implementation, usefulness, and reliability of hardware and software, and will include a meteorological evaluation: Have local forecasts of severe weather improved from the use of new techniques?

INTERAGENCY COORDINATION AND PRODUCT IMPLEMENTATION

This group collects and analyzes local weather service requirements. It is the liaison between PROFS and other governmental and private groups, and is responsible for coordinating operational implementation of PROFS systems.

Accomplishments FY 1981

(1) A detailed analysis of mesoscale service users' requirements was completed, and a comprehensive requirements document, providing the basis for PROFS system development activities, was prepared.

(2) Close liaison has been maintained with various levels of NWS to ensure compatibility with current and future NWS operational requirements.

(3) 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.

(4) Economic value analyses of specific short-range forecasts were begun and will be completed in FY 1982.

(5) An automated warning dissemination network was designed using the NWS Forecast Office in Denver as the example warning office.

Plans FY 1982

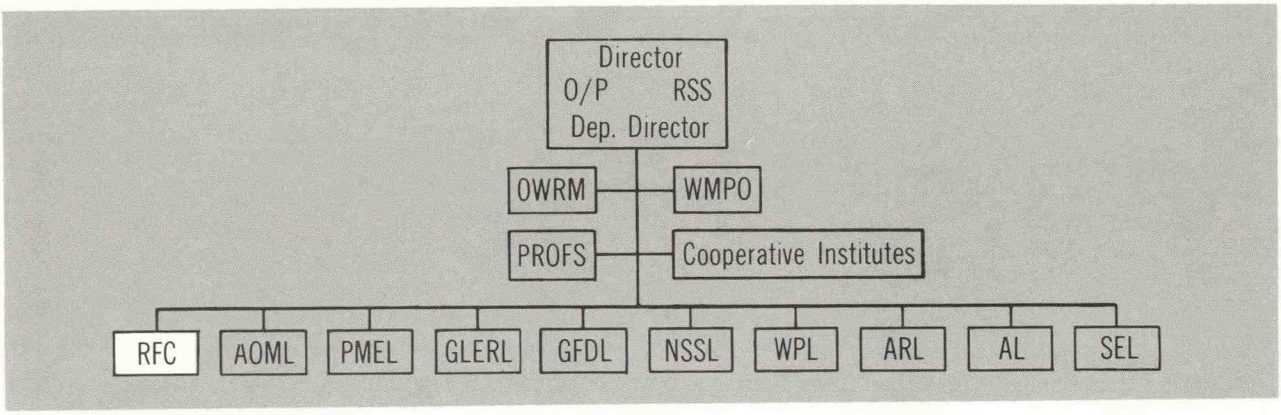
Documentation of user service requirements will be updated late in 1982. Close coordination will be continued with NWS for the effective handoff of an automated warning dissemination network design, which will be generalized to most NWS warning offices. Economic value analyses of short-range forecasts to the electricity generation industry, urban snow removal operations, and energy management will be completed. Cooperative demonstration programs with the FAA and NASA will be initiated to test the utility of various mesoscale service products in the aviation operational environment.

COOPERATIVE PROGRAMS

In addition to its internal work, PROFS does extensive cooperative work with other groups. Two of those are NOAA institutes: CIRA at Colorado State University in 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 Director of Forecast Operations at the Royal Netherlands Meteorological Institute, who joined CIRES in January 1981, has worked with PROFS staff on the application of research results to practical forecasting situations. Another cooperative effort involves the Advanced Technology Division of the National Center for Atmospheric Research in a program to incorporate Doppler radar technologies into PROFS observational capabilities.

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 1981, RFC operated two WP-3D and one C-130B, four-engine turboprop aircraft. All three aircraft carry a multitude of sophisticated research systems capable of measuring a wide range of atmospheric and oceanic parameters.

Accomplishments FY 1981

RFC continued to improve its airborne scientific research systems for infrared radiometry, aerosol sampling, bulk water collection, and hot-film and pitot-tube anemometry. Several of these systems were developed and installed on the aircraft in direct response to user requirements. Designs are being completed for permanent inclusion in the RFC package of research capabilities.

RFC completed the design, fabrication, and installation of the Aircraft Satellite Data Link (ASDL) on a U.S. Air Force reconnaissance aircraft. Late in the year, RFC also completed the interface design, fabrication, and associated software linking the ASDL with the NOAA ADDS (Atmospheric Distributed Data System) which has also been installed on a USAF reconnaissance aircraft.

Other project-specific installations, checkouts, and program participation accomplished during FY 1981 included the NASA Langley stepped-frequency radiometer and surface scatterometer, the ERL Airborne Doppler Radar, the Sea-Air Interaction Laboratory (SAIL/AOML) laser wave-height and radar-imaging systems, and the USAF Flight Dynamics Laboratory's lightning system.

Significant progress has been made in technique development and application at RFC's calibration facility. Methods for precision static calibration of various pressure, temperature, and dewpoint sensors have been developed and standardized, and procedures have been initiated for routine data quality assurance. Development work is continuing in the dynamic

calibration area, with completion of the design for a remotely controlled, tower-mounted instrument package.

RFC supported the following research programs during FY 1981 with 692.8 hours flown by the turboprop aircraft:

- Equatorial Pacific Ocean Climate Studies (EPOCS)
- Tall Islands Vortices Program
- U.S. Navy AXBT Performance Program
- Winter Storms--Upslope Study
- Storm Transfer and Response Experiment (STREX)
- Airborne Doppler Development
- Irregular Terrain Boundary Layer Study
- Florida Sea Breeze Program
- Coastal Waves Study
- Hurricane Research Program
- Hurricane Reconnaissance
- U.S. Air Force Flight Dynamics Laboratory Lightning Program

EQUATORIAL PACIFIC OCEAN CLIMATE STUDIES (EPOCS)

In support of an EPOCS objective to investigate the significant air-sea processes in the production, maintenance, and dissipation of major ocean cloud systems, RFC flew 90.1 hours with N42RF (WP-3D). Of these flight hours, 20.6 were from Acapulco, Mexico, and 69.5 were from San Diego, Calif. To support the full array of programs that are relevant to EPOCS, the aircraft carried radar, gust probe, and solar short- and long-wave radiation systems, in addition to atmospheric dynamics and cloud physics instrumentation.

TALL ISLANDS VORTICES

While in San Diego in support of EPOCS, N42RF flew an additional 18.4 hours in support of the Tall Islands Vortices Program. The objective of this program was to define the three-dimensional structure of the airflow within atmospheric vortices of a tall island--in this case, Guadalupe, Mexico. Flight patterns were designed so that, in addition to the structure, the downwind extent and the rate of shedding of vortices downwind of the island were studied.

AXBT PERFORMANCE AND INTERCOMPARISON TESTS

Flights were conducted over the Acoustic Tomography Experiment Area of the Atlantic to test the performance of the newly designed deep AXBTs (Aircraft Expendable Bathythermographs), compare these with the standard operational units, and map the thermal structure of the ocean over the test area. The WP-3D (N42RF, N43RF) aircraft supported this program with 36.7 flight hours.

DYNAMICS AND PHYSICS OF UPSLOPE CLOUD SYSTEMS

N43RF made one flight totaling 5.3 hours in support of this program. The area of investigation was northeastern Colorado and parts of Wyoming, Nebraska, and Kansas. The objective of the flight program was to collect the relevant data for the characterization of the thermodynamic and dynamic structures of upslope storms in terms of the microphysics and the dynamic dispersion mechanisms.

STORM TRANSFER AND RESPONSE EXPERIMENT (STREX)

N43RF was deployed to Seattle in support of the STREX program. A total of 105.6 hours was flown over the Gulf of Alaska. The objective of the program was to specify the structure of the atmospheric boundary layer of the mature Pacific extratropical cyclonic storms and to determine the interaction of the passage of such storms with the oceanic mixed layer.

DOPPLER RADAR DEVELOPMENT

In support of the developmental work to modify the WP-3D tail radar (X-band, RHI) to operate in a Doppler mode, N42RF flew 9.2 hours. The flight was over Muskegon, Mich., where the CHILL (Chicago-Illinois) radar was operational.

GUST PROBE FLIGHT OVER IRREGULAR TERRAIN

In support of boundary layer measurements of momentum, heat, and moisture fluxes over complex terrain, N43RF flew 4.8 hours in northwestern Colorado.

SEA BREEZE

Both WP-3D aircraft participated in support of this program, flying 29.2 hours. The objective of the program was to collect atmospheric measurements relevant to the description of the development of the mixed layer, the cloud layer, and the sea breeze circulation over the southern Florida peninsula.

COASTAL WAVES STUDY

RFC supported the Coastal Waves Study with 8.8 hours flown, and the Data Buoy Search efforts with 14.8 hours flown on the C-130B.

HURRICANE RESEARCH AND RECONNAISSANCE

RFC was on alert for hurricane flights--research and reconnaissance--from 15 July through 31 October 1981. Both hurricane research and reconnaissance are multiyear programs.

The objective of the hurricane research program during FY 1981 was to improve microphysical measurements, especially of liquid water and ice crystals. The long-range objective 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.

Hurricane reconnaissance is conducted only when requested by CARCAH (Chief, Aerial Reconnaissance Coordination, All Hurricanes). Data are transmitted via the Aircraft Satellite Data Link (ASDL) to the National Hurricane Center for upgrading forecasting models of hurricane tracks/intensity.

The RFC responsibilities are to (1) augment USAF aircraft reconnaissance with high-density/accuracy data where storms are within 24 hours of landfall of the continental United States; (2) augment USAF aircraft reconnaissance when Department of Commerce needs exceed the capabilities of Department of Defense resources; and (3) assume responsibility for hurricane reconnaissance over foreign airspace from which military aircraft may be restricted. Totals of 56.0 hours of research and 136.3 hours of reconnaissance were flown in FY 1981.

LIGHTNING PROJECT

The objective of this program is to characterize the natural lightning environment and to identify lightning-aircraft interaction mechanisms that could affect flight safety. Specific characteristics to be investigated are (1) the radiated electric and magnetic transient fields produced by a lightning flash, (2) aircraft skin current and surface charge distribution resulting from field transients and direct strikes, and (3) the induced transients on representative interior aircraft wiring. A total of 46.8 hours was flown by the C-130B in FY 1981 in support of this effort.

THE HELICOPTER OPERATIONS GROUP

In support of OCSEAP and the Bureau of Land Management, the four UH-1 helicopters flew 1046 hours in FY 1981. The program distribution was as follows:

Alaska Seismic Activity Monitoring Network

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

Offshore Permafrost Study

The extent of permafrost on the Alaska continental shelf is being investigated by the University of Alaska for OCSEAP. Projects were flown in both the Chuckchi and Beaufort Sea regions.

Beaufort Sea Under-Ice Currents

Annual patterns of currents, predominantly nearshore, are under study in areas of the Arctic Coast being considered for oil lease. This project was concentrated between Flaxman Island and Cape Halkett.

Coastal Oil Spill Damage Susceptibility Assessment

Portions of the Alaska coast that may be affected by the opening of oil lease areas were studied to determine their susceptibility to both long- and short-term damage from oil spills. This effort was concentrated on the Kuskokwim and Bristol Bay areas.

Marine-Mammal Population Study

Investigations into the natural history and size of the ring seal population continued in the Simpson Lagoon, Harrison Bay, and Prudhoe Bay regions. Investigations were conducted from the helicopter; a camp on Pingok Island was also supported.

Arctic Bird Population Study

A camp for bird population studies was maintained on Cooper Island southeast of Barrow, Alaska, by the University of Alaska for OCSEAP. NOAA helicopters were used in the setup, maintenance, and removal of the camp.

Ice Pack Circulation in the Bering Sea

During spring a NOAA helicopter operated from the NOAA Ship Surveyor in the Bering Sea. Weather stations and positioning transponders were placed on portions of the ice pack between the Pribilof Islands and the Bering Strait to determine the relative importance of wind speed and direction, and surface currents on ice pack drift.

Under-Ice Algae

As part of the OCSEAP project to determine the variables of the food chain in the Beaufort Sea oil lease areas, this project studied the extent, makeup, and growth rate of the under-ice algae in Prudhoe and Harrison Bays.

Prudhoe Bay Marine Fauna

This project is an extensive study of the marine plant formations and animal populations in rocky areas of Prudhoe Bay known as the Boulder Patch. Helicopter support includes transportation of gear, portable buildings, and personnel to Narwhal Island, and to the camp at the research site when ice conditions permit.

Arctic Shoreline Ice Buildup

An extensive survey was conducted on shore buildup of sea ice on the Arctic coast. The area surveyed extended from Barter Island to Prudhoe Bay and from Nome to Point Barrow. Offshore, shallow-water ice buildups were also studied.

Plans FY 1982

With the elimination of the C-130B from its inventory in FY 1982, RFC plans to support the following programs with the two WP-3D aircraft and helicopters:

- Alpine Experiment (ALPEX), 200 flight hours
- Lake Erie Surface Wave Study, 30 flight hours
- New England Winter Storms, 15 flight hours
- Ice Crystals/Rocky Mountain Winter Clouds, 45 flight hours
- Radiative Processes, 18 flight hours
- Hurricane Research, Sea-Breeze and Air-Sea Interaction, 175 hours
- Marginal Ice Zone Experiment (MIZEX), 85 flight hours
- Cyclonic Extratropical Storms (CYCLES), 35 flight hours
- Pre-CDMP (Cumulus Dynamics and Microphysics), 12 hours
- OCSEAP, about 1,000 helicopter flight hours

Planned improvements to data quality control include the following:

- Complete spectral and statistical analysis data-handling package.
- Color graphics capability for radar data quality control.
- Sensitivity studies on critical variables.

RFC plans to make aircraft system improvements as follows:

- Replace video distribution system.
- Streamline analog data collection system.
- Replace graphics system and add hard-copy capability.
- Redesign and repackage selected components of data collection system for weight-space considerations.
- Upgrade flow-angle pressure transducers.
- Add alphanumeric capability to radar displays.
- Add Lyman-alpha system to one aircraft.
- Instrument all aircraft for radiometric measurements.
- Fabricate third AXBT system.
- Add automated radar calibration capability to all aircraft.
- Reinitiate procurement for replacement of radar altimeter systems.
- Install hot-film system.
- Develop gust probe system.
- Develop airborne Doppler radar system.

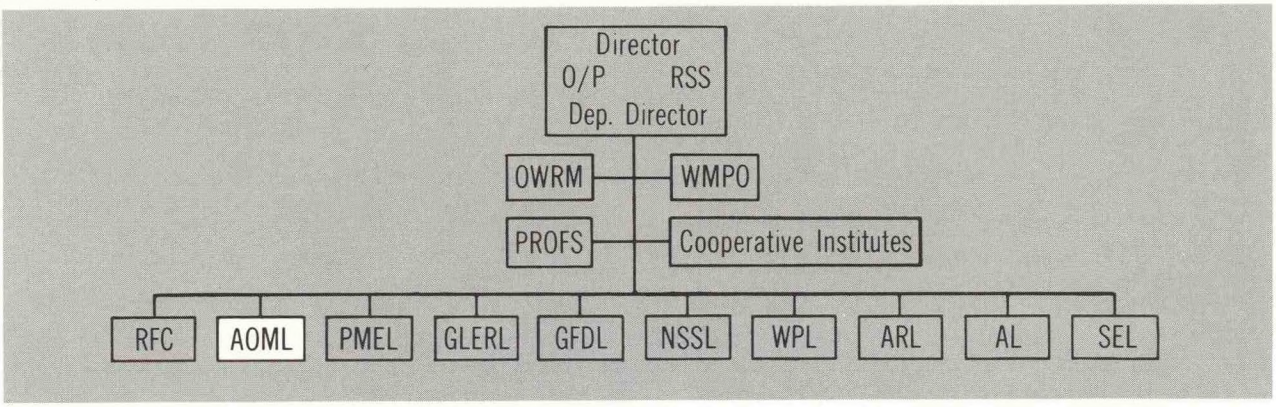
Continuing efforts to improve sensor calibrations will include the following:

- Install and integrate environmental chamber.
- Design and install pressure-vacuum calibration system.
- Design and fabricate tower instrumentation package.
- Develop techniques for system calibration.
- Complete error analyses of major calibration techniques.

ATLANTIC OCEANOGRAPHIC AND METEOROLOGICAL LABORATORIES

Miami, Florida

Hugo F. Bezdek
Director



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 the structure and dynamical processes of the seafloor. 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 environmental assessment, marine resources, ocean services, and weather prediction. 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--university laboratories, and overseas investigators, particularly in western Europe and South America.

Accomplishments FY 1981

Analysis and interpretation of data collected for the Global Weather Experiment in 1979 were completed, and results from an intensive investigation of the response of the Indian Ocean to the onset of the Asian monsoon were presented at the international SCOR (Scientific Committee on Oceanic Research) meeting in Venice. Results from this meeting will be published in several journal articles. These results currently provide the most definitive basis for evaluation of skill levels in modeling the response of the tropical oceans to variations in atmospheric circulation, a critical problem in understanding the mutual roles of the atmosphere and the ocean in determining climate variation.

The major climate-related activity of the Laboratory in 1981 was our continuing participation in the NOAA program, Equatorial Pacific Ocean Climate Studies (EPOCS). Laboratory personnel led three major research cruises into the eastern tropical Pacific Ocean. The research focus was on the structure and variability of the equatorial currents in the vicinity of 110°W, the transition of the Pacific Equatorial Undercurrent from the central Pacific to the

Galápagos Islands, microstructure and turbulent mixing in the intense current shear and density stratification characteristic of the equatorial region, and surface temperature and currents over a wide expanse of the eastern tropical Pacific Ocean. Among the results from this work may be cited the discovery of surprisingly vigorous mesoscale disturbances that appear between the Equator and about 6°N, from about 100°W to 130°W. These disturbances are believed to arise from a barotropic instability of the intense shear zone between the South Equatorial Current and the North Equatorial Current. They make this part of the tropical Pacific distinctly different from the central Pacific, and enormously complicate the problem of determining the variability in this part of the ocean.

A new program for climate, the Subtropical Atlantic Climate Studies (STACS), was initiated in FY 1981. This program was developed and is being executed as a joint activity with the Office of Technology and Engineering Services of OA, in which other NOAA components (PMEL, WPL, NOS) and some universities are participating. The major near-term objective of this program is to develop a technique and strategy for economical monitoring of the flow and temperature structure of the Florida Current. The motivating rationale for this work is to determine the importance of the Florida Current in the poleward transport of heat by the North Atlantic Ocean. Additionally, collection of consistent time series of flow and temperature over a number of years will provide an excellent data base for evaluation of skill levels in modeling the ocean circulation as an element in addressing a number of climate questions. In a sense, the Florida Current may provide an index to the vigor of circulation in the North Atlantic gyre. Systematically sampling the former can be a major U.S. contribution to future international climate research activities such as the Pilot Ocean Monitoring Study (POMS) or the Global Ocean Circulation Experiment. To this end, preparations were begun in FY 1981 to implement and test over a period of two or three years a combination of conventional, but costly, methods and some promising novel methods of observing the flow and temperature structure in order to select and calibrate an economical mix of techniques that could be continued for a decade or more. The novel methods under evaluation include electromagnetic induction, radar backscatter, and low-frequency acoustic transmission. Data from conventional methods, to be used for comparison, include moored current meter data, profiles of temperature, salinity, and currents from research vessels, and sea level measurements.

AOML scientists and the NOAA vessel Researcher participated in the STACS Local Tomography Experiment. This project, conducted in cooperation with scientists from MIT, WHOI, and SIO in the southern Sargasso Sea, will develop and test the technology and inversion algorithms for sampling the thermal structure and currents over scales of hundreds of kilometers, using low-frequency acoustic propagation between moored arrays. Three major research cruises were carried out for this project.

Plans FY 1982

During FY 1982, activities will continue to focus more strongly on a small number of major projects. The laboratory will continue its intensive participation in the EPOCS program. During FY 1982, and probably FY 1983, emphasis in the oceanographic component of this program will shift to the region between the coast of Peru and Ecuador out to about 95°W, where the El Niño anomaly is manifest earliest and most strongly. Primary objectives will be to determine circulation patterns in the "corner" where the Equator intersects the continent, and to observe propagation of current disturbances along the Equator from remote parts of the equatorial Pacific into and along the continental boundary. AOML staff will lead two major research cruises into the region in FY 1982. Cooperative arrangements have been worked out to assist oceanographers at the Instituto del Mar del Peru, Callao, in monitoring oceanographic conditions along the coast of Peru to the benefit of EPOCS and global climate research. Efforts are continuing to complete arrangements for a cooperative program with the Instituto Oceanográfico de la Armada, Guayaquil, Ecuador, for establishment of a ship-of-opportunity program between Guayaquil and the Galápagos Islands. Cooperation with Chilean scientists to obtain expendable bathythermograph (XBT) observations between Valparaiso and Juan Fernandez and Easter Islands is also being considered.

Analysis of data collected from the equatorial Atlantic Ocean during the Global Weather Experiment will continue. A scientist from AOML will spend the year working with oceanographers of the French Museum of National History on this data set. This work is conducted within the climate research component of the U.S.-France Cooperative Program in Oceanography, and is expected to foster the future international cooperation so important to climate research.

Analysis of data from the Local Tomography Experiment will proceed in concert with investigations from other organizations. AOML is responsible for collection and processing of the essential core initialization and verification data for this experiment. This year will also see initiation of the field phase of work on the Florida Current for the STACS program. A substantial effort is planned for implementation and evaluation of a novel Doppler acoustic current-profiling capability on the NOAA vessel Researcher. This activity, which could provide a real breakthrough in oceanographic sampling strategy, is being undertaken in cooperation with the NOAA Office of Technology and Engineering Services, National Ocean Survey, and possibly, the University of Miami and Scripps Institution of Oceanography.

Work will continue also on evaluation of poleward oceanic heat transport by larger scale process. Historical data sources will be used and ocean surface data from satellites will be applied to ocean circulation modeling in cooperation with scientists from Harvard University.

Late in FY 1981 a project was established to identify and exploit opportunities for using underwater acoustics to measure and study oceanic processes that cannot be measured using direct means because of economic or other constraints. The focus of the work is on wide-area oceanic processes where horizontal scales are large compared with the water depth. In 1982 work will start on the development of an inversion algorithm in support of the acoustic experiments to be conducted in the Straits of Florida as part of the STACS program.

MARINE ENVIRONMENT ASSESSMENT

A major goal of the AOML research programs in marine environmental 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) regional programs, such as the developing northern Gulf of Mexico Program, the Valencia Shelf Project off the Spanish coast, and the Flower Garden Banks Project, where processes are studied in terms of actual or pending environmental threats; and (2) basic programs, such as the Role of Organics in the Marine Environment (ROME) and Pollutant Particle Relationships in the Marine Environment (P-PRIME) in which natural processes themselves are studied to develop information necessary for conducting regional programs.

Accomplishments FY 1981

AOML continued research efforts on natural processes affecting fish resources in the northern Gulf of Mexico and potential pollutants' impacts on these processes. 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 organic material and bioactive metals on the food web and larval fish health for three target species that spawn in that area, i.e., spot, croaker, and Gulf menhaden. Results show that metals (copper, cadmium, zinc, and manganese) have clear effects on

- Primary productivity as measured by ^{14}C uptake.
- Amino acid turnover rates in marine bacteria as measured by ^{15}N turnover.
- Phytoplankton growth rates.

These effects can be modulated by naturally occurring organic materials through the formation of metal/organic complexes. One large class of these organic materials, fulvic and humic acids, has been isolated, its modulating effect demonstrated, and its structure characterized by both analysis and synthesis from laboratory stock reagents. These results represent major steps forward in an understanding of how ocean chemistry and its variations control and affect ocean productivity and health.

AOML has addressed the problem of identifying and tracking drilling fluid components that have been discharged into the marine environment in order to determine the degree to which these components have impacted an area. Suspended-matter barium (Ba) concentrations have proved to be a sensitive indicator of dispersion pathways. Particulate Ba distributions have enabled AOML to (1) identify rapid differential settling of much, but not all, of the barium relative to other constituents upon discharge; (2) note that deposits rich in barium sulfate ($BaSO_4$), common in sediments near a rig, are less susceptible to resuspension than normal aluminosilicate detritus, and (3) distinguish normal particle-rich layers in the water column from lenses of drilling materials. Organic tracers in petroleum-drilling fluid have made possible the identification of concentrations of particulate hydrocarbons at depths in

the water column not associated with other particles or density surfaces. Pattern distributions of sedimentary trace metals have proved to be a very sensitive indicator of the long-range transport of deposited material.

A 6-week cruise to the Flower Garden Banks area was carried out as part of the joint NOAA/EPA energy pass-through-funds program. Acoustical, hydrographical, and chemical data gathered during the cruise provided information on particle distributions and transport and on chemical (e.g., barium, chromium) distributions.

Activities in the Gulf of Valencia project, in cooperation with Spanish scientists, included field studies of sediment transport using boundary layer instrument systems, and interpretation of modern sediment transport environments. Preliminary data from the field studies indicate that the frequency of transport events is low--about 0.3 to 1.0 event per month. These events are related to storms; tides have little influence on transport. Evidence from cores and sub-bottom acoustic profiles indicates an onlapping sequence of layers, fining upward in grain size. Linear topographic highs on the middle and outer shelf are probably relict barrier beaches left behind during the last rise of sea level. Current meter records obtained by Spanish scientists were examined, and flow in the interior of the water column was found to be related to wind forcing. However, these effects are complex since the wind directions are subject to steering by mountainous terrain along the coast. A diagnostic circulation-modeling study was initiated to investigate these effects.

Modeling efforts on the New York Bight physical system, for both water and sediments, were completed in FY 1981, and resulting models were used in analysis of MESA/NYB data sets. Results of these efforts will be included in synthesis documents now in preparation.

Field efforts in the study concerning capping of the New York Bight dredge spoil dump were successfully completed. Effects were documented of at least one winter storm in which bottom currents exceeded sediment transport thresholds. The fine-grained sediment transport model developed for the Bight was used with a perturbation at the dredged material dump site as an initial condition. Runs showed that material from the dump site is transported into the apex region of the Bight and that the characteristic time scale of this transport is on the order of decades.

Plans FY 1982

The AOML/SEFC cooperative research on chemical processes affecting productivity and health of larval fish will continue in FY 1982 with a view toward quantifying the effects and their variations noted to date. Efforts will focus on determining the following:

- The stability constants of metal/organic complexes formed.
- The rates at which these complexes are formed.
- The amounts of fulvic and humic acids produced in various environments and the stability of these compounds. This will include studies of photochemical reactions that result in destruction of these materials in surface and near-surface waters.
- The efficiency of these materials in modulating effects on specific biological processes.
- Methods for more realistic measurements of biological growth rates, e.g., "instantaneous" biochemical measurements of growth to integrated (^{14}C uptake) measurements.
- In situ effects on specific phytoplankton species to augment experiments with cultures that were conducted in FY 1981.
- Variations in food sources for larval stages of target fish species to correlate with SEFC studies of larval fish health.

Most of this work will be conducted in the laboratory. Three cooperative cruises will also be conducted, two aboard the R/V Oregon II in December 1981 and February 1982 and one aboard the R/V Researcher in September 1982.

Coincident with the AOML/SEFC program in the northern Gulf of Mexico, AOML plans to initiate research studies on processes involved in dissolved-phase-particle interactions. Such research is critical to understanding how dissolved chemical species, e.g., pollutants, are removed by particle adsorption, how and where these particles are incorporated in bottom sediments, and whether they are redissolved into interstitial waters of these sediments so as to be redistributed in the overlying dissolved phase. Initial studies will focus on two re-

gions: (1) the Mississippi Delta, which is perceived as a storage area of large quantities of pollutants adsorbed onto Delta sediments; and (2) the Puget Sound main basin which is a fjord-like estuary with an adjacent urban population. Both studies will complement other studies in progress, in particular the AOML/SEFC program in the northern Gulf of Mexico and the PMEL program in Puget Sound.

Research on the Flower Garden Banks project will complete routine analysis and data reduction from all samples collected over the past two years for the purpose of tracing and understanding transport processes. Efforts will concentrate on detailed sediment profiling to develop an understanding of barium geochemistry on the bottom. In addition, laboratory research on partitioning of petroleum hydrocarbons between dissolved and particulate phases will be conducted in order to provide a better understanding of field observations of different concentration mechanisms operating on particulate hydrocarbons in the water column.

Continued reduction of data obtained in the NOAA/EPA pass-through program is planned. A research cruise is planned to study the dispersion of drilling fluids in the Georges Bank area. Studies in a program to measure particulate flux in the Hudson-Raritan estuarine system will begin.

Application of the diagnostic circulation model to the circulation on the Spanish Valencia Shelf will be completed in FY 1982. This model will be used to describe the modern sediment transport processes and pathways in the Gulf of Valencia, and the factors (wind, shelf topography) influencing circulation on the shelf. The model results will be evaluated in terms of recent sedimentation patterns.

Plans for the dump-capping study in the New York Bight include mapping of sediment with sonar data collected in the FY 1981 field effort as well as a determination of the spatial and temporal variability of threshold shear stress for erosion of the cap, using results from SEAFLUME studies conducted by AOML in FY 1981. The New York Bight sediment transport model will be applied to a study of probably cap life by considering the combined mean and surface wave flows using data from the MESA Climate Atlas and MESA/NYB current meter data, along with data collected at the dredge spoil dump site in FY 1981.

MARINE RESOURCES

NOAA responsibilities in this area were addressed at AOML in studies of (1) marine mineral resources and the processes controlling them, and (2) geotechnical properties of the seafloor.

Accomplishments FY 1981

An FY-1983 initiative, "Deep Sea Metals," aiming to develop a commercial awareness of polymetallic sulfide deposits in deep-seabed areas accessible to the United States, was prepared under the coordination of NOAA R&D in close cooperation with OME, NOS, and NMFS as part of NOAA's statutory responsibilities under PL 96-283 (Deep Seabed Hard Mineral Resources Act).

The first book treating the implications of the recent discoveries of metal-rich hot springs and associated deposits of critical metals at seafloor-spreading centers (oceanic ridges) for the metallic mineral potential of the deep seabed was published. In addition, articles reporting results of AOML research treating hydrothermal metal deposits of the deep seabed were published in scientific journals, providing a public information base on this economically interesting frontier of research.

An international cooperative cruise of the NOAA Ship Researcher, organized and directed by AOML, performed the first investigations of a 1,000-nmi-long segment of the Mid-Atlantic Ridge, applying geophysical and chemical criteria developed at AOML for the recognition of hydrothermal mineral deposits. Ground truth in the form of dredged rocks and water samples revealed that hydrothermal deposits were actually present at five out of six sites where the presence of such deposits was predicted by direct methods.

Design and fabrication of a new, in situ geotechnical instrumentation platform for use on the DSRV Alvin was completed and field-tested during dives off the U.S., Atlantic continental slope and rise. The system consists of a miniature resistivity/conductivity prove, a min-

iature piezometer, a core penetrometer, an inclinometer, and a rotary table coring system. Cores 4 feet (1.3 meters) long were obtained, and in situ geotechnical properties of surficial sediments were determined. Instruments are controlled by scientists aboard the Alvin without the previously required manipulators. (This is a major advance in engineering design over earlier Alvin capabilities.)

A miniature piezometer was designed and built for the Sandia National Laboratories' Seabed Program to be deployed with its In Situ Heat Transfer Experiment (ISHTE). The piezometer is designed to operate under in situ hydrostatic pressure of 10,000 pounds per square inch while measuring small differential sediment pore pressure on the order of 0.05 to 0.10 pounds per square inch.

A series of Alvin dives was successfully completed in the Wilmington Geotechnical Corridor. Seven of the ten dives used the newly developed geotechnical instrument platform. Significant discoveries of sedimentary features provided insight to geophysical processing in the ocean-bottom canyon. Observations support earlier interpretations of large-scale slumping.

Plans FY 1982

AOML plans to conduct a series of submersible dives coordinated with deep-towed instrument measurements involving scientists from AOML, Woods Hole Oceanographic Institution, MIT, and the University of California. This research, jointly supported by NOAA and NSF, will investigate metallic ore-forming processes of the TAG (Trans-Atlantic Geotraverse) Hydrothermal Field, which is located on the Mid-Atlantic Ridge crest at latitude 26°N. It is the only active submarine hydrothermal field known on any slow-spreading oceanic ridge. The results of this investigation will make possible comparison of ore-forming processes on a slow-spreading ridge with such processes on fast-spreading ridges in the Pacific, and thus provide the basis for understanding ore-forming processes on the entire global oceanic ridge system.

AOML will organize and convene a NATO Advanced Research Institute (ARI) on "hydrothermal Processes at Seafloor Spreading Centers." The ARI will bring together leaders in geological, geophysical, geochemical, and biological aspects of this research frontier to define the state of the art and to stimulate cooperation in research with potential economic payoffs, particularly among scientists in NATO countries.

The newly developed miniature piezometer will be tested at the Naval Ship Research and Development Center, Annapolis, in support of the Sandia ISHTE program. High-pressure testing will be carried out on the piezometer in conjunction with other instrument tests by the Applied Physics Laboratory of the University of Washington, the University of Rhode Island, and Sandia National Laboratories.

AOML plans to publish a series of six detailed (10-m contours) bathymetric slope maps of the Wilmington Geotechnical Corridor.

MARINE OBSERVATION AND PREDICTION

Ocean surface effects at the sea-air interface, especially under extreme conditions, are important to short-term forecasting of coastal and marine weather and wave conditions.

Accomplishments FY 1981

The development of advanced numerical techniques for the simulation of storm surge continued. Exact solutions to the nonlinear shallow-water wave equations have been found, which are useful in determining the accuracy of the numerical values. The wave set-up contribution to the storm surge has been investigated by improving the shallow-water wave prediction model. The problem of anomalous dispersion due to numerical effects has been addressed in collaboration with the NWS application of storm models to a number of specific bays and estuaries. The products will be used by NWS for real-time forecasting of storm surges.

Intercomparison studies of numerical wave prediction models were performed using the newly developed hybrid, discrete, spectral wave model. These studies were part of an international effort to probe the relative strengths and weaknesses of different physical and numerical approaches to wave prediction. Wave researchers from Japan, England, Italy, Ger-

many, Norway, Netherlands, and the United States gathered in Miami in May 1980 to present their results in a dedicated session of the Symposium on Wave Dynamics and Radio Probing of the Ocean Surface. The principal finding was that the physics and numerics of the models were the limiting factors in accuracy of prediction, not the surface windspeed. In particular, the adjustment of the directional properties of the wave spectrum to changing wind direction was found to be the source of the significant model-to-model differences.

A surplus Navy APD-7 radar was successfully used to image the directional properties of the waves in Hurricanes Floyd and Gert. Gert, a relatively fast-moving storm with a forward velocity of 10 meters per second was imaged in all quandrants during three successive days. With its fast forward velocity, Gert represents a class of storms urgently in need of study, because linear theory predicts such storms to produce higher-than-normal waves.

Development of analysis techniques for extracting wave information from radar images has produced interesting results on the directional distribution of waves generated by hurricanes. Comparison of directional spectra hindcast by the AOML wave model with radar data acquired by the Seasat Synthetic Aperture Radar (SAR) has shown remarkable agreement. These analysis techniques are also being applied to real-aperture data acquired using a side-looking radar (SLAR) on board the Research Facilities Center's (RFC) WP-3 research aircraft during recent Atlantic hurricane penetrations.

Plans FY 1982

The possibility of incorporating nonlinear wave-wave interactions directly into models of wave spectra will be investigated. If computational demands are not too great, it may be possible to evaluate the Boltzmann integral at each time step of the simulation, using the computed spectra. Attention will remain focused on the problems of inland inundation and effects of waves on storm surges.

Radar imagery obtained in Hurricanes Floyd and Gert, and Seasat radar imagery obtained in 1978 Hurricane Fico will form the basis of intercomparison and timing of the directional properties of the AOML wave model. Additional imagery radar data sets will be obtained during the 1982 hurricane season. Modeling efforts will continue to emphasize extremes and intercomparison with real situations.

Experiments will be initiated to examine the stability of the boundary layer of the atmosphere, extremely critical in the exchange of heat and momentum between the atmosphere and the ocean. The project will use RFC's WP-3 airfraft equipped with an imaging radar and wave-profiling laser altimeter. This is a collaborative effort with GLERL and its surface air-sea interaction tower and littoral-zone current meter program in Lake Erie.

AOML

A collaborative research project between AOML and the Max-Planck Institute for Meteorology in Hamburg, Germany, will start in early 1982. The purpose of the project is to develop a dynamical objective analysis scheme to produce global surface wind and wave field estimates from satellite data of the type produced by Seasat. Seasat showed that the relevant geophysical parameters could be measured from space and that, if the data are to be useful in near-real time, sophisticated data assimilation schemes, which do not yet exist, are absolutely necessary. The project is aimed at laying the necessary groundwork for the next generation of oceanographic/meteorological satellites, beginning with ERS-1, of the European space agency.

Development of the wave model will continue with the incorporation of the shallow-water effects. The model will also be applied to a study of the decomposition of surface wind stress into components supported by tangential friction and wave growth, from which the momentum flux available to drive currents may be estimated.

WEATHER OBSERVATION AND PREDICTION

AOML is NOAA's primary focus for research in tropical meteorology and hurricanes. Research teams actively engage in 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) on problems of hurricane prediction and with the National Center for Atmospheric Research (NCAR) on scientific investigations of the inner cores of hurricanes.

Accomplishments FY 1981

In 1981, research missions were flown in Hurricanes Floyd, Gert, and Irene. On September 7, two WP-3 aircraft successfully executed flight patterns in Floyd that were designed to obtain data for studies of hurricane rainbands. Early on the morning of September 10, 1981, flights into Hurricane Gert were started that were designed to gather continuous long-term observations of the temporal variability of the hurricane. The two aircraft alternated in the storm with each aircraft flying three 10-h missions. The experiment was terminated early on the morning of September 12 after a continuous data set of about 48 hours duration was obtained. On September 26, both aircraft gathered cloud physics data in the supercooled portions of Hurricane Irene's convective clouds. Data were obtained at temperatures as low as -13°C. On September 27, both aircraft were used to obtain an additional set of hurricane rainband data. Scientists from NCAR and the University of Washington accompanied the NOAA flight crews into Hurricane Gert. NCAR scientists were also on board for the Hurricane Irene flights.

On July 29, 1981, both WP-3 aircraft were used to gather a second sample of data for an observational study of the Florida west-coast sea breeze. (The first sample was obtained in August 1, 1980.) On September 4, 1981, one aircraft was used to obtain a third but more limited sea breeze data sample. This project is aimed at describing the development of the mixed layer, the cloud layer, and the sea breeze circulation from shortly after sunrise until midafternoon when deep convection is normally prevalent.

Data from Hurricanes Anita (1977), David (1979), and Allen (1980) have been used to develop new conceptual model for the evolution of the hurricane core, in which outer wind maxima (accompanied by circular cloud bands) constrict about the preexisting eyewall and supplant it. The NHRL prototype axisymmetric nonhydrostatic model was used for a numerical experiment in which the simulated hurricane underwent concentric eye cycles similar to those observed in Hurricanes Anita, David, and Allen. Many of the details of the convective- and vortex-scale structures and evolution agreed closely with observations.

New ice particle discrimination techniques were applied to data from selected Hurricane Allen flight legs. As in prior analyses, the ice concentrations are considerable even in updraft regions.

Analyses of the airborne radar data from Hurricane Allen have confirmed findings from Hurricanes Anita (1977), David (1979), and Frederic (1979). Vertical cross sections of reflectivity show pronounced outward slope of the inner edge of the eyewall, especially above 5 kilometers. Analyses of the vertical velocity, and the tangential and radial components of wind reveal a consistent radial displacement between the location of maximum updraft (and highest cloud water content) and the tangential windspeed peak and radar reflectivity maximum. This displacement varies with altitude, with the largest displacements occurring at low levels, indicating an updraft that slopes with height.

The core vertical velocities in Hurricane Allen were found to be weak compared with velocities in continental thunderstorms but were comparable with those found in GATE clouds. Eyewall core mean updraft velocity was nearly constant with height, from 4 meters per second at 500-m altitude to about 4.5 meters per second at 6-km altitude. Mean updraft velocity in rainbands is consistently much less than that of the eyewall. Hurricane Allen downdraft cores in the eyewall were found to increase with decreasing altitude (-2.0 meters per second at 6-km altitude, -3.1 meters per second at 500 meters), a result opposite to that found in GATE. This suggests that water loading, rather than entrainment drying, is the important mechanism for initiating and driving downdrafts in hurricane eyewalls.

Initial analyses of a supercell observed in Hurricane Gladys in 1975 were completed using Goddard Space Flight Center's AOIPS interactive computer system and GOES-East satellite visible and IR imagery. Results reveal that an eye with diameter less than 2 kilometers existed for several hours, accompanied by rainfall rates in excess of 400 millimeters per hour. The structure resembled a tornadic cyclone. For nearly 24 hours, intense convection was maintained by a series of convective pulses every 3 to 5 hours. Rapid hurricane deepening followed the cessation of the supercell convection.

Data from Hurricane Frederic (1979) were composited for two periods of several hours duration before and after landfall. The effect of landfall was to shift the region of maximum inflow from the right rear portion of the storm to the landward side. Winds just inland from the coast were found to be 20% smaller than winds just offshore.

Detailed comparisons were made of winds derived from airborne radiometer and scatterometer data and winds measured from aircract in Hurricane Allen. Excellent agreement was found, except for a slight underestimate of low winds and overestimate of high winds in derivations from radiometer data. Windspeed and wind direction derived from the scatterometer data agreed well with flight-level reduced winds in regions with rain rates less than 100 millimeters per hour.

The total land area covered by 40- and 45-dBZ radar echo contours during the landfall of Hurricane Frederic has been determined from digital radar data recorded at the National Weather Service's WSFO station in Slidell, La. Similar areas, or swaths, of the 40-dBZ contour were determined from microfilm pictures of the Pensacola, Fla., WSR-57 displays. These swaths were compared with wind contours estimated from a ground damage survey and were found to be in reasonable agreement with the 100-mi/h windspeed area.

Correlations have been computed between interannual fluctuations of hurricane incidence in the Atlantic basin and large-scale patterns of seasonally averaged sea level barometric pressure (1899-1978), sea surface temperature (1899-1967), and 500-mb heights (1946-1978). By use of empirical orthogonal function (EOF) analysis, dominant models of interannual variability in average August-September-October hurricane incidence were determined and used as measures of activity and track. The hurricane modes were related to dominant modes of seasonal variability in sea level pressure, sea surface temperature, and 500-mb heights, also derived from an EOF analysis. May-June-July large-scale anomalies in sea level pressure can be used to predict August-September-October hurricane activity; the anomalies are significant at the 0.5% level. The correlation predicts about 17% of the variance in hurricane activity. Lower pressure at sea level precedes more active seasons; although physically significant, the correlation is minimally useful for actually predicting the activity of a given hurricane season. Other significant correlations were found: high sea surface temperature just west of Africa precedes more active seasons, but adds little predictive skill to that of sea level pressure. Relationships between 500-mb heights and hurricane track are consistent with steering concepts, and the results of previous investigators; weaker westerlies exist concurrently with more active seasons.

A long-range project to understand and improve prediction capabilities for hurricane tracks was initiated. The basic tool for this study is a new numerical method (quasi-spectral time integration on nested grids or QSTING) that is free of most of the numerical problems associated with more conventional grid-nesting techniques. During 1981, the method was extensively tested with a one-dimensional shallow-water equation model. Programing of a two-dimensional barotropic version was nearly completed. **AOML**

In cooperation with NHC, a new objective analysis scheme to initialize the operational, barotropic, hurricane track prediction model SANBAR (Sander's Barotropic) was completed and implemented in the operational NHC job stream.

In cooperation with NHC and NWS's Techniques Development Laboratory, work was started on the development of operational storm-surge-basin models for Florida Bay, Corpus Christi, Lake Sabine, and Mobile Bay.

Considerable progress was made in the processing, analysis, and interpretation of data from the 1980 sea breeze experiment. The time variations of the ground temperature, the sea breeze inflow and outflow at the coastline, and the inward propagation of the sea breeze convergence zone were determined from the aircraft observations. From the side cameras on the WP-3 aircraft, the time variations of cloud base, width, and height during the 8-h flight were computed. Divergence values at low levels have been computed at hourly intervals for surface stations on the Florida peninsula scale and from the flight data at 300-m height for horizontal scales of 30 kilometers.

Plans FY 1982

The 1982 hurricane field program will focus on gathering data from omega dropwindsondes released from the RFC aircraft on the periphery of mature hurricanes (those predicted

to be within 48 hours of landfall on the U.S. mainland). The observations will be obtained in the middle and lower troposphere over normally data-void ocean areas, at pressure levels that previous studies have shown to be important for determing storm tracks. This dropwindsonde data will be combined with conventional surface and upper-air observations.

The omega dropwindsonde flights are designed to define the synoptic-scale flow around a hurricane more accurately than is possible with the current, sparse, real-time observational network. These flights are distinctly different from the previous research missions flown by RFC. One important goal of the project is to determine whether the special dropwindsonde observations can improve operational track forecasts, and, possibly, intensity forecasts in the near future. Flight-level data and mandatory-level wind, temperature, and humidity measurements from the dropwindsondes will be transmitted by radio from the aircraft to NHC for input to the operational data stream. Within a few months after the end of the 1982 hurricane season, track forecasts from the operational dynamical and statistical models will be computed from initial analyses, both with and without the dropwindsonde data.

Data from the long-term monitoring missions into Gert (1981), together with data from David and Frederic (1979), will be analyzed in an attempt to determine why some storms exhibit the concentric eye cycle while others do not.

A detailed analysis of water-ice division related to the draft-scale vertical winds is planned for the data sets from Irene. Analysis of the microphysical data from Hurricane Allen will be completed.

Analysis of the rainband data sets gathered in Floyd and Irene (1981) will be started. Analysis of the Allen (1980) rainband data will continue. These analyses will focus on estimating the mesoscale forcing of the bands and statistically summarizing the convective updrafts embedded in the bands.

The importance of stratiform precipitation areas in hurricanes will be investigated using the airborne radar data from Hurricane Allen as the principal data source. The analysis will concentrate on the data collected in the multi-aircraft mission on August 8, 1980. The three-dimensional structure of the precipitating convection will be determined from the WP-3's tail radar data. Areas of stratiform precipitation will be delineated, and areal coverage and rainfall amount will be estimated for the stratiform areas.

Analysis of the land-based radar data from the Slidell WSR-57 during the landfall of Frederick (1979) will continue. Further work will be conducted to determine the usefulness of land-based radars for local flood determination. The results from the land-based radar will be used with rainfall composites generated from NOAA aircraft data before Frederick made landfall. Differences in precipitation structure when the storm is over open water and when it is moving inland will be stressed.

An extensive study of air-sea interactions induced by hurricanes will be completed. The study uses data obtained from airborne expendable bathythermographs in Hurricanes Ella (1978), Anita (1977), Ginger (1971), Eloise (1975), Gloria (1976), and Ellen (1973), and Australian Tropical Cyclone Kerry (1979). Aircraft, ship, and buoy data are also used. Scales of time and space associated with decreases in sea surface temperature induced by hurricanes will be documented. The study will emphasize the two-way interaction between the hurricane and the ocean.

Programing of the barotropic (two-dimensional) QSTING model will be completed, as will performance tests of the model. A manuscript of the QSTING method will be prepared for publication.

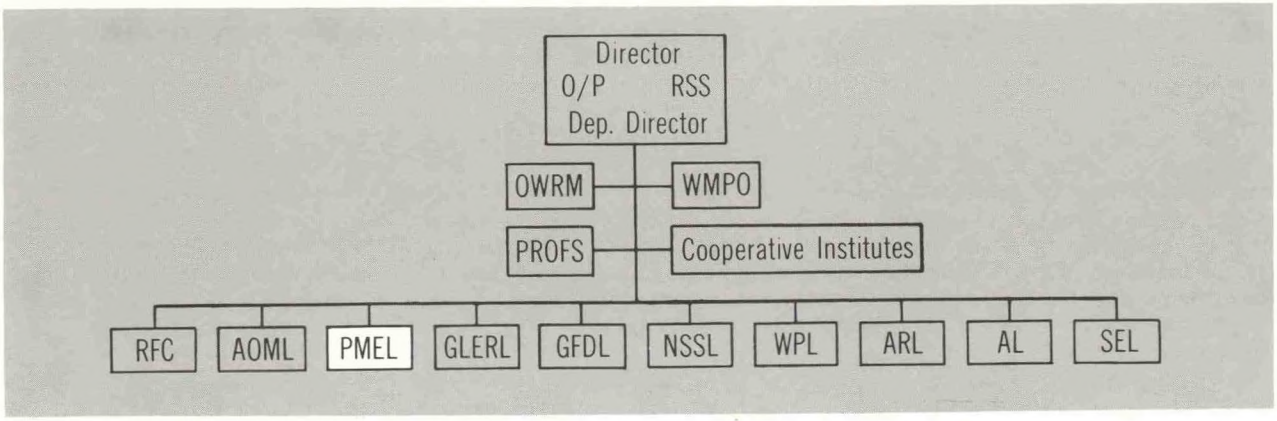
A landfall experiment with the NHRL 12-layer nested-grid hurricane model will be run and evaluated. To bridge the gap between this research model and operational models such as the NMC movable fine mesh (MFM) model, experiments will be conducted using the Kuo cumulus parameterization in place of resolvable latent heat release.

Further refinements of the operational SANBAR barotropic hurricane track prediction model will be tested and made operational. This will include use of initial data taken within the hurricane circulation.

The storm-surge-basin models for Florida Bay, Corpus Christi, Lake Sabine, and Mobile Bay will be completed and implemented on an operational basis.

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: marine environmental assessment, marine observations and prediction, climate, 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.

MARINE ENVIRONMENT 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 1981

Research in the Puget Sound--Strait of Juan de Fuca system has been under way for the past several years. In the Strait of Juan de Fuca, the emphasis has been on transport mechanisms that might affect the distribution of spilled oil. During FY 1981, continued study of circulation in the western Strait has focused on interactions between coastal flow and flow in the outer Strait. Observations during several years have shown that winter storms having predominantly southerly winds are capable of significantly reversing flow within the estuary and causing large intrusions of coastal water lasting several days. Outflow often occurs only in the deeper water, with surface water being retained within the estuary. Observations of water properties over the shelf and in the estuary indicate a sloping density surface which is consistent with a recent numerical model. Although there is no sill at the mouth of the Strait of Juan de Fuca, some characteristics of the flow seem similar to those observed in the Norwegian fjords that have sills near the mouth. Nonlocal wind forcing appears to be common to both and the major cause of these characteristics. These results will be synthesized with results from a major circulation experiment being conducted off Vancouver Island by Canadian investigators at the Institute of Ocean Sciences.

In Puget Sound and populated embayments such as Elliott Bay and Commencement Bay, the emphasis has been on understanding the Sound's ability to accommodate pollutant inputs.

Examination of month-long average currents at various locations show that some seaward-flowing surface water is mixed with new water at the southern end of Admiralty Inlet and is recirculated into the Sound in the deep water. This will have significant implications on whether and how quickly dissolved pollutants can be removed from the Sound. This work plus a comprehensive review of tidal research in the Puget Sound--Strait of Juan de Fuca region will appear as chapters in a book Puget Sound: Oceanography of the Inshore Waters of Washington.

Since many pollutants adhere to particulate matter, PMEL has begun an extensive study of the fate of particulates and the circumstances under which pollutants are transported or transformed while in association with particulate matter. Suspended particulate matter (SPM) is high in the surface layer and varies with river runoff and phytoplankton growth. SPM is also high near the bottom because of sediment resuspension by tidal currents. The middle third (depths of about 30 to 100 meters) of the main basin has low, uniform particle concentrations with the lowest concentration consistently found around 50 meters. Settling through the water column is generally limited to large particles such as fecal material from zooplankton.

MESA-sponsored studies have focused on processes to provide background information useful in describing the fate and effect of dissolved and suspended contaminants introduced into Elliott Bay. Observations were made during low-river and high-river discharge, using moored current meter arrays and hydrographic surveys.

Currents in Elliott Bay were found to be very weak, dominated by the semidiurnal tide and the Duwamish River effluent. Current directions in the outer bay are coupled to the main basin, and average currents suggest a counterclockwise gyre at middle depths, about 130 meters. Contrary to University of Washington hydraulic model findings, the Duwamish River plume appeared on the north side of Elliott Bay at all times. Speeds of 23.5 centimeters per second, necessary to resuspend bottom sediment, occurred very infrequently in the inner bay, yet suspended sediment was concentrated near the bottom. This sediment may come from outside the Bay from the main basin of Puget Sound.

Metals and toxic organics (such as lead, copper, cadmium, and selected petroleum-derived species) have been found to be transported from the Duwamish River through Elliott Bay to Puget Sound by surface currents with relatively little deposition in the bay itself. Much of this occurs as dissolved species flocculate on particulates and are moved with the particulates through the estuary. Studies in the main basin show that organics resuspended from near-bottom sediments have undergone active biochemical alteration during both dynamic and quiescent periods.

In response to a request made by the Seattle District Office of the Army Corps of Engineers, the State of Washington Department of Ecology, Clallam County, and the City of Port Angeles, PMEL scientists reviewed various materials pertaining to the potential oil spill problems that might accompany the Northern Tier Pipeline Company's (NTPC) proposed oil terminal in Port Angeles. These reviews and subsequent PMEL contributions to a hypothetical oil spill scenario in the Port Angeles region of the Strait of Juan de Fuca were used by the National Marine Fisheries Service Regional Office (NOAA's lead agency in the permit process) to formulate the NMFS position under the Fish and Wildlife Conservation Act.

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. During FY 1981 the results of earlier work were reported extensively, including major contributions to the two-volume set The Eastern Bering Sea Shelf: Oceanography and Resources. Field work continued in an effort to refine our understanding of physical and geochemical processes of particular importance to environmental assessment.

Examination of continental shelf circulation around the Gulf of Alaska has allowed a qualitative description of the major circulation features. Along the eastern side of the Gulf, sea level and hydrographic data indicate that coastal flow is mainly barotropic, with a maximum in early winter. In the northern Gulf, the dominant feature is the strongly baroclinic Kenai Current which has maximum transport ($\sim 1 \times 10^6$ cubic meters per second) in October, coincident with peak accumulation of freshwater discharge.

Hydrographic, current, and bottom pressure data from Unimak Pass indicate that the Kenai Current flows through Unimak Pass, providing forcing for the long-term (6-month)

mean flow into the Bering Sea. Strong fluctuations about the mean, with 60- to 70-cm/s maxima, were observed; coherence estimated between currents at Unimak Pass and the bottom pressure gradient along the pass indicates that at periods between 3 and 10 days the fluctuations were driven by the pressure gradient. Geostrophic wind accounted for most of the variance in the bottom pressure gradient at these periods, indicating that the pressure gradient was primarily caused by set-down/-up along the Gulf (Pacific) side of the Alaska Peninsula.

Methane tracer studies in the southeastern Bering Sea have developed estimates of turbulent diffusion coefficients and mean horizontal velocities that are of use for predicting contaminant transport associated with oil and gas leasing.

Data from a 6-mo current mooring at 1,700-m depth off Kodiak Island were analyzed. The deep flow appears to be essentially geostrophic, with low-frequency variations in velocity which appeared to be caused by meanders in the Stream induced by interactions with the bottom topography. The relative stability of the Alaskan Stream is believed to result from the fact that it is a westward flow near a western barrier (retrograde flow) rather than eastward flow typical of western boundary currents.

The relationship of coastal sea level and bottom pressure to offshore currents at the subinertial frequencies has been investigated in data taken from earlier field programs. A series of bottom pressure measurements taken across the continental shelf in the northeastern Gulf of Alaska was found to be dominated by fluctuations on time scales of 8 to 20 days. Coastal sea level measurements by coastal tide gages are substantially affected by fluctuations in the geostrophic currents coherent over scales substantially larger than the near-shelf region, extending to the continental boundary currents. The coastal tide gages provide long time series (~20 years) of available data that may be applied to the study of the temporal continental variability of the continental boundary currents.

Research in the behavior of solitary internal waves includes an experiment in the Sulu Sea using satellite imagery and field data, and laboratory studies in a stratified tow tank. Results of these studies are expected to be applicable to the dynamics of fjords, including Puget Sound, where vertical mixing, hydraulically controlled flows, and recirculation play a dominant role in bottom-water flushing and general circulation. A multidisciplinary study of sediment dynamics of the Yangtze River (Chang Jiang) estuary was carried out jointly with the National Bureau of Oceanography of China. One noteworthy instance of mixing resulted in the water column's changing from two layered to vertically homogeneous, indicating that a large fraction of the vertical salt flux occurs in a small fraction of the tidal cycle. This observation may be of considerable general interest, since the phenomenon has been recently observed in another salt wedge estuary.

An Acoustic Echosounding and Profiling System (AESOPS) was developed to permit remote sensing of particles in the upper water column utilizing high-frequency (200-kHz) acoustic signals. **PMEL**

Plans FY 1982

Field studies on the Bering Sea Shelf will be made to provide input and verification data for a numerical tidal model of the shelf flow under development by the Rand Corporation.

PMEL will continue to participate in a multidisciplinary field study of sediment dynamics on the East China Sea shelf. A low-river runoff experiment will be made in November from Chinese research vessels.

PMEL will continue theoretical studies and analysis of field data related to the dynamics of tides, internal waves, and other long-period waves on the continental shelf for a variety of shelf environments.

In conjunction with Canadian studies, research will continue in the Strait of Juan de Fuca and the adjoining continental shelf to improve understanding of the storm-induced intrusions of coastal water into the estuary.

A major experiment will be conducted in Puget Sound to help quantify flushing and erosion-deposition processes in the main basin. The study will be part of PMEL's Long Range Effects Research Program. The Acoustic Echosounding and Profiling System will support this and other programs during field operations.

An observational program designed to study the seasonal and spatial variations of dissolved methane in Puget Sound waters will commence in 1982. Emphasis will be placed on the quantification of source and sink processes, including benthic production and air-sea exchange rates. These data will ultimately be subjected to a two-dimensional, time-dependent analysis for the purpose of quantifying seasonal variations in mean circulation and vertical mixing parameters in the main basin of Puget Sound.

In the forthcoming year, studies in the Duwamish-Green River system will focus on near-bottom transport phenomena. Our previous studies indicate a significant reduction in suspended organics following wastewater discharge; thus, we hypothesize that "bed load" transport is a large if not dominant mechanism by which toxic organics are removed to the lower portion of the estuary.

Research in 1982 will attempt to correlate vertical fluxes of organics with sedimentation rates and in situ diagenetic degradation rates. The experiment will be conducted in Elliott Bay, Washington, in which vertical sediment fluxes, bottom boundary layer dynamics, and sediment cores will be examined. From this study we hope to gain estimates of the half-lifes of toxic PAH compounds in estuarine sediments.

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 the National Weather Service (NWS) in defining research needs and assuring that products of the research are made available to operational elements of NOAA. Research subjects include tsunami propagation and run-up, near-shore winds and waves, arctic ice dynamics, and satellite oceanography.

Accomplishments FY 1981

The Puget Sound Wind Study, designed to improve marine wind forecasts, was completed in 1981. The contributions by researchers at PMEL, the National Weather Service, the University of Washington, and the University of Maryland have collectively described the regional wind patterns of the Puget Sound region. An important development was an index that can be calculated from routine meterological data, which provides forecasters with an indicator of whether a particular winter storm may lead to severe surface winds in the Puget Sound region. This index is in operational use at the Seattle National Weather Service Office.

During FY 1981 theoretical studies of breaking waves concentrated on developing computational tools for analyzing the mathematical nature of the flow in breaking waves as a necessary precursor to the development of simple models of breaking. Mathematically, the problem is best solved with the Cartesian coordinates expressed as complex Fourier series in the velocity potential and stream function. PMEL succeeded in inverting the series, thus giving the flow field as a function of the space coordinates. This technique makes calculation of velocities and accelerations at predesignated locations in space much easier and should be of use to engineers calculating wave-induced structural loads.

The remote-sensing data taken by the Seasat satellite of the August 1978 Hurricane Iva were used to study open-ocean wind and wave fields with a horizontal resolution (<50 kilometers) not possible with conventional observations. The data collected are unique in that they represent a snapshot of the wind and dominant surface wave fields near a hurricane eye. The isotachs (lines of constant wind speed) derived from the Seasat-A Scatterometer System (SASS) data delineate the classic banana-shaped pattern which is expected for a hurricane moving on a northerly track. SAR data were acquired in a 100-km-wide swath. Square regions of the imagery, 25 kilometers on a side, were digitized and subjected to two-dimensional transformations to extract dominant surface-wave information. The resulting dominant wave field was characterized by wavelengths of approximately 200 meters, and a fan-shaped directional distribution. Such information will enable researches working on wave forecasting to determine how waves are generated in hurricanes and how waves propagate out of the region of the storm.

A unique set of oceanographic, meteorological, and ice data was obtained along the ice edge in the Bering Sea from February 26 to March 11, 1981, during a cruise of the NOAA Ship Surveyor. Local weather dominated oceanographic and ice conditions throughout the

observation period. During the cruise, an intense gale passed through the area advecting the ice northward as much as 35 kilometers per day. After the passage of the gale, the ice returned to its former position. The temperature structure of the water beneath the ice edge showed marked effects of the gale; however, the vertically integrated heat content of the water column did not change measurably during the gale. The change in structure was caused by wind mixing of the upper layer. Further, the lateral boundary between the layered thermal structure and the vertically homogeneous water to the south did not shift appreciably during the gale, suggesting the the oceanographic structure responds slowly to local meteorological processes.

During the period of northeast winds immediately following the gale, ice growth occurred in newly forming leads. Comparison of flow trajectories near the edge with those 60 to 100 kilometers into the pack showed a divergence during these periods of off-ice winds. Ice trajectories from radar transponder buoys deployed on individual floes along the ice edge revealed clear tidal signals, although the time series were too short for rigorous analysis of the tidal components. Buoy trajectories obtained from ARGOS transponders deployed on ice floes over the same period suggested that the ice responded to the wind with little evident internal ice stress. The southward extent of sea ice during this period was determined by the balance between the southward wind-driven advection rate of the ice and the decay rate of the ice, controlled principally by heat from the ocean.

Plans FY 1982

PMEL will focus on delivering forecast products to the National Weather Service for improved forecasting of sea ice in the Bering Sea and hazardous waves at the Columbia River entrance.

Studies of ice edge dynamics will be continued with meteorological and sea-ice field measurements in the eastern Bering Sea. The measurements will be made from drifting buoys deployed on the ice by a helicopter and from instruments borne by the NOAA WP-3D research aircraft over the region. Three ice stations measuring only position will be deployed from Nome and Cape Romanzof. The array is designed to check the free drift approximation for floes as a function of geographic location and wind regime. The geophysical data from the ice stations will be telemetered to the GOES system, and the positions will be telemetered to the ARGOS system.

Two sets of wave data collected for the Columbia River Bar study will be analyzed to provide a description of the interaction of waves and currents at the river entrance. The data sets result from waverider and current meter records, drifter studies, and aircraft reconnaissance. Guidance material will be developed for the National Weather Service to forecast bar conditions as functions of offshore wave height and direction, tidal currents, and river outflow.

Theoretical research will continue in improving the accuracy of breaking-wave computational experiments. Additional plans call for the generalization from purely deep-water waves to shoaling waves and waves in an adverse current.

A small tsunami observation program will begin in FY 1982 to measure tsunami characteristics in deep (4,000-m) water, shallow (10-m) water, and at the shoreline. Internally recording pressure gages will be deployed for monitoring tsunami activity from April to October 1982.

CLIMATE RESEARCH

The purpose of PMEL research in ocean climate dynamics is to understand and predict large-scale, long-term interactions among major Pacific Ocean currents, heat transport, and the general atmospheric circulation. Observations of the dynamics of equatorial waters began at PMEL in FY 1976 with the EQUA-1 expedition and have continued and expanded through the North Pacific Experiment (NORPAX) and the NOAA Equatorial Pacific Ocean Climate Studies (EPOCS), which began in FY 1979. Other ongoing programs pertinent to climate include western boundary current dynamics, middle-latitude air-sea interaction, statistical approaches to climate prediction, and the uptake of CO_2 by the oceans. The research draws on PMEL's capabilities in design and deployment of deep ocean moorings, numerical and theoretical analyses, application of remote-sensing techniques to large-scale measurement problems, and trace chemical analysis.

Accomplishments FY 1981

Sea-surface temperature data (30°N-25°S, 15°E-70°W) have been collected for 1975-1980 and the large-scale variability of the biweekly means described by an objective analysis. These time series show that the anomalies associated with the 1975-1976 El Niño conditions off Peru were accompanied by significant low-temperature anomalies at 25°N and 0° and high-temperature anomalies at 30°S; thus, the ocean surface temperature was anomalous from Australia to Baja California. Those studies illustrate the very large scale of the temperature perturbations and the need for more than an analysis of the change in a limited region if one is to understand the dynamics of the phenomena.

As a part of the EPOCS program the meridional structure of near-equatorial currents is being studied using directly measured velocity profiles and geostrophic currents computed from CTD data. Strong eastward flow was observed in the North Equatorial Countercurrent (4°N-6°N), the Equatorial Undercurrent (0.5°N to 2°S) and the sub-thermocline countercurrent (4.5°S-5.5°S). These are balanced by the westward flow, largely in the South Equatorial Current. Velocity profiles show that the vertical structure is complex. As one proceeds southward the eastward velocity core of the Equatorial Undercurrent tends to rise from about 100-m depth at 0.5°N to about 40-m depth at 1°S. Largest eastward transport was found at 0.5°S. These velocity sections are being combined with temperature and salinity data in a study of the zonal transports of heat and salt. Of particular interest is the role of the heat transport of these zonal currents in changing the near-surface temperatures.

The relationship of winds, currents, and zonal slope of the thermocline was also examined to help determine the processes controlling sea surface temperature. No significant difference in the middle and bottom of the thermocline was seen in three long temperature sections on the Equator, but striking differences were observed in the upper thermocline. In July 1981 the 25° isotherm reached the surface. This could have been produced by wind-forced equatorial upwelling, turbulent entrainment of cooler water from 50 to 70 meters depth, or westward advection of cooler water in the South Equatorial Current.

A meridional array of bottom-moored pressure gages has been maintained at the Galápagos Islands since June 1979 to study equatorial trapped waves near their eastern terminus. Most theoretical models of the response of the tropical ocean to atmospheric fluctuations indicate that these trapped waves are important in the rapid zonal propagation of properties that has been observed. Studies based on data for 17 months show that the dominant sea level signal, which contains 95% of the low-frequency variance, has the meridional shape predicted for a first-baroclinic-mode internal Kelvin wave with a phase speed of 2.7 meters per second. Numerical model studies of the effect of the islands on equatorial waves suggest that on the western side Kelvin waves may dominate, and on the eastern side a mixture of Kelvin and Rossby modes is expected. This possibility is being studied by extending our array across the Galápagos archipelago.

In 1979-1980 an intensive study of the currents in the central Pacific (150°W-158°W) was carried out in conjunction with NORPAX. The within-cruise variation of the transports of the North Equatorial Countercurrent is less than one-half of the Undercurrent transports. There is a clear inverse relation between the transports of the Undercurrent and Countercurrent. The relation between the central Pacific transports and those measured in the eastern Pacific during the same period will be studied to determine whether the current system is responding to very-large-scale forcing by the winds or whether the regional mesoscale forcing is important in determining the transports.

Western boundary currents (subtropical latitudes) are believed to be important in the meridional heat transfer in the ocean. The Gulf Stream and Kuroshio have been studied by means of a combination of Seasat satellite altimeters and thermal infrared radiation data from NOAA operational satellites. These data, taken where the geoid is well known, provide an opportunity to measure the surface velocity across the Stream and its associated mesoscale features. A parallel study was done of the Kuroshio, and it was determined by comparison of altimeter data with those from a hydrographic survey that the altimeter gave a good picture of the slope of the sea surface across the Kuroshio. These studies demonstrate the usefulness of the altimetric-derived surface current estimate in the vicinity of western boundary currents.

The Kuroshio Extension extends from the western boundary out to at least the position of the Emperor Seamounts (170°). An analysis of the existing data in the vicinity of the

seamount chain has revealed some of the effects of the chain on the Kuroshio. Eddy potential energy drops dramatically east of the chain, and the velocity and transport of the Kuroshio also decrease. The Kuroshio tends to be deflected northward along the weastern flank of the chain and then is displaced southward so that there is strong anticyclonic curvature to the path. This suggests that the chain has a profound effect on the structure of the Kuroshio; a field program has been designed to study the interaction of the current with the topographic barrier presented by the Emperor Seamounts.

One of the main obstacles to successful modeling of the general ocean circulation is the inadequate understanding of the role of eddies in the transfer of momentum and heat. In order to gain some insight into the dynamics of the mesoscale eddies, an experiment was carried out in the southern part of the Gulf Stream return flow in 1978 as a component of the POLYMODE program. A surprising result has been the strong property anomalies on scales of 24 to 50 kilometers. These anomalies appear to be advected by the large-scale flow, and their properties suggest a distant North Atlantic origin. These origins imply relatively low rates of mixing.

Air-sea interaction research was undertaken as a part of the Storm Transfer and Response Experiment (STREX). Surface waves in interaction with the atmospheric surface layer were studied during nine low-level flights into storm systems in the Gulf of Alaska. Aircraft-mounted laser wave profilers were used to measure the surface wave spectra immediately behind atmospheric fronts. Contemporaneous measurements of stress in the surface layer have allowed cross correlation of surface drag coefficients with spectral changes in sea state. Preliminary results show that the increase in drag accompanying an abrupt change in wind direction may be related to the change in surface-wave spectral composition.

This year scientists from PMEL began a study of the dynamics of the carbon dioxide system in the surface and intermediate waters of the North Pacific. The purpose of the study is to determine the penetration and reactivity of fossil carbon dioxide in these waters. Measurements of total carbon dioxide, alkalinity, freons, tritium, calcium, and suspended matter were made during two north-south transects of the North Pacific aboard the NOAA Ship Miller Freeman. Preliminary results from the study indicate that fossil carbon dioxide has penetrated to depths between 500 and 800 meters in the study area, with the deeper penetrations occurring in the northern latitudes around the Subarctic Convergence. The data have also been used to determine the degree of undersaturation of these waters with respect to calcium carbonate minerals. Saturation depths for calcite range from less than 400 meters for the northern stations to more than 1,000 meters for stations located south of 20°N. These preliminary data indicate that in the depth range of the North Pacific Intermediate Water the water is undersaturated with respect to calcite, and neutralization of fossil carbon dioxide by carbonates is probable.

Theoretical research on climate predictability was continued during FY 1981. Seventeen principal-component selection rules were designed, and then systematically tested on carefully controlled artificial data sets that simulated, under realistic conditions, a dynamical system buried in environmental noise.

Model/data intercomparison tests were developed for use by researchers who wish to test global circulation models (GCMs) of the atmosphere or the sea for their ability to mimic their real counterparts. The tests are based on new statistical procedures, and preliminary tests have shown that certain statistics possess great power (in the technical sense). The statistics tests are in turn based on the idea that a natural field evolving through time, such as sea level and pressure or sea surface temperatures, can be represented as a single moving point in p-dimensional space. These statistics describe, in turn, the average location, the variance, the time evolution, and the spatial pattern of a trajectory (or swarm). Two data swarms can then be compared for comparable sizes of these statistics. Significance tests have been derived for these statistics using Monte Carlo procedures.

Experimental and theoretical research on electromagnetic measurement of ocean mass transport was continued during FY 1981. The main goal of this research is to develop methods for removing geomagnetic noise from electric field measurements and for interpreting the geomagnetic noise in terms of the Earth's electrical conductivity. The latter goal has been accomplished by the development of a new inversion technique for layered-earth interpretation. The method provides a one-dimensional model and an evaluation technique for assessing the uniqueness of the model and has been successfully applied to electromagnetic data

from Bermuda, Tucson, Hawaii, and Midway. The goal of removing geomagnetic noise from electric field measurements has been accomplished by using local simultaneous magnetic data.

A study of the influences of mooring motion on surface buoy wind observations was begun with the deployment of a 14-m spar buoy near three EPOCS toroidal buoys. Small intercomparison experiments of this type are important in defining the relative effects of different platforms on the meteorological sensors and in the general understanding and improvement of mooring performance.

A Simplified Ocean Profiling System (SOPS) has been developed, which incorporates the self-tracking capabilities of the earlier Total Ocean Profiling System (TOPS) and allows rapid and simple velocity profiling in the area of a bottom transponder array. Temperature, pressure, and acoustic travel times from the array are internally recorded on cassette tape. The free descent and return are controlled by a combination hydrostatic and bottom contact release. The hardware for a prototype Electric Field Data Acquisition System has been successfully bench tested and will be deployed in the field in FY 1982 upon completion of microprocessor software.

Plans FY 1982

Studies of the EPOCS data set will be pursued to develop hypotheses about the processes that are responsible for modification of the surface layer temperatures in the eastern Pacific. The central Pacific (NORPAX) data will be incorporated in the analysis to study the possible effects of advection from the central Pacific.

Our investigators will take part in the new EPOCS field program undertaken to study the circulation of the Pacific east of the Galápagos Islands (90°W).

Analysis of the STREX data and the POLYMODE and NORPAX density data will be completed during FY 1982.

Theoretical climate research will focus on applying the 17 principal component selection rules to atmosphere and ocean data sets in the EPOCS regions of the Pacific Ocean. Significance tools derived from statistics based on the idea that a field evolving through time can be represented as a single moving point in p-dimensional space will also be applied to these data.

Instrumentation for measuring electric and magnetic time variations from essentially unattended remote sites will be used to measure and study the time-varying transport fluctuations of the Florida current as PMEL's contribution to the Subtropical Atlantic Climate Studies (STACS) program.

A low-cost satellite-telemetering thermistor chain buoy will be developed and deployed.

A semi-automated freon stripper system, which will prepare and inject water/gas samples to a gas chromatograph, will be designed and fabricated.

The marine CO_2 observational program will be extended to the tropical and western Pacific Ocean. Measurements of dissolved freons, total CO_2, alkalinity, and dissolved and particulate calcium will be made between Hawaii amd Kwajalein and north along 160°E longitude to quantify the rate of CO_2 penetration and transport in the ocean and the rate of vertical mixing and neutralization of CO_2. Participants will include physical and chemical oceanographers and geochemists from government and academic institutions.

MARINE RESOURCES

PMEL participates in research activities that provide information for resource management decisions by NOAA or 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.

Accomplishments FY 1981

Theoretical investigations of particulate transport processes continued with emphasis on distribution and dynamics of solid matter in the ocean and on the seafloor. Earlier work on the re-deposition of deep-sea mining plumes had indicated that plume blanketing length scales are strongly dependent on the absorbing capacity of the seafloor. PMEL research has now been able to express the deposition velocity, which determines re-deposition length scales, in terms of the structure of the turbulent boundary layer by comparing two theoretical formulations. The results are of use to those who wish to make more realistic numerical calculations of plumes moving across the seafloor.

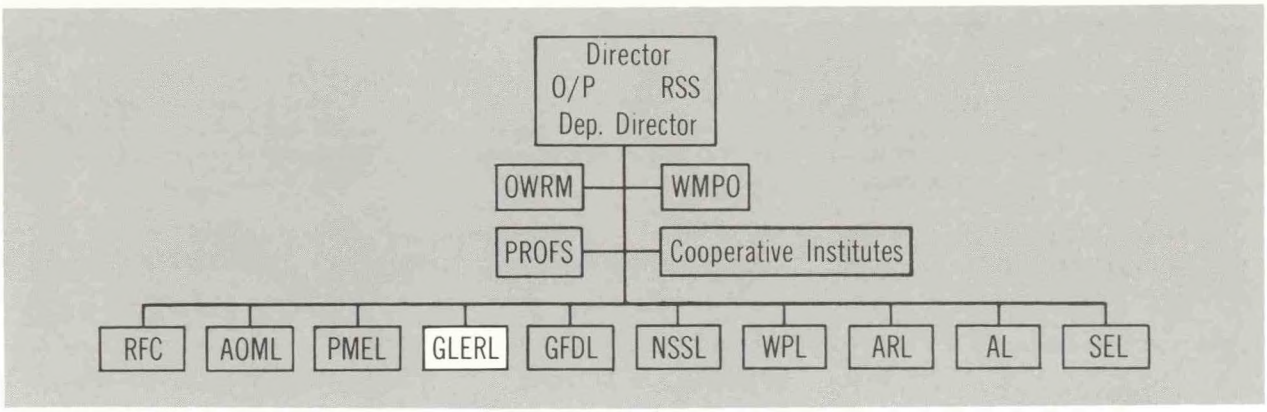
Plans FY 1982

Theoretical investigations of particulate transport processes will continue in the coming year with emphasis on exploring other processes potentially leading to pycnocline accumulations in the open ocean.

An assessment will be undertaken to determine the potential of chemical tracers for locating polymetallic sulfide deposits.

GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY
Ann Arbor, Michigan

Eugene J. Aubert
Director



The Great Lakes Environmental Research Laboratory (GLERL) conducts a program of research on the physics, chemistry, and biology of the Great Lakes and their connecting channels. The environmental information developed through this program 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 and theoretical approaches.

Research is carried out through four groups: Chemistry and Biology, 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 that synthesize first-order eutrophication process and 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, 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.

MARINE ENVIRONMENT ASSESSMENT

GLERL research in FY 1981 emphasized numerical modeling of lake processes, with a matching field observation program to provide data for development, calibration, and testing of numerical models for environmental simulation and prediction. Research in such fields as runoff simulation modeling, long-term toxic substance dynamics, nonpoint source pollution models, risk assessment and assimilative capacity, detailed models of biological and chemical processes, lake circulation and particle dynamics are included. Some specific in-house research accomplishments follow.

Accomplishments FY 1981

The cost effectiveness of alternative phosphorus control strategies was evaluated as part of an ongoing program to assess the eutrophication problem in the Great Lakes. The primary objective of the evaluation was to determine the least costly phosphorus control program capable of achieving water quality objectives for the Great Lakes by identifying the most economical mix of point and nonpoint source controls and ranking the various control options according to their cost-effectiveness.

A nonpoint source pollution model, WATERSHED, was developed to determine the most cost-effective pollution control strategy for the U.S. Soil Conservation Service and the U.S. Environmental Protection Agency. A users' handbook was included to promote wide application of the technique, which includes trade-offs between cost and effectiveness of controlling point and nonpoint pollution sources.

Recent contributions by GLERL staff to the Great Lakes Environmental Planning Study include technical reports on (1) phosphorus bioavailability of pollutant inputs and its impact on management, (2) risk assessment as applied to Great Lakes water quality management, (3) ecological factors in Great Lakes water quality management, (4) hazardous spill modeling, (5) a Great Lakes environmental atlas, and (6) a chloride budget for the Great Lakes.

A water quality risk assessment framework, to explore possible applications to water quality management, was developed with the methodological components of risk identification, estimation, and evaluation.

Recent research on assimilative capacity indicates that Great Lakes sediments serve as a burial ground for many pollutants, particularly in the deep basins where much particulate material eventually accumulates.

GLERL, the University of Michigan, and the University of Wisconsin completed an assessment of the state of knowledge about nutrient cycling in the Great Lakes ecosystem. Nutrient release by zooplankton was identified as a major recycling mechanism of nutrient supply to algae and is a major focus for future process studies.

Autoradiographic methods have been used to identify the presence of nutrient patches produced by zooplankton. Algal cells that encounter patches of radiophosphorus released by swimming animals become differentially labeled with respect to cells that do not enter the patches. Nutrient patchiness on a scale of millimeters or less probably influences the course of competition and coexistence among the phytoplankton.

A program continued to study the cycling, transport, and fate of toxic organic compounds, in cooperation with NOAA's Office of Marine Pollution Assessment. A model designed to estimate the equilibrium partitioning of synthetic organic compounds within an aquatic ecosystem, based on the solubility and vapor pressure of the compound, has been developed. This model estimates the concentration and mass distribution of synthetic organics among various compartments of an ecosystem and can be used as a screening tool for monitoring programs. Photodecomposition rates for several PCB isomers have been measured in lake water. This decomposition pathway is one of the major organic-contaminant removal mechanisms within the Great Lakes system, and accurate rate measurements are necessary to predict concentrations at any future time.

Present ecosystem modeling efforts are centered on two themes: (1) detailed models of biological and chemical processes, with emphasis on the phytoplankton-zooplankton interface, and (2) interactions (on various space scales) of the biological-chemical system with physical processes. Results from recently completed studies, including error analyses, have demonstrated the importance of stochastic effects on aquatic systems and their models.

A study is continuing to identify present-day species distributions of benthic animals and, by comparison with previous studies, to identify trends over the last half century in southern Lake Michigan. Benthos are important in the food chain and are sensitive to water quality and sediment conditions.

A variable-grid barotropic model, made possible by the increased capability of the ERL computing facility, will be useful in examining the dynamical response of Lake Erie to atmospheric forcing. A free-surface version of the model was developed and tested on a storm surge analysis of Lake Erie. The rigid-lid version of the prediction model will be tested against Lake Erie observations of currents and circulations collected by GLERL and the Canada Centre for Inland Waters in 1980.

A project was initiated to develop mathematical models to predict and simulate runoff into each of the Great Lakes from their land basins. A simple, physically based, conceptual model has been completed that uses only daily precipitation and temperature data to estimate weekly or monthly basin runoff.

A generalized monthly evaporation model for Lakes Superior, Erie, and St. Clair shows that both monthly and annual evaporation from the individual lakes can vary substantially

from year to year, but the normal annual water losses through evaporation are approximately 500, 700, and 600 millimeters, respectively, from these lakes. The seasonal variation of evaporation from each lake is governed by atmospheric stability conditions.

The portion of a major lowering of Lakes Michigan and Huron in the late 1880's that could be explained by a change in the precipitation climatology was determined with a mathematical response model of the system and simplified statistical rainfall-runoff models.

A field study to determine the spectral reflectances of fresh and metamorphosed snow and of various types of freshwater ice was completed. The information is important to verify and improve existing snow reflectance models and to develop new models for energy-budget-based ice forecasts and for remote-sensing applications.

Plans FY 1982

Analyses of the Lake Erie data base will provide basin-scale circulation patterns. The dynamical responses during lengthy episodes of steady wind stress will be compared with the results predicted from recent model studies and used to estimate interbasin exchange of hypolimnion water.

A field experiment to record long time series of current velocities near the center of northern Lake Michigan will be undertaken. A recently completed computational scheme to forecast rotational wave properties from the predictions of a circulation model will be used to aid experiment design.

Further work on consumptive uses of water will refine withdrawal estimates and consider additional growth alternatives that affect use rates. The overall effect of withdrawals on the ecosystem will be considered.

Techniques such as risk assessment, cost-effectiveness analysis, and optimization analysis will 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 is an additional subject for further research.

Recently inititated efforts in the particle dynamics program will be continued, including development of radiotracer methods for particle dynamics studies, determination of present and historical records of contaminant deposition in the high-sedimentation areas of each of the Great Lakes, and investigation of the role of zoobenthos in vertical sediment transport.

The experimental program on zooplankton nutrient ingestion rates will be aimed at testing a process model that relates nutrient release to ingestion rates and food quality.

Comparisons of the number and kinds of benthic invertebrates currently in southern Lake Michigan with those present 17-50 years ago will continue.

Additional work on a large-basin runoff model will involve assessment of spatial-temporal resolution trade-offs, data acquisition and reduction, model fits to watersheds throughout all the Great Lakes, and integration of the models into lake level determinations.

Standard river flow measurements by the U.S. Geological Survey, U.S. Army Corps of Engineers, and Water Survey of Canada will be used to calibrate the winter flow current meters on the St. Clair River. Remote monitoring of flows will continue throughout the winter.

MARINE OBSERVATION AND PREDICTION

Marine observation and prediction activities have focused on better understanding leading to improved prediction of phenomena primarily involved with marine warning and forecasting services. GLERL research in such fields as waves, flooding, water level oscillations, and lake ice are included. Researchers in these areas work closely with their colleagues at such agencies as the National Weather Service 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. Specific in-house research and service accomplishments during FY 1981 follow.

Accomplishments FY 1981

A simulation model of ice-cover growth and decay on the upper St. Lawrence River was developed and tested over two winter periods. Simulation results identified processes that exert the greatest control on growth and decay rates. Those processes are currently being incorporated into river ice-cover growth and decay prediction models to be used by the St. Lawrence Seaway Development Corporation and the Army Corps of Engineers.

Difficulties in making direct and accurate measurements of surface stress and airflow structure over the water surface prompted development of a new, indirect hydrodynamic method by which wind stresses over water are inferred from readily measured water level fluctuations. Surface wind stress is the main process coupling momentum transfer from the atmosphere to the water and forcing surface waves, storm surges, shoreline flooding, and currents. In this method, based on linearized, vertically integrated, shallow-water equations with rotation and friction, the water surface fluctuation is expressed as the convolution integral of time- and space-dependent wind stress with a response function kernel. Calculations of wind stress magnitude can be used with overwater windspeeds to determine drag coefficients as a function of windspeed and atmospheric stability.

A generalized spectral representation for Great Lakes waves, characterized by a variable equilibrium range constant and exponent, both with clear, tractable properties that distinguish the stages of wave growth and provide realistic spectral representation, has been developed and will be used in a numerical model for possible improvement in wave predictions.

A directional wave and coastal-boundary-layer experiment was successfully implemented with the deployment of an instrument array to measure various water movements and meteorological components in Lake Erie along a transect from the shore out to about 6 kilometers. Data from this experiment will facilitate analysis and understanding of directional wave spectra under varying wind conditions, spectral transformation of surface waves from deep to shallow water, and the momentum balance due to waves and currents in the coastal boundary layer and surf zone.

With the completion of the digitization of 3,000 Great Lakes ice charts spanning the 20-yr period, 1960-1979, the improved Great Lakes ice atlas is now targeted for publication in 1982. This ice atlas will facilitate planning by many users of the Great Lakes.

Long-term prediction of movement of chlorinated hydrocarbons, oil, heavy metals, and radioactive wastes is under development using the Great Lakes spill model.

During the past year, GLERL's Information Services provided 2,100 research products relating to both marine environmental assessment and marine observations and prediction, in response to nearly 1,400 documented requests. Of these, 48% were from universities and State governments, 38% from private industry, and the remainder from private citizens and the U.S. Government. This activity is in addition to regular mailings to recipients who have indicated interest in a bimonthly listing of one or more of the five types of GLERL publications.

Plans FY 1982

Ice breakup forecasting development for connecting channels will continue by transferring portions of the St. Lawrence breakup model to the St. Marys River.

The generalized spectral representation of Great Lakes waves will be used to develop a numerical model for possible improvement in wave prediction as well as adoption for operational use.

Spectral transformation of waves from deep to shallow water, including shoaling, refraction, and bottom friction effects, and momentum balance in the coastal boundary layer and surf zone, will be investigated using data from the Lake Erie directional-wave and coastal-boundary-layer experiment.

GLERL's Information Service will continue to supply information, data, and reports to various user groups. A goal of this activity is to provide research products that are understood and applied correctly to the solution of planning, management, or operational problems.

FACILITIES

This past year the primary field activity of personnel of the marine instrumentation laboratory has been deployment of the Lake Erie coastal-boundary-layer measurement system, and current monitor and data acquisition system in the St. Clair River. A flow tank for current meter calibration and testing was designed and built by marine instrumentation laboratory personnel and a contractor. The unit achieved all expectations and provided linear flow up to 4.5 feet per second.

New approaches to fractionation and characterization of organic and inorganic dissolved phosphorus forms were developed in the chemistry laboratory. In the biology laboratory, nutrient release rates by individual zooplankton were measured with a flow-through incubation cell, high-performance liquid chromatographic plumbing, and an AutoAnalyzer.

A particle dynamics laboratory was established this year as part of the cooperative program with the University of Michigan. It will support expanded studies in this field. Since natural and artificially produced radionuclides serve as excellent process indicators, the laboratory provides the capability for measurement of very low levels of these substances in water, sediment, and biota.

Biology experiments supported by the research vessel Shenehon included benthic, planktonic, and bacterial studies aimed at better understanding of nutrient cycling in the aquatic environment and long-term effects of pollutants. In lake chemistry investigations, colloids were extracted and analyzed after collection to determine amounts of inorganic and organic phosphorus. Investigation of the dynamics of materials movement and characteristics of the nepheloid layer continued.

INTERNATIONAL AND INTERAGENCY ACTIVITIES

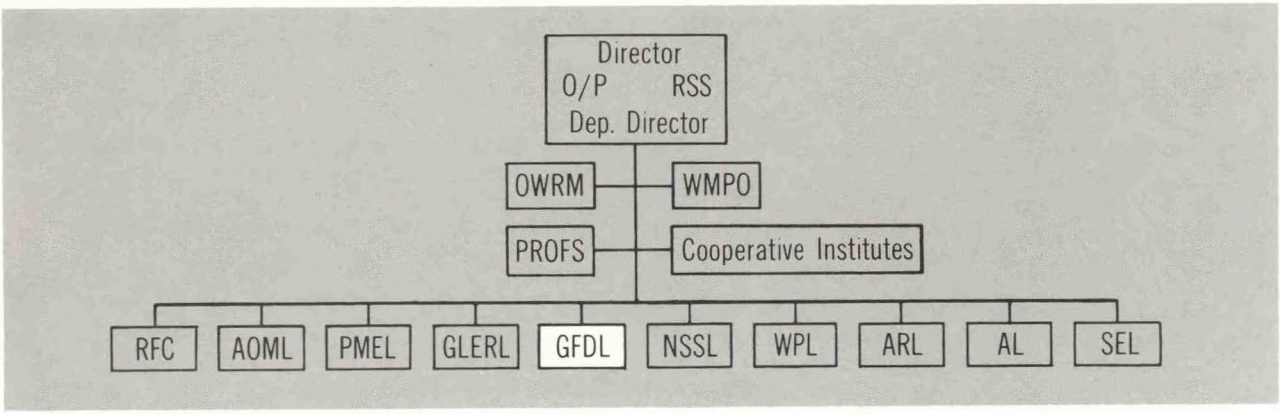
GLERL staff members were active in several International Joint Commission boards and committees, including the Science Advisory Board, Levels and Flows Advisory Board, Technical Information Network Board, Aquatic Ecosystem Objectives Committee, International Great Lakes Diversions and Consumptive Use Reference Working Committee, and Phosphorus Management Strategies Task Force.

GLERL participated in activities of the International Coordinating Committee on Great Lakes Hydraulic and Hydrologic Data, the Joint United States-Canadian Ice Information Working Group, the International Association for Great Lakes Research, the Great Lakes Experimental Team for the Coastal Zone Color Scanner, and the Regional Response Team for Spills of Hazardous Substances.

GLERL staff participated in Great Lakes Basin Commission activities as Alternate Department of Commerce Commissioners, and as members of the Great Lakes Basin Plan Committee, the Priorities Committee, the Coastal Zone Management Committee, the Standing Committee on Research and Development, the Long Range Planning Subcommittee, and the Great Lakes Environmental Planning Study.

GEOPHYSICAL FLUID DYNAMICS LABORATORY
Princeton, New Jersey

Joseph Smagorinsky
Director



The Geophysical Fluid Dynamics Laboratory (GFDL) is engaged in comprehensive long-lead-time research fundamental to application areas in support of NOAA's mission.

The 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 studied by computer simulation methods. In particular, research is conducted toward understanding the following:

- The predictability of weather, large- and small-scale.
- The particular nature of the Earth's atmospheric general circulation within the context of the family of planetary atmospheric types.
- The structure, variability, predictability, stability, and sensitivity of climate, global and regional.
- The structure, variability, and dynamics of the ocean over its many space and time scales.
- The interaction of the atmosphere and oceans with each other, and the way 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, in part, is supported by NOAA funds. Visiting scientists to GFDL may also be involved through institutional or international agreements, or through temporary Civil Service appointments.

Accomplishments FY 1981

For the first time, the transient response of climate to increasing atmospheric CO_2 was investigated in a climate model including an active full ocean. The model solutions show that, in spite of a very rapid initial response of sea surface temperature in the tropics, the response on a time scale of the order of decades is greatest at higher latitudes. Results from the atmosphere, mixed-layer ocean model indicate that the summertime zonal mean soil moisture decreases significantly in two belts of middle and high latitudes in response to an increase of CO_2 concentration in the atmosphere. Calculations with an energy balance model of climate incorporating the finite height of ice sheets show it to be less sensitive to perturbations in insolation than a model with thin snow cover.

The onset, maintenance, and breakdown stages of a blocking episode have been studied in the 15-year integration of a global spectral model with seasonally varying, prescribed sea surface temperature. Analysis of the results of the 15-year simulation shows year-to-year variations less intense but qualitatively similar to observed variations. The structure and behavior of the westward-moving external Rossby wave have been successfully simulated by spectral general circulation models (GCM's) with and without mountains. These results indicate that mountains are not necessary for the generation of the wave.

Parametric studies with the GFDL spectral GCM have yielded a wide range of circulation forms, some of which resemble those observed on the various planets. Jupiter is found to be meteorologically similar to a rapidly rotating Earth, Venus to a very slowly rotating Earth. Topographic anomalies placed in the Earth-analog circulations produce long-lived vortices resembling the Great Red Spot.

A simple technique has been devised to parameterize the effect of scale dependence on infrared damping rates in the stratosphere. This parameterization is applicable to a wide variety of analytic and mechanistic dynamical models. Isentropic analysis of GFDL tracer model experiments has led to a much-clarified understanding of the processes causing the well-known downward slope of tracer isolines toward the pole in the stratosphere.

Various general circulation models were integrated for 1 month, starting from the same initial conditions, with the objective of simulating the extraordinary blocking event of January 1977. Blocking could be reproduced only by those models with sufficient horizontal resolution and good parameterizations of sub-grid-scale physical processes. Less intense zonal mean westerlies north of about 40°N apparently provided a favorable condition for local resonance, thereby serving to maintain the blocking. The January simulations further suggest that GCM's can have predicted skill, in a time-mean sense, for periods of 1 month or longer, even without sea surface temperature anomalies.

Long-range forecasting experiments are using a simple ocean-atmosphere anomaly model in which variables are departures from climatological mean conditions. Results from a one-layer version of this model show good agreement with observations and GCM results, thus suggesting that both GCM and anomaly model approaches may be useful for long-range forecasting.

Studies of the oceanic response to winds parallel to a coast suggest that eastern boundary currents, such as the California and Canary Currents, form when there is westward Rossby dispersion of the coastal jet. An observational study of the hydrological balance shows tentative evidence that seasonal variations in the surface salinity of the tropical oceans are due largely to seasonal variations in the evaporation-precipitation balance. A new diagnostic calculation that uses observed wind stress, density fields, and bottom topography gives realistic results for the North Atlantic circulation.

The role of the large-scale wind field in the genesis of a tropical storm has been clarified. These winds were shown to affect the latent energy supply and the dynamical coupling between the upper-level and the lower-level disturbances. Extensive analysis of a hurricane eye in a quadruply nested model is in progress.

The surface convergence zone within a simulated cold front was shown to move ahead of the line of maximum vertical vorticity as the front evolved from an intensifying to a steady, mature stage. This movement not only clarifies the evolution of dry cold fronts, but also helps to explain why a frontal squall line often moves ahead of the front that generates it. Three consecutive 48-hour mesoscale forecasts have been produced for the period of 8-13 April 1979, using an 18-level, open boundary model of the eastern United States. A preliminary analysis of these solutions indicates that many mesoscale features, such as vorticity and cloud patterns, may be predicted successfully for a period of at least 48 hours.

Several 4-hour simulations of moist deep convection have been completed using time-invariant large-scale convergence and observed initial profiles of temperature and water vapor. These calculations produce a time-averaged balance of the heat and moisture budgets and a realistic moisture distribution in the vertical.

Plans FY 1982

The influence of oceanic heat transport and storage upon climate sensitivity and transient response will be investigated using coupled general circulation models of the atmosphere

and ocean. Detailed parametric experiments will be performed to test resolution, boundary layer formulation, and the effect of seasonal changes. To explore the mechanisms responsible for the cold climate of an ice age, the influence of extended ice sheets and reduced CO_2 concentration on climate, based upon the results from a series of numerical experiments with an atmosphere, mixed-layer ocean model, will be examined.

To evaluate the influence of orography on the dynamical structure and variability of the atmosphere, an analysis will be made of the 15-year integrations of general circulation models with and without mountains. Analysis will be continued of the long-term variability produced by an idealized atmospheric general circulation model (GCM) with a flat surface and no seasonal variation. A dynamic interpretation of its structure will be sought. The nonlinear interactions among transient planetary waves appearing in a model atmosphere will be investigated by a space-time spectral analysis. Analysis will be made of planetary circulation experiments which have been produced for a wide range of parameters. A better understanding of the processes determining the persistence of vortices such as Jupiter's Great Red Spot will be sought.

A research project to produce month-long forecasts for six observed January cases with a general circulation model will be continued. Three realizations, corresponding to slightly different initial conditions, will be used in each case in order to assess the statistical validity of the results. Two cloud prediction schemes will be tested in a GCM, and an investigation of the influence of cloud-radiation interaction upon long-range forecasts will begin. A more computationally efficient GCM will be completed and will then be applied to a real forecast situation.

The FGGE (First GARP Global Experiment) operational analysis will be continued. Production of Level III-b data will be completed. A pilot study will be initiated, using FGGE data, to investigate the role of diurnal variations in the operation of the atmospheric general circulation.

The new venture to understand the global dispersal and removal (as acid rain) of surface combustion nitrogen will be intensified. The collaborative effort with members of NOAA's Aeronomy Laboratory to investigate the interaction of radiation and ozone chemistry will continue, with strong emphasis on the radiative damping problem. Development of a new seasonal troposphere-stratosphere-mesosphere GCM will be started.

Studies will continue of the seasonal variability in the southeast Pacific Ocean where El Niño phenomena originate. A hierarchy of different mixed-layer ocean models will be run for 12 years, and the resulting ocean circulations and surface temperature will be compared. A three-dimensional coastal ocean model will be applied to the Hudson-Raritan Estuarine System in order to represent properly the salinity and current structure as well as the sediment transports of this system.

Two comprehensive NOAA Professional Papers will be completed. These papers describe (1) the observed global atmospheric climate, based on 15-year rawinsonde data and surface ship reports, and (2) the observed climate of the World Ocean, based on all available historical oceanographic data.

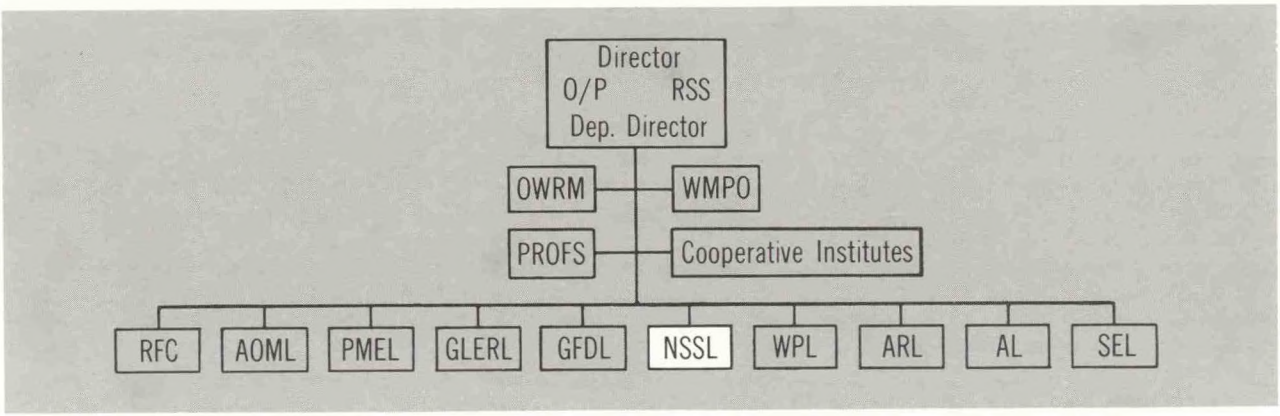
A study will be made of the sensitivity of a tropical disturbance to the sea surface temperature. The process of landfall of a hurricane will be investigated using a movable nested-mesh model.

Research will continue in the area of mesoscale predictability to determine the impact of initial and boundary errors on mesoscale numerical forecasts. The severe-storm outbreak of 10-11 April 1979, observed in SESAME (Severe Storms And Mesoscale Experiment) '79, will be simulated by a nested mesoscale model that includes Texas and Oklahoma.

Numerical calculations of deep moist convection with an imposed large-scale convergence will be continued in order to explain how this factor modifies the vertical transfer of heat, water vapor, and momentum in a tropical atmosphere.

NATIONAL SEVERE STORMS LABORATORY
Norman, Oklahoma

Edwin Kessler
Director



The National Severe Storms Laboratory has historical antecedents extending to the former U.S. Weather Bureau and its former National Severe Storms Project, located in the early 1960's in Kansas City, Mo. Described more fully in a 1976 special report (NSSL History and 1976 Program), the NSSL mission has changed little over the years, but the areas of major thrust have changed considerably in response to new technological developments, new scientific discoveries, and new expectations. The Laboratory studies severe-thunderstorm circulation and dynamics, and investigates techniques for improved storm detection and prediction. The Laboratory has progressively given greater relative emphasis to technologies for 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 of boundary layer parameters. Two 10-cm Doppler radars on a 42-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 electric fields can be recorded contemporaneously, and their interaction examined.

Through numerous relationships with other government agencies and universities, the National Severe Storms Laboratory 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 our observing tools. The Laboratory is working closely with the Joint System Program Office of the NEXRAD Program to help develop an effective national weather radar network for the late 1980's and beyond.

METEOROLOGICAL RESEARCH GROUP

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 1981

A new look at the vorticity equation in tensor form reveals that the traditional view of

the convergence and tilting terms in the vertical vorticity equation is misleading. By treating vorticity amplification as a kinematical initial-value problem, certain observed aspects of tornadoes and their surrounding flow fields have been explained, and a scenario of processes leading to the formation of major tornadoes has been presented. In brief, it is hypothesized that the ultimate rotation source for large tornadoes is ambient horizontal vorticity, and that the rear flank downdraft sometimes depicted in NSSL's Doppler radar data is indirectly instrumental in lowering the tornado circulation to the surface.

Squall lines of large horizontal extent often include an area of intense and severe convection along the leading edge and a larger rear area of fairly uniform but also sometimes heavy rainfall. A multiscale analysis and numerical simulation of a squall line that occurred on 19 May 1977 is near completion; it should provide understanding of how intense convection along the leading squall edge is maintained, and how this convection interacts with the environment to produce and maintain the broader rain area to the rear. One aspect of this study is a comparison of squall line structure and evolution (as determined from a two-dimensional numerical model simulation) with velocity and reflectivity fields analyzed from multiple Doppler radar observations.

Interactive use of both Doppler radar analyses and numerical model simulations also has proved valuable for examining various features of a tornadic storm. Complete and self-consistent data sets have been utilized from a three-dimensional simulation of the 20 May 1977 Del City storm, along with the more complex fields arising from analysis of Doppler data for the same storm, to investigate general structure, air parcel trajectories, and vorticity distribution near the time of storm maturity. When the two approaches are in agreement, the results of each can be viewed with greater confidence, whereas areas of disagreement allow focusing of efforts to improve analyses of Doppler data and the model.

Verification of numerical simulations of convective clouds is somewhat limited by lack of observed thermodynamic information. Initialization of numerical experiments using observed data also hinges upon the availability of a complete set of fields of the state parameters. In an effort to provide thermodynamic information for application to a number of cloud physics areas, a temperature retrieval method has been tested. Here, detailed wind and water information in convective storms is used as input to the diagnostic retrieval method to produce temperature and pressure information throughout the same volume. Testing is complete, and conversion of the method to utilize wind and reflectivity fields derived from Doppler radar data is now proceeding.

As part of the international Alpine Experiment (ALPEX) cyclogenesis in the lee of the Alps has been studied at NSSL to understand better the similar processes in the lee of the Rocky Mountains that lead to severe storm outbreaks in the southern Plains. The analysis indicates that lee cyclogenesis is a multistage process that starts with a shallow, terrain-induced barotropic phase (i.e., a phase determined by inertial properties of the initial flow fields), a rapid development phase where baroclinic processes (i.e., effects of temperature contrast) are added, and a mature stage in which the storm system is dominated by baroclinic processes. A critically important effect of the mountain range is the increase in strength of the zone of temperature contrast as it passes over the ridge. Secondary flow responds in the lee of the mountains, with upward flow at middle levels superimposed over descending air at low levels on the mountain slope. Such vertical stretching produces a dynamical response that appears as increased cyclone strength.

The disposition of forces that drive convection has been indicated by analysis of a squall line that passed through the NSSL surface and rawinsonde mesonetworks on 26 April 1969. A composite cross section normal to the squall line shows a mesoscale descent-ascent doublet in the vertical motion field. Descent was centered about 10 kilometers ahead, and ascent about 5 kilometers behind the leading edge of the squall line. The downdraft appeared to be driven by evaporative cooling from the tops of the convective clouds; the updraft seemed to be driven mainly by condensational heating. This and other cases suggest that the doublet of mesoscale vertical motions may be a distinguishing feature of large convective-storm systems in their mature stages of development.

We have documented the role that thunderstorm-produced gust front can play over time intervals of an hour or two, in the production of new severe-storm activity. When the gust front from one storm intersected (and occluded) the gust front remaining from an earlier storm, the portion of the storm near the intersection experienced explosive growth with production of a tornado. At times, the pre-existing gust front is evident in satellite pictures; enhancement of approaching storms can then be forecast with more than usual confidence.

The NSSL Tornado Intercept Project (TIP), in conjunction with intercept teams from the University of Oklahoma and University of Mississippi, had a very successful 1981 spring data collection period. TIP aims to document the life cycles and the evolutionary characteristics of tornadoes and their parent storms with the aid of visual and photographic data. On 17 and 22 May 1981, nine tornadoes were photographed. Several of the movies obtained are suitable for estimating tornado windspeeds. Three tornadoes observed on 17 May were filmed with the "Vonnegut camera" (which records lightning flashes on the audio track of a super-8-mm movie camera); however, no lightning events were recorded, indicating that there was little lightning near the tornadoes.

NSSL cooperated with the University of Oklahoma and with ERL's Wave Propagation Laboratory in the deployment of an instrumented package (TOTO--totable tornado observatory) in front of advancing tornadoes. Data were obtained within 1 kilometer of two tornadoes on 22 May and beneath a wall cloud (without a tornado) on 17 May. The largest tornado (up to 2-km wide at cloud base) on 22 May started near Binger, Okla., and was on the ground for 24 kilometers as it moved east-northeastward. Doppler velocity and reflectivity signatures associated with the tornado extended to the unusual height of 13 kilometers (storm top was 14 kilometers). Maximum tornado speeds of 90 meters per second (relative to ground) were apparent in Norman Doppler velocity spectra.

Data collected during the spring program help us to understand how severe storms form, how they evolve, and how mesocyclones (initiation region for tornadoes) develop. In all mesocyclone data collected with single Doppler radar from 1971 through 1977, the average radius of identified mesocyclone cores is 5 kilometers, peak core tangential velocity is 23 meters per second, and, during its mature stage, the mesocyclone extends from the ground to a height of 9 kilometers. Two-thirds of the mesocyclones that reach the mature stage produce a tornado. The mesocyclone radar data indicate that mesocyclones with only one core (75% of the cases) exist for about 1.5 hours, whereas the remaining 25% with multiple sequential cores last an average of 3.0 hours. We postulated that the sequential cores--which appear at 45-min intervals--reflect the surface gust front occlusion process, wherein the old updraft (vorticity concentration mechanism) becomes cut off from moist low-level inflow and a new updraft forms at the new point of gust front occlusion.

Hail suppression is attempted in various parts of the world to try to save crops. However, no such operation exists in the United States because not enough is known about basic hail growth processes in severe storms to design suppression procedures intelligently. Part of the NSSL research effort--in conjunction with the National Center for Atmospheric Research and the University of Oklahoma--has been to try to understand hailstone growth. The plan of attack has been to combine growth characteristics revealed by the structure of collected hailstones with a numerical hail growth model that incorporates wind fields and environmental thermodynamic parameters derived from multiple-Doppler-radar data.

Most severe hailstorms occur with supercells, which are large single entities contrasting to the multiple cells characteristic of most thunderstorms. Hailstones collected beneath a supercell storm on 17 May 1980 had similar embryos (core regions 0.5 to 1.0 centimeters in diameter) over a distance of 100 kilometers and a time period of 1.5 hours. This finding suggests that neither small-scale nor short-lived storm flow features affected hailstone embryo formation. However, the different outer crystalline structures of two hailstones collected 7 kilometers apart at the same time indicate that hailstones in supercell storms are not necessarily produced along similar growth trajectories, contrary to past hypotheses. There apparently are significant small-scale variations in growth trajectories that must be understood before hail growth in supercell storms can be explained adequately.

A numerical hail growth model indicates that hailstone density differences influence hail growth most significantly in stages. Although all the hailstones grow in the same portions of the updraft, trajectories for different sizes and weights of stones differ significantly.

Analyses of single- and multiple-Doppler-radar data were compared to determine the relative abilities of the various techniques to deduce storm structure. The best results were obtained when vertical-velocity computations based on the vertical integration of the continuity equation were constrained at both the top and bottom boundaries. Basic features of the Radar Analysis (RADAN) System for multiple-Doppler-radar data sets have been presented in a report.

By use of colocated 5- and 10-cm-wavelength Doppler radars, the disappearance of the Wichita Falls tornadic storm from the 5-cm radar scope on 10 April 1979 has been documented.

Attenuation of the 5-cm signal by an intervening severe storm illustrates once again an inherent risk associated with the use of 5-cm radars for storm detection and warning.

Plans FY 1982

During FY 1982, major efforts of the Meteorological Research Group will continue to emphasize analyses of multiple-Doppler-radar data on severe storms and the establishment of relationships connecting the coevolving distributions of wind, temperature, and precipitation in storms. Several approaches will be used: (1) Theoretical investigation of tornadogenesis and mesocyclone structure will continue. The development of a warm/cold cloud numerical model with parameterized microphysics will be completed, and it will be used in conjunction with observed data in selected storm cases. In addition, the thermodynamic retrieval method will be applied to one or more storm velocity data sets to ascertain its utility as a diagnostic tool. (2) Analysis and modeling of the 19 May 1977 squall line will be completed to obtain insights into squall line dynamics on several scales. Data collected from severe storms on 2 May 1979 and 6 June 1979 will be examined to ascertain the dynamics of storm organization and intensification. A tornadic storm on 22 May 1981 was well situated in the observing network for wind and electric fields to be related.

Lee cyclogenesis near the Rocky Mountains will be examined in relation to dry-line formation and subsequent severe-storm development.

A study of temporal and spatial correlations for surface mesonetwork data pertaining to thunderstorm occurrences in the period 1973-1979 is expected to be completed. The correlations will be used to establish optimum weighting functions for objective analysis of mesonetwork data.

The size and shape of thunderstorm updrafts, which appear to be critical parameters in the hail growth process, will be investigated and compared in storms that produced hail and in those that did not in order to confirm or revise present conceptual hail models.

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 in order to determine the interaction between storm processes, especially microphysical processes, and the storm's electric field.

Accomplishments FY 1981

DOPPLER RADAR DATA COLLECTION PROGRAM--1981

NSSL's spring 1981 data collection effort was most intense in May when several tornadic storms developed in the vicinity of NSSL radars. One of them, on 22 May, provided a unique data set from the birth of a storm to subsequent tornado formation. Also, unique time series data were collected with high pulse repetition frequency from a maxi-tornado. Very strong storms also occurred on 9, 17, and 23 May. Low-level wind data were obtained from the KTVY-TV meteorological tower and from the FAA's LLAWS system for reporting near-surface winds around Will Rogers International Airport at Oklahoma City, Okla., on 17 and 22 May.

The NASA F-106 aircraft instrumented to measure wind, turbulence, and atmospheric electricity participated in the data acquisition program from 25 March to 24 April. Although no direct lightning strikes were encountered, the sensing equipment was triggered by a number of nearby flashes, and moderate-to-severe turbulence was encountered on several flights.

A cooperative experiment with NASA's Marshall Space Flight Center began on 29 June when NASA's Convair 990 aircraft equipped with a Doppler lidar arrived at Tinker Air Force Base. The NASA program involves studies of air flow in the boundary layer and in thunder-

storm environments to test lidar capabilities for measuring the wind and to illuminate properties of boundary layer flow.

As part of a joint NOAA and FAA Air Transport Association program, a test of commercial prototype airborne Doppler radar began in mid-July. An FAA DC-9 based at the FAA Technical Center, Will Rogers International Airport, Oklahoma City, Okla., was made available to the project, and the necessary modifications were completed.

USING DOPPLER RADAR TO MAP KINEMATIC WIND PROPERTIES IN THE PRESTORM ENVIRONMENT

Although two Doppler radars can provide definitive measures of the horizontal wind, the spacing of radars in the future national network (NEXRAD system) will be too wide to permit use of dual-Doppler-radar techniques. Therefore, we have been investigating means for utilizing the data of single Dopper radars to the fullest extent practicable. For example, computational algorithms for single Doppler radar and the assumption of a linear wind field within analysis volumes (termed velocity volume processing, VVP) permit mapping of certain mesoscale (20-100 kilometers) kinematic properties of the convective boundary layer a few hours in advance of subsequent thunderstorm development. Results improved after sophisticated editing procedures were applied to the radial velocity fields, to remove spurious point target echoes (e.g., birds, aircraft). Maximum convergence and deformation were observed along a frontal zone, and effects of these features on frontogenesis have been estimated.

In a variation of the VVP technique noted above, horizontal wind fields have been computed by assuming uniform wind in each analysis volume (40° x 0.8° x 20 kilometers). The results appear reasonable when compared with in situ rawinsondes and mesoscale analysis of surface and upper-air data. A frontal surface was resolved clearly from the wind field, and its slope with height was measured. Although a local maximum of convergence was observed near an area where thunderstorms later developed, the magnitude of convergence was only about one-fourth that necessary to initiate moist convection as estimated from parcel theory. However, the minimum resolvable scale for these convergence estimates is several times the actual shower scale.

DOPPLER RADAR OBSERVATIONS OF MOMENTUM FLUX IN A CLOUDLESS CONVECTIVE LAYER WITH ROLLS

We are investigating use of dual Doppler radars to estimate momentum flux and turbulence intensities in the convective boundary layer. These phenomena related to the generation and dissipation of atmospheric flows and therefore are basic to the interests of both theoreticians and forecasters. Reasonable agreement was observed between horizontal turbulence measured by radar, tower, and aircraft. The momentum flux in the flow eddies observed by radar appears to be in the vertical direction opposite to that of smaller scale eddies. Although such a difference has been observed elsewhere at times, it is at variance with some previous theories, and calls for further study. We observe a sink of turbulence production due to shear in the upper half of the boundary layer, in agreement with measurements obtained elsewhere.

TURBULENCE STUDIES

Improvements in flight safety and in use of critical airspace should follow improved detection of thunderstorm turbulence and display of turbulence locations. Studies using NSSL Doppler radar and aircraft data have shown close correspondence between turbulence and velocity spectrum width, and studies of view-angle dependence are in progress to test the ability of Doppler radar to detect turbulence from any perspective.

Studies of gust fronts also include this view-angle-dependence feature to determine the reliability of a single Doppler radar for accurate identification of gust fronts and other wind shear events.

LIFETIMES AND VERTICAL SCALE SIZES OF WEATHER FEATURES

Studies on lifetimes of atmospheric features relate to the design of the next-generation national weather radar (NEXRAD) system. The first phase of study at NSSL was based on visual interpretation of sequences of photographs of the reflectivity, velocity, and spectrum width fields corresponding to a well-developed storm observed on 24 April 1980. Important features of the storm were found to be stable over a period of 10 minutes. The vertical size of significant features was found to be at least 1.5 kilometers. The determination of feature

lifetime has been automated, and a computer program based on time-delayed and space-shifted correlation is now available. Findings from this correlation study about decay rate and lifetime of selected storm features are in good agreement with the photograph-derived values and should help to determine appropriate scanning and data rates of future weather radars, and hence their cost.

DOPPLER RADAR ECHOES OF LIGHTNING

Doppler radar can be used to study lightning associations as well as some physics of the lightning process. Thus, digital time series data at 16 heights through two storms were collected at vertical incidence with a 10-cm Doppler radar. On several occasions during data collection, lightning echoes were observed as increased reflectivity on an oscilloscope display. Simultaneously, lightning signals from nearby antennas that sense electric field change were recorded together with the radar echoes. Reflectivity, mean velocity, and Doppler spectra were examined by means of time series analysis during and after lightning discharges. Spectra from locations where lightning occurred show peaks due to the motion of the lightning channel. These peaks are considerably narrower than those due to precipitation. Besides indicating the vertical air velocity that can then be used to estimate hydrometeor size distribution, the lightning spectra provide a convenient means to estimate the radar cross section of the lightning channel and hence the ion density. Subsequent to one discharge, a rapid change in the orientation of ice crystals seems to have occurred within the radar resolution volume.

REAL-TIME PROCESSING AND DISPLAY OF DOPPLER WEATHER RADAR DATA

A new real-time computer for Doppler data signal processing, funded through the NEXRAD program, was delivered to NSSL; software development of some algorithms began, and an automatic method to detect mesocyclones and shear lines was programed.

A new display was developed for the Cimarron Doppler radar, and hardware and software for improved display of data from the WSR-57 radar and aircraft-identifying radar (IFF) have been completed.

From studies on mean velocity estimators, based on a small number of samples, we found that a vector pulse pair processor operating with four lags for clear-air observations and single lag (pulse-pair mode) for storm observation may represent an optimum way to estimate Doppler velocities over the entire gamut of weather phenomena.

STUDY OF A GROUND CLUTTER FILTER

Returns from ground targets interfere with the processing and visualization of meteorological data. Therefore, we are studying ground returns with the objective of their reduction or elimination. This study is contributing to the fabrication of an improved ground target filter for test on our Doppler radars.

BOOK ON DOPPLER WEATHER RADAR

The first nine chapters of a forthcoming book Doppler Weather Radar have been completed. The book's eleven chapters will deal with Doppler weather radar signals and techniques to observe weather. We expect the book to be published by Academic Press.

Plans FY 1982

NASA scientists will again use their lidar-equipped aircraft and NSSL facilities to evaluate lidar capabilities for wind mapping in clear air.

Design of interfaces and development of programs for the real-time radar signal processor will begin. Composite display of hazardous weather will be developed.

Relationships between turbulence in storms and Doppler spectral moments will be examined. Doppler spectrum width data will be collected by two radars so that orientation sensitivity of turbulence can be evaluated. Turbulence-generating mechanisms will be investigated, gust fronts sensed by Doppler radar will be studied, and data will be collected to determine predictability of rapid storm growth from the first echo. The algorithm for automatic recognition of mesocyclones, shear lines, and strong divergence will be tested.

STORM ELECTRICITY

This program deals with the many complex aspects of lightning and other storm electricity parameters. Major objectives include (1) evaluation of storm electricity parameters as indicators of thunderstorm severity, and inferences of precipitation and wind structure, (2) refinement of techniques for locating and tracking thunderstorms and for remote determination of lightning ground-strike locations, (3) development of techniques for predicting and warning of lightning hazards, (4) definition of lightning characteristics for inputs into engineering criteria for lightning hazards and into models used in environmental studies, (5) measurement of effects of electric fields and lightning on radar-derived meteorological parameters, and (6) development of new observational techniques.

Accomplishments FY 1981

The NSSL facility to observe electrical and kinematical processes contemporaneously with precipitation phenomena and in great detail, has no parallel elsewhere; we accordingly gave top priority to observation of storm electricity during the 1981 spring program. Data acquisition at the VHF lightning-mapping sites (colocated with NSSL's dual, 10-cm-wavelength Doppler radars and other storm electricity sensors at the Storm Electricity Building) was closely coordinated. Simultaneous observations were made of numerous severe storms and several tornadic storms within the dual-Doppler mapping areas. Lightning echoes from L-band (23-cm wavelength) radar were simultaneously observed with VHF mapping of discharges for comparison and correlation, and the radar data were used to track lightning in the mesocyclone region of storms. This combination of sensors was also used to identify regions of lightning activity for guidance information to a NASA F-106 which penetrated storms to measure turbulence and lightning strikes to the aircraft. A mobile laboratory was used to record electrical activity in many severe storms and near several tornadoes in the Oklahoma, north Texas, and Texas Panhandle regions.

The VHF mapping instrumentation at Norman was modified to accommodate switching into a vertically looking mode for observing lightning overhead. A four-station crossed-loop direction-finding network was installed to locate cloud-to-ground strike points within about 400 kilometers of NSSL. Two stations were operated as prototypes for locating strike points of cloud-to-ground lightning carrying positive charge to ground (+CG).

Intracloud lightning development presents a very complex picture, as revealed by VHF mapping data. Some discharges are more than 50 kilometers long and generally progress at speeds between 5×10^4 and 3×10^5 m s^{-1}. Many of these long discharges do not appear to be a single interconnected flow of current made up of many channels, but rather appear to be composed of several closely related discharges. Range and time fluctuations of the L-band lightning echoes seem consistent with the lightning structure obtained from the VHF mapping data. The rise time of a radar lightning echo is consistent with channel propagation through the beam. The Norman Doppler radar was used in a vertically pointing mode to determine the true vertical windspeed by using lightning echoes as a tracer.

NSSL

Positive CG flashes were verified to emanate from high on the back of the main storm tower through the wall cloud, and from the downshear anvil. A typical field change for +CG flashes shows a slow change prior to the abrupt return stroke that is followed by a larger, slow change indicative of continuing current. Acoustic mapping of thunder sources shows that major channels of +CG flashes extend to 15 km.

The core of lightning activity moves relative to the precipitation core during storm evolution. However, the horizontal extent of flashes increases as a storm begins to decay. Lightning was found to propagate between individual cells in squall lines. A class of intracloud lightning has been identified that occurs almost continually at altitudes greater than 10 kilometers in some storms. These small flashes have little or no time relationship with lower altitude flashes in the same storm.

Plans FY 1982

We expect to complete analyses of storm electricity data obtained from all storms of 19 June 1981, and begin analyses for other selected observation periods. We expect to determine relationships between storm electricity and the phenomena of precipitation, kinematics, and dynamics inferred from Doppler radar.

We will seek electrical indicators of storm severity, and develop and evaluate techniques to identify lightning flash types.

We expect to obtain and analyze ELF (extremely low frequency) waveform data to test the feasibility of using a hybrid ELF-optical system for lightning detection from satellites.

The VHF lightning-mapping system will be improved through redesign of the logic circuitry for better resolution of lightning flash characteristics.

We will continue to develop techniques to detect, track, and warn of lightning hazards and other severe-weather hazards through the use of lightning observations.

ENGINEERING SUPPORT AND DEVELOPMENT GROUP

The Engineering Group provides engineering development, maintenance, and operation support of the NSSL. The group develops techniques and equipment for evolving Laboratory programs, while maintaining existing systems and assisting in data acquisition and data quality control monitoring. The group also provides engineering support to the JSPO/Interim Operational Test Facility of NWS, which is colocated with NSSL.

Major research facilities at NSSL include two 10-cm Doppler weather radars, a WSR-57 surveillance radar, an ATCBI-3 beacon radar, a meteorologically instrumented 1,500-ft tower (KTVY), and a surface observation network (52 stations).

Accomplishments FY 1981

Much of the NSSL engineering effort centers around support of the spring observational program. In 1981, this program was configured primarily for support of atmospheric electricity observations. A limited aircraft program and special studies--such as clear-air observation and meteorological studies for other in-house research--and the NEXRAD program were also supported. Participation by organizations outside NSSL was not as great as in 1980, but the in-house effort remained substantial.

Engineering development in direct support of atmospheric electricity consisted of continued development and expansion of the acquisition-and-analysis terminal and interface between a custom data processor and recorder for the L-band radar. An L-band radar processor was developed to provide computer-compatible data suitable for semiautomated detection of lightning channels.

A significant step in the upgrading of NSSL facilities for air traffic control was taken with the replacement of the MPX-7 interrogator with the ATCBI-3 beacon radar. The new system will improve air traffic control from NSSL with the addition of the decoder and associated signal-handling capability. Work on the display terminal continues.

Study of radar ground clutter characteristics and suppression techniques culminated in a functional design of a clutter suppression device that operates on the signal envelope, and is thus applicable to both coherent and incoherent radars. The hardware for this device will be designed and fabricated in the NWS Equipment Development Laboratory, and tested at NSSL.

During FY 1981, NSSL constructed and installed antenna elevation controllers on the NWS radars at Limon, Colo., and Cheyenne, Wyo., in support of the ERL PROFS program. These controllers are similar to those used on the NSSL WSR-57 and provide limited automation of the radars for systematic data acquisition.

A request for bids was issued and a contract let for the entire solar power system to be used with NSSL's digital mesonetwork. The solar power system will release the NSSL mesonetwork from commercial power or rotating battery requirements and facilitate selection of sites and deployment of sensors.

A proposal for NSSL to provide specific engineering development in support of the NEXRAD program was submitted to and accepted by the NEXRAD Joint System Program Office (JSPO). This proposal identified two tasks: engineering development of a dual-frequency meteorological radar with emission contained within one radar emission bandwidth as

defined by the FCC, and design and construction of a hardwired device to suppress ground clutter, specifically for the velocity channel of the meteorological Doppler radars. NSSL will do this work under contract to JSPO.

The first phase of a significant upgrading of the Radar Analysis and Display terminal at Norman (NRO) was completed with the delivery and temporary installation of the P-E 3240 computer. The machine is being used as a stand-alone terminal pending cabling work and renovation of the NRO Operation Building.

The NSSL NRO Doppler radar served as the standard for ground-based testing of airborne Doppler radars developed by Bendix and Collins for commercial aviation. Results of the ground testing are encouraging, and plans are being made for continued airborne testing in spring 1982, using the FAA DC-9 training aircraft and the NSSL radar facilities.

Plans FY 1982

Engineering development and support in FY 1982 will, in general, consist of support of the spring data acquisition program, equipment and techniques development for special studies and general facilities upgrading, and contract work for groups outside NSSL.

Preliminary planning relating to the spring program is for a configuration again strongly supporting atmospheric electricity observations with outside agency participation. As before, we expect an aircraft program in the new year to include storm penetration aircraft, electric-field measurements, clear-air or boundary layer measurements, and evaluation of the prototype airborne Doppler radars. There are also plans for data acquisition to support NEXRAD in both contract engineering evaluation and meteorological analysis development.

Two engineering projects are currently under way as part of the preparation for the FY-1982 observation program. A radar data terminal to upgrade the NSSL air traffic controller facility is under development. This is a high-resolution color display capable of compositing the IFF transponder data and the WSR-57 weather data, with the two radars operating independently. The minimal system is scheduled to be commissioned by April 1982 for use during the spring program. The SAM solar power systems are scheduled for delivery deployment in late fall and winter for use during the spring program.

A major engineering development effort in early FY 1982 will be the work under the JSPO contract as noted above. We expect to complete design and fabrication of a dual-frequency meteorological radar with transmitter emission contained in a single-frequency radar emission bandwidth. This type of radar would enhance capability for suppression of ground clutter, and increase the data acquisition rate, while producing only minimal increase in frequency congestion of the meteorological radar band. The NRO radar will serve as the test bed for this activity.

Testing and evaluation of the clutter suppression device under development by NSSL, under the JSPO contract, and the other device by EDL/SDO/NWS noted above under FY-1981 accomplishments are scheduled for spring and summer of 1982.

Installation of the P-E 3240 computer in the NRO Operation Building and completion of the radar interface is scheduled for early 1982. This system and its associated peripherals will significantly increase the online computational power of the NRO terminal and allow real-time testing of meteorological analysis techniques for NEXRAD. Such testing will probably be conducted by the JSPO Interim Operational Test Facility located at NSSL; an operational period is scheduled for September 1982.

COMPUTER AND DATA PROCESSING GROUP

This group (CDP) operates the NSSL computer system; develops application software for engineering and meteorological support; performs quality control of data, archives data, and disseminates data to outside groups; and maintains systems software for in-house computers. CDP consults with all NSSL groups for selection of data acquisition and real-time processing equipment, evaluation of computer requirements, and recommendations for replacement hardware.

Accomplishments FY 1981

In support of the 1981 spring data collection program, quality control and indexing were performed for this data set: 564 Norman and Cimarron Doppler tapes; 4 WSR-57 radar tapes; 51 instrumented-tower tapes. Additionally, 3 rawinsonde stations took 112 soundings, and the NSSL surface network operated 14 stations.

Work on the universal Doppler data exchange format progressed to the state that universal-format NCAR Doppler tapes were successfully converted to NSSL archive format and analyzed. NSSL produced a Cimarron Doppler tape in the universal format which was read by the NCAR FOF group. In the future, NSSL will do all exchange and internal archiving in the exchange format.

The universal format for surface data has been implemented on NSSL computers. NSSL's Meteorological Research Group is converting important storm cases and the NCAR PAM mesonet data to this format for internal use. The archiving of the 1979 SAM mesonet data is in the final phase; the data are being archived in the universal format.

Work on the ERL FY-1982 computer initiative continued with attendance at ERL meetings and added responses to several drafts of the Request for Proposal.

Data collected at the National Severe Storms Laboratory are used by many university programs, other government agencies, and private industry. Organizations receiving NSSL data during the past year include the following:

Control Data Corp., Minneapolis, Minn.
Environmental Research Technology, Inc., Lexington, Mass.
Equipment Development Laboratory, Silver Spring, Md.
Finnish Meteorology Institute, Helsinki, Finland
MIT Lincoln Laboratory, Lexington, Mass.
NASA, Troposphere Branch, Goddard Space Flight Center, Greenbelt, Md.
NCAR, Convective Storms Division, Boulder, Colo.
NCAR Field Observation Facility, Boulder, Colo.
NCAR, Mesoscale Research Section, Boulder, Colo.
Ohio State University, Atmospheric Sciences Project, Columbus, Ohio
Oklahoma Corporation Commission, Oklahoma City, Okla.
Old Dominion University, Dept. of Geophysical Sciences, Norfolk, Va.
Sperry, Great Neck, N.Y.
Sperry Gyroscope, Independence, Mo.
Texas A & M University, Department of Meteorology, College Station, Tex.
University of California, Department of Atmospheric Sciences, Los Angeles, Calif.
University of Oklahoma, Norman, Okla.
University of Virginia, Charlottesville, Va.
University of Washington, Seattle, Wash.
University of Western Ontario, London, Ontario, Canada
University of Wisconsin, Madison, Wis.
University of Wisconsin-Milwaukee, Milwaukee, Wis.

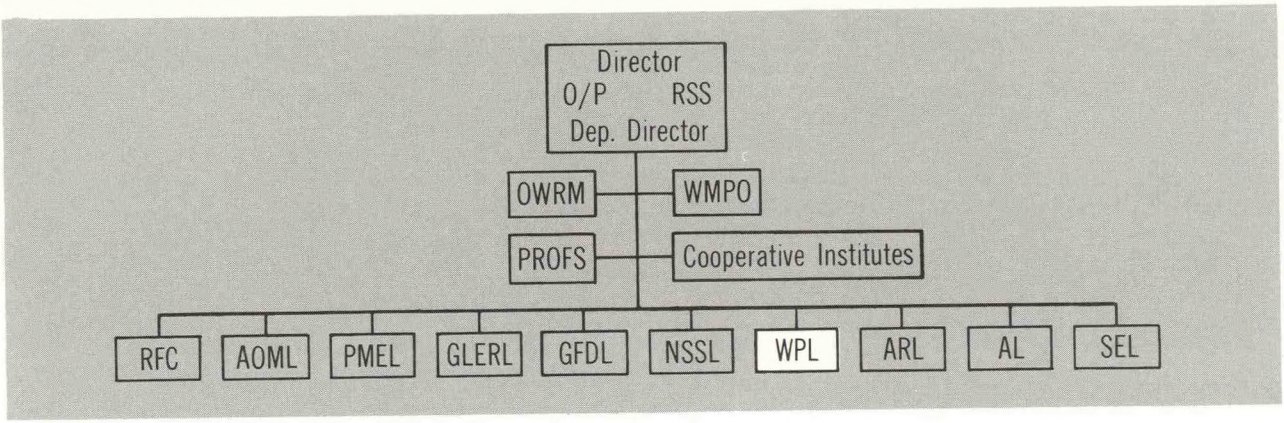
Plans FY 1982

The award for the FY-1982 computer initiative should be made this year with installation early in FY 1983. Future growth of NSSL research is dependent on the acquisition of a new computer and proper support.

The Computer and Data Processing Group will be officially abolished 28 November 1981, and most of its functions will be transferred to the Engineering Support and Development Group. Other functions will be redistributed within the laboratory, and contract personnel will be hired as needed.

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 state of the atmosphere and ocean in order to be able to predict their future state. 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, by transfer of the newly developed remote-sensing technology to others.

Because observational capability underlies essentially all geophysical research and services, WPL's research has broad impact and already contributes to five of RD's nine programs. Where appropriate, the research within a single program is divided in this document 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-1981 program and FY-1982 plans.

WEATHER OBSERVATION AND PREDICTION

WPL's contributions to weather observing and prediction support NOAA's largest and most important single service, namely, weather forecasts and warnings. Support is 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 can contribute uniquely to 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 of remote sensors and their application to this field.

Accomplishments FY 1981

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 several advances in scintillation theory during FY 1981, as follows.

The diffraction theory of optical scintillations, when applied to the case of light sources of large angular extent, predicts that the intensity of sunlight reaching the ground fluctuates 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.

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. It has been shown that an appropriate spatial filtering of the received scintillation pattern should permit path-averaged measurements of the inner scale of turbulence, and the vertical fluxes of heat and momentum.

Early work by WPL showed that the intensity of scintillations eventually saturated as the intensity of temperature eddies along an optical path increased. The theory of this phenomenon has been extended in two recent WPL papers to cover arbitrary refractive index spectra (including, for example, the effects of the inner scale of turbulence), and the propagation of plane (as opposed to spherical) waves.

The degradation of performance of coherent optical lidar systems due to the presence of atmospheric refractivity turbulence along the intervening path was analyzed theoretically, and shown to be significantly less than that proposed by other authors.

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. Two WPL LWI's were tested operationally at Stapleton Airport, Denver, and at Otis AFB, Massachusetts, and a report on their performance was prepared.

The real-time acquisition of surface wind data at multiple locations over an area for either research or operational purposes can be expensive, since electrical power and telemetry are usually required at each location. Earlier work by WPL had shown that path-averaged transverse wind speeds can be measured by scintillation techniques. The need for power line or phone support to these instruments has recently been eliminated by using solar cells to provide electrical power, and optical beams as the telemetry channel as well as the indicator of transverse wind speed.

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 1981, two improvements were in process. The mobile carriage on the tower has been instrumented to permit the measurement of mean profiles of wind, temperature, and humidity, as well as fluxes of momentum, heat, and water vapor, and an infrasonic observatory is being set up at BAO, with new noise-reducing microphones tested at the site as its basis.

BOUNDARY LAYER RESEARCH

Theoretical

A numerical model of the statically stable planetary boundary layer, using a parameterization that relates turbulence quantities to mean gradients of temperature and wind, successfully simulated winds and backscatter profiles observed with acoustic sounders under quasi-steady conditions at the South Pole. This has led to the design of an experiment at BAO to test the turbulence parameterization under unsteady conditions and in turbulent layers that are decoupled from the surface.

One of the critical problems affecting aviation safety and maximum landing rates at commercial airports is the wake vortex problem. In support of FAA interest in the WPL FM-CW radar as a technique for remotely monitoring wake vortices, calculations were completed predicting the roll-up and mutual interaction of aircraft wake vortices in the lower boundary layer, i.e., as the vortices begin to sense the presence of the ground.

Experimental

Definitive studies of the atmospheric boundary layer have hitherto been limited to studies over smooth, horizontal terrain (e.g., Kansas). BAO has permitted the extension of this work to uneven terrain; analysis of data from the first major BAO boundary layer experiment (April 1978) has given the important result that the daytime temporal and spatial properties of the turbulence around the site are very similar to those observed over flat, uniform terrain.

One significant application of turbulence statistics is to the design of wind energy conversion systems. A major report has been completed for the Department of Energy on turbulence statistics observed at the BAO meteorological tower during high wind conditions.

The depth of the planetary boundary layer is a parameter important for air pollution models. Since this parameter is highly variable, remote methods are desired for monitoring it continuously. Five remote-sensing techniques for measuring the height of the boundary layer were compared at BAO; agreement between the different methods was generally good, with some tendency for the lidar and short-wavelength (8-mm) radar to show additional layers above the primary boundary layer.

Most of the boundary research to date has been limited to the convective, daytime case. WPL has initiated what we hope will be a definitive series of studies at BAO of the much less simple (yet more important) stable boundary layer case. The STABLEX (Stable Layer Experiment) 1981 experiment used the fixed and carriage instrumentation on the BAO tower, plus an acoustic echosounder and the FM-CW radar, to collect information on the structure of elevated and ground-based inversions.

A study of erosion of stable boundary layers over the Boulder Valley during the 1980 AEOLUS experiment was completed. The erosion process, monitored by an acoustic echosounder, typically lasted several hours; the time of erosion impact at the surface (and hence of the onset of strong surface winds) was well predicted by linear extrapolation of the erosion process as monitored by the acoustic echosounder.

Measurements of windspeeds in atmospheric vortices are notoriously difficult to obtain. Two papers were published, presenting analyses of 21 data sets of velocities of waterspouts, obtained by an airborne CW infrared Doppler lidar. Maximum velocities ranged from 4.2 to 33.6 meters per second, and visible funnel diameter from 6.6 to 90 meters.

Plans FY 1982

SENSOR DEVELOPMENT

Experimental tests of recent theoretical advances in whole-sun scintillation, inner-scale measurement, and saturation of scintillations will be initiated. A new algorithm will be developed for the Laser Weather Identifier systems to improve their ability to differentiate between snow and high wind conditions. The transverse wind-measuring capability will be expanded to measure path-averaged water vapor, leading to an ability to measure near-surface moisture convergence.

Under Army Research Office sponsorship, WPL will undertake, in cooperation with the Georgia Institute of Technology, a multi-year research program to advance the understanding of the interaction of submillimeter waves with the atmosphere. These waves, lying in the relatively unknown spectral region between infrared and radiowaves, are of interest to the Army Research Office for military purposes, and their strong interaction with the atmosphere offers NOAA the possibility of new remote-sensing capabilities.

BOUNDARY LAYER RESEARCH

The STABLEX 1981 data will be analyzed to gain further understanding of turbulence in stable boundary layers, and especially the quantitative interpretation of electromagnetic and acoustic backscatter records.

Wind statistics from the Boulder Wind Network will be used to investigate drainage flows in the Boulder Valley area, and compared with laboratory simulations of the flows.

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, and for short-term local weather nowcasting and forecasting purposes. Progress in the development and general application of these sensors is covered in this section; specific applications to air quality, climate, or weather modification are covered elsewhere.

Accomplishments FY 1981

MESOSCALE SENSOR DEVELOPMENT

IR Doppler Lidar

The Doppler lidar components received from industry were assembled into the first U.S. pulsed TEA (Transverse Excited Atmospheric) laser atmospheric Doppler lidar system. The lidar is housed in a 32-ft semi-trailer van, and has been carefully tested and calibrated against standard reflectance targets. Preliminary measurements of winds aloft were accomplished by means of a VAD (velocity-azimuth display) scan. Winds measured alongside the BAO tower at a horizontal range of 22 kilometers consistently agreed to within 0.1 meters per second with the tower data.

Microwave Doppler Radar

WPL pioneered multistation Doppler radar observations of chaff and precipitation more than 10 years ago. This capability has now been extended to cloud particles by the design and construction of a steerable, 8-mm-wavelength Doppler radar and the upgrading of the sensitivity of the two existing WPL 3.2-cm-wavelength Doppler radars. The new 8-mm-wavelength system has dual-polarization capability, to permit differentiation between echoes from spherical cloud liquid droplets and ice crystals. A mobile data-processing system based on a DG S-250 computer is under development, to provide in-the-field data analysis capability.

For some years, WPL has used the 10-cm-wavelength FM-CW radar for clear-air research. Such radars benefit from a very linear frequency sweep; in a new technological breakthrough, WPL has developed a very flexible digital frequency synthesizer that permits greatly improved ground-clutter suppression and long-range performance.

MESOSCALE RESEARCH

Theoretical

A theoretical relationship between the mean gradient of refractive index in elevated layers and the micrometeorological properties measurable by atmospheric radars was developed.

Experimental

Predictions of a Bragg component in radar return from clouds were verified observationally, and the results published.

Elevated weather fronts traversing the BAO tower were monitored by in situ instruments and the FM-CW radar to evaluate the above theoretical relationship, and to examine in detail the turbulent structure of statically stable layers. Other layers, occurring above the height of the tower, were studied by the FM-CW radar and by a C_T^2 radiosonde system developed in-house.

Plans FY 1982

MESOSCALE SENSOR DEVELOPMENT

IR Doppler Lidar

Subject to availability of funds, the IR lidar data processing will be improved to achieve real-time Doppler wind measurements at multiple ranges.

8-mm-Wavelength Doppler Radar

Software will be prepared to speed the processing and analysis of the 8-mm-wavelength data, including provision of color displays of Doppler and polarization data.

FM-CW Radar

An array processor will be incorporated into the FM-CW system to speed data processing and analysis.

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. WPL

Orographic Clouds and Precipitation

An initial upslope cloud experiment will be undertaken, comparing Doppler radar and microwave radiometric measurements of cloud liquid water.

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 of course 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 provide continuously the three-dimensional fields of these parameters on the meso-α (200- to 2,000-km) and synoptic scales (2,000- to 10,000-km) for numerical weather prediction (NWP) purposes. Such a system would have major impact on NWP since the observational data (a) could be time averaged to remove

aliasing of high-frequency components, (b) could be entered more frequently into the NWP algorithms, and (c) could be 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 1981

PLATTEVILLE VHF WIND PROFILING RADAR

The Platteville wind-profiling radar was restored to automatic operation, with the cooperation of the Aeronomy Laboratory. Tests of the accuracy of the wind profiles were made, using comparisons with Denver radiosondes, NCAR aircraft, and the WPL 3.2-cm-wavelength radar. An automatic algorithm for the rejection of aircraft-contaminated data was prepared and is now operational.

A third, zenith-pointing, antenna, transmitter, and receiver system was added, to provide profiles of vertical wind speed, and automatic identification of tropopause height (as verified by comparison with NWS-Denver radiosondes).

STAPLETON UHF WIND-PROFILING RADAR

The principal components of the new 915-MHz radar for Stapleton Airport, Denver, were designed and procured, for integration into a complete three-beam wind-profiling radar system.

SIX-CHANNEL TEMPERATURE/HUMIDITY-PROFILING RADIOMETER

The six-channel microwave radiometer was installed and is operated continuously at the Denver WSFO at Stapleton Airport. Automatic temperature and humidity profiling was demonstrated; continuous time series of selected pressure heights and temperature levels agreed extremely well with radiosonde data for up to at least 500-mb heights. Marked improvement of upper tropospheric and lower stratospheric temperature measurements was demonstrated when radar-derived tropopause heights (obtained automatically at Platteville) were added to the radiometric data.

Two two-channel radiometers were tested side-by-side and showed excellent agreement (rms difference ~3%) in measurements of total precipitable water vapor. Corresponding measurements by the National Weather Service of the performance of their radiosonde humidity sensors indicate rms difference of ~20%.

Plans FY 1982

The newly received DG S-250 master computer will be installed at Denver and used to integrate the Platteville radar data with the surface, radiometric, and UHF radar data obtained at Denver.

Components for three additional VHF tropospheric VHF wind profilers will be procured, and installation will be started at Sterling, Craig, and Cortez, Colo.

Research will continue on optimum ways to use the radar echo intensity and velocity profiles to improve the accuracy of radiometrically derived temperature and humidity 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 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 1981

WINDSAT

The Phase-B Hardware Feasibility Study of a Space Shuttle-borne lidar was extended to utilize multiuser experiments of both coherent and incoherent detection of water vapor, temperature, aerosols, and atmospheric species. It was found that the WINDSAT feasibility experiment could be modified with only minor changes to accommodate a number of experiments originally proposed for other lasers.

An analysis of the preliminary design of the operational system of WINDSAT wherein weight and power were traded off against pulse repetition rate showed that a useful WINDSAT performance could be obtained with a satellite weight of less than 1,000 kilograms and power less than 1 kilowatt.

The trailer-based lidar was used to measure the aerosol backscatter function to heights as great as 20 kilometers in the atmosphere. More than 100 profiles were obtained, and the beginning of a backscatter or β climatology is now being assembled.

Discussions were initiated with NOAA's National Meteorological Center (NMC) which has undertaken to conduct numerical simulation of the impact of WINDSAT data on numerical weather prediction.

PROFILER-SATELLITE COMPARISONS AND COMBINATIONS

Satellite and PROFILER profiles have many desirable complementary features. Thus, 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 loud liquid water content are well measured by the PROFILER; neither is well measured by current operational satellites. Thus, there are 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.

With the development of the first PROFILER, the opportunity now exists for the comparison of WPL radiometrically derived values of integrated water vapor, and of profiles of wind, temperature, and humidity, with corresponding satellite data. Preliminary comparisons of temperature and humidity data show unexpectedly good agreement, with the PROFILER and satellite data often in excellent agreement, but both differing slightly from the radiosonde data.

Plans FY 1982

WINDSAT

The compilation of backscatter profiles under different meteorological regimes will be continued at Boulder, and (as practicable) at other locations. **WPL**

Interagency discussions with NASA and DOD will be initiated, to identify what steps should be taken to create a national WINDSAT capability.

PROFILER-SATELLITE COMPARISONS

The comparison of PROFILER and NOAA-6 and -7 data will be accelerated, and extended to include the development and evaluation of composite profiles derived by using simultaneous ground-based and satellite radiance measurements.

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 1981

The capabilities of the EPA-funded WPL multi-wavelength, dual-polarization lidar were extended during FY 1981 by increasing the pulse repetition rate from 1 hertz to 10 hertz. The data-processing capabilities are now undergoing corresponding improvement. Lidar measurements were made of a plume of known particles as a step toward assessing the quantitative accuracy of multi-wavelength lidar plume tracking. Earlier lidar data from the EPA Small Hill Impaction Study #1 have been reduced and supplied to the plume modelers.

An optical crosswind sensor was installed across the Platte River Valley northeast of Denver to demonstrate its usefulness in air pollution studies. Three solar-powered optical wind sensors participated in the Atmospheric Studies in Complex Terrain (ASCOT) experiment, measuring path-averaged airflow down the valley at various heights above the valley floor. Acoustic echo intensity profiles and Doppler wind profiles were also obtained during the ASCOT experiment, to provide additional insights into the morphology of the air flows in that irregular terrain.

Chaff releases from the BAO tower were tracked by Doppler radar and demonstrated the potential of radar for atmospheric diffusion studies and modeling. The intercomparability tests of three air quality monitoring systems was studied at BAO at the request of the Environmental Protection Agency.

Plans FY 1982

The development of the data processing system and software needed for high-speed scanning and real-time display of lidar data will be completed on EPA funds. The lidar will be used in plume experiments at BAO to investigate the usefulness of multiple wavelengths for quantitative measurement of plume parameters. The lidar will also participate in an EPA-sponsored diffusion experiment in complex terrain, planned for fall 1982.

The analysis of the 1981 ASCOT data will be completed, and plans will be made for airflow studies in irregular terrain associated with energy development now ongoing in western Colorado.

Data from the PROFILER system at the Denver WSFO will be made available to the Colorado Department of Health for its studies of the Denver "brown cloud."

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 1981

WPL has begun a joint program with AOML/OTES called STACS (SubTropical Atlantic Climate Studies). With 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. It has been determined that conventional, in situ oceanographic sensors are too costly by orders of magnitude to provide such data.

CODAR (Coastal Ocean Dynamics Applications Radar) is to be used to provide surface current information. Operating from the Florida coast near Jupiter Inlet, a CODAR system will observe 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. This last year, contracts were awarded to construct and install such a CODAR system in Florida. Most of the required hardware has already been procured by the contractor, and assembly has begun.

Studies are under way in WPL on extending the use of CODAR to understanding 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 model appears to have the capability of explaining and predicting thermocline formation and erosion. Since CODAR can observe surface wavefields and surface currents, these models are therefore the key to the extension of CODAR observations to subsurface mixing, heat storage, and flux.

The applicability and utility of underwater acoustic techniques for observing heat flux through the Florida Straits is being extended by WPL. An acoustic analog of an optical scintillation method developed at WPL for measuring transverse wind is being developed for water transport through the straits. Preliminary studies show that by using two hydrophones instead of one in a reciprocal transmission mode across the straits, the total water flux as well as water temperature can possibly be monitored routinely. Essential to the success of this technique is the knowledge of how the acoustic energy along the path spreads out vertically. WPL is developing and extending ray-tracing programs to understand this vertical distribution, taking into account the unique bottom topography across the Florida Straits.

Satellite oceanic observations will ultimately play a key role in climate studies. WPL scientists are therefore attempting to interpret and apply the output of orbiting microwave radars in terms of climate information. For example, various height biases in the radar altimeter have been identified and analyzed; removal of such biases is necessary if the satellite altimeter is to observe global circulation, which is the purpose of the TOPEX satellite system. The altimeter is being extended at WPL to measure the sea-ice boundary from space; seasonal advances and retreat of polar ice are important in climate studies.

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 the 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 Study) program. Further studies of the relation between the physical and optical properties of clouds have been performed, employing optical sensors and a lidar system to define the physical boundaries of the clouds.

Data from flights in the NOAA WP-3 aircraft in a highly disorganized large cloud system near Panama (1980) and in the uniform California cloud (1980) are being processed. The analysis shows that a wide range of cloud types have emissivities approaching 1 in the 3.5- to 50-μm spectral range. This result may be turned around to permit an accurate measurement of temperature in clouds by a pyrgeometer. The data from Panama show the importance of measurements of liquid water content of clouds. Because cloud cover is not sufficient to characterize solar heat flux from satellite measurements, integrated liquid water content must also be measured.

A combination of lidar and optical measurements of average solar spectral attenuation by cirrus and other clouds relative to their thickness has established narrow limits for the ratio. Thus measurement of cirrus thickness by backscatter methods can provide a measure of radiative effects.

Plans FY 1982

The CODAR system will be installed and checked out near Jupiter Inlet, Fla., for use in the STACS program. Preliminary data of Gulf Stream surface flow will be gathered. Software will be developed to allow CODAR to process data at the site, arriving at the few key parameters required for use in STACS.

Hydrodynamic models for upper-layer mixing and thermocline formation/erosion will be developed, and their utility for climate studies will be evaluated. These models will be checked where possible with data observed in the Florida Straits from various instruments.

Research on extending underwater acoustics to ocean heat flow monitoring will continue. In particular, data from a pilot experiment in Florida will be analyzed to evaluate the scintillation concept for observing transverse flow. Acoustic ray-tracing programs developed at

WPL will be completed. These will be tested against actual observations by others in the Florida Straits, if such observations have been successfully finished.

Assessment of the utility and accuracy of the satellite radar altimeter for measuring the sea-ice edge will be completed.

A final set of research flights will be performed in June 1982 in cumulus clouds. The data from all flights will be published in a data report. Analysis of the 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 modulating 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 1982, the WPL cloud radiation study will be complete.

WEATHER MODIFICATION

The Cleveland Report on Weather Modification called for an increase of basic studies of cloud physics and precipitation processes. WPL's radars, lidars, and radiometers can contribute strongly to such research, and, with the arrival of CDMP (Cumulus Dynamics and Microphysics) funding in FY 1981, the application of these sensors to cloud studies is now incorporated in the RD Weather Modification Program.

Accomplishments FY 1981

A very major effort went into WPL participation, on CDMP funds, in the CCOPE (Cooperative Convective Precipitation Experiment) experiment near Miles City, Mont. The new, 8-mm-wavelength, dual-polarization steerable Doppler radar, and the two 3.2-cm-wavelength steerable Doppler radar were operated during the 3½-month period. Six hundred magnetic tapes, amounting to 200 hours of data, were acquired.

A steerable, dual-channel microwave radiometer was used successfully to identify supercooled liquid water in the Sierra Pilot Program of the Bureau of Reclamation.

Plans FY 1982

The newly acquired DG S-250 computer will be used to speed the processing and analysis of the CCOPE dual-polarization and multistation Doppler data.

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 1981

NEAR-COASTAL WATERS

Skywave radar has the capability of observing wind fields and sea state out to distances of 3,500 kilometers by reflecting its signals from the ionosphere. The SRI Wide Aperture Radar Facility (WARF) was successfully operated with real-time online software, to produce waveheight and wind direction maps over areas of 5×10^6 square kilometers after 3 hours operation. Accuracies better than ±10% in waveheight and ±13° in wind direction were obtained. NOAA hosted an international workshop promoting the use of skywave to monitor sea state; as

a result of successful U.S. research efforts, at least four other countries have begun national programs to exploit the utility of skywave radars (i.e., Britain, Canada, France, and Australia).

CODAR research, development, and application have continued. New mathematical processing techniques for angle determination with the CODAR four-element antenna eliminate spurious "ghost" signals and remove the original size constraint on element spacing. Extraction of surface currents, based on this and other signal-processing advances, has improved considerably in accuracy and speed. CODAR was used with a cross-loop/monopole antenna system to measure the waveheight directional spectrum in both deep and shallow water (where the wavefield is inhomogeneous). A circular antenna concept for operation with CODAR was discovered that is a major advance over conventional phased-array technology; it was successfully tested experimentally at Duck, N.C., last winter. New hardware and data acquisition software were designed and developed under sponsorship of NOAA's Office of Ocean Technology and Engineering Services. They will make CODAR a commercially available, operational tool for use by other groups inside and outside NOAA.

CODAR and skywave radar provide vast data sets containing information about the ocean surface, continuous in space and time, that were heretofore unavailable. The first step toward a predictive capability involves use of these tools to discover the fundamental hydrodynamic processes that govern air-sea interaction and upper-ocean mixing. WPL has developed hydrodynamic solutions for wavefields and upper-layer processes that include effects of large waveheights and water viscosity. The latter studies explain for the first time why water and/or oil particles constituting the upper centimeter or two near the surface appear to drift considerably faster than currents observed at 0.5-m depth.

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, and scatterometer) in terms of the surface observables. Effects of rain on these instrument signals can now be taken into account. An electromagnetic height bias occurring in microwave satellite altimeter signals was identified, and analytical methods were formulated that relate this bias to the ocean waveheight spectrum; this height bias must be known and removed if satellite altimeters are to measure oceanic circulation. WPL also developed methods for removing tracking-system bias, attitude bias, and waveheight skewness bias from altimeter signals.

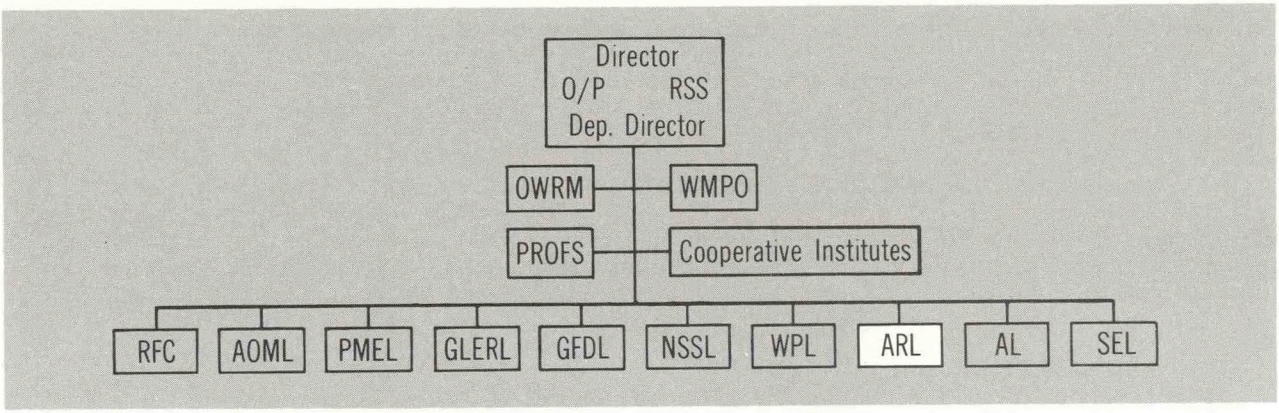
Plans FY 1982

The application of CODAR to the understanding of fundamental ocean mixing processes will continue. In particular, WPL involvement in CODE (Coastal Ocean Dynamics Experiment) (jointly with 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.

Theoretical studies on upper-layer hydrodynamics will continue. The effects of wind stress at the surface and 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 LABORATORIES
Silver Spring, Maryland

Lester Machta
Director



The Air Resources Laboratories (ARL) include a headquarters group in Silver Spring, Md.; the Field Research Office in Idaho Falls, Idaho; the Atmospheric Turbulence and Diffusion Laboratory in Oak Ridge, Tenn.; the Meteorology Laboratory in Research Triangle Park, N.C.; the Solar Radiation Facility and the Geophysical Monitoring for Climatic Change Laboratory (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 group in Silver Spring 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 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 1981

ATMOSPHERIC TRANSPORT

Modeling studies are proceeding in several directions. A standard Gaussian short-range dispersion model has been combined with NWS twice- daily computer forecasts of wind, cloud cover, and ceiling to develop an objective technique to forecast local pollutant dispersion.

A workbook has been published that uses the ARL regional transport model to provide quick and easy calculations of seasonal and annual pollutant concentration patterns and deposition over the United States from any number of sources throughout the country.

The ARL long-range trajectory forecast model has been used to forecast the path of radioactive debris from the Chinese nuclear test in October 1980. Forecasts were provided to

NWS, FAA, DOE, EPA, and other agencies. The model was also used to forecast the path of ash from the Mt. Alaid volcanic eruption in April 1981.

The atmospheric tracer system, developed by ARL, played a key role in the DOE-ASCOT (Atmospheric Studies in Complex Terrain) experiments in the Geysers geothermal development area in California in August 1981. Perfluorocarbon tracers were released at a geothermal power plant, one at ground level, the other through the plant's cooling tower, to study nocturnal dispersion of pollutants. More than 1,500 tracer measurements will provide a data base for generalized models of dispersion in complex terrain.

ARL provided engineering and software support for DOE's High Altitude Sampling Program. The program measures CO_2, SO_x, NO_x, Cl, radioactivity, and other constituents from sea level to 37 kilometers by balloon and aircraft over Alaska, New Mexico, and Panama. With recent improvements in the balloon support instrumentation, this is the most up-to-date balloon command, control, and communication system available for high-altitude sampling.

CARBON DIOXIDE

NOAA, through ARL, has accepted the responsibility in the Federal establishment for many of the atmospheric measurements to determine the Earth's CO_2 budget. Besides the four GMCC baseline stations measuring CO_2, additional stations are part of the NOAA network taking air samples. The flask network has been extended to 15 stations, and data from it are being analyzed. The coverage, which is global, can provide time trends, seasonal variability, and geographical gradients. Development of instrumentation to measure very accurately the atmospheric 0_2 concentration is under way. This program endeavors to determine non-fossil fuel combustion sources of atmospheric CO_2.

ACID RAIN

Acid rain has continued to be an issue of great national and international interest. In FY 1981 ARL scientists have been active in evaluating this problem at a number of levels. In the recent U.S.-Canadian bilateral work on long-range transport, several of the documents on modeling, monitoring, and atmospheric chemistry were contributed by ARL. On a national level, ARL has been active in the National Atmospheric Deposition Program (NADP) with the incorporation of its 12 WMO stations into the NADP. Also major contributions have been made to the National Acid Assessment Plan, which will outline Federal activites in acid rain for the next ten years.

Scientific research on acid rain has followed several directions. The research network of precipitation collection sites in Hawaii, Samoa, and Alaska has continued; recent publications have documented the fairly high acidity at these remote sites. Continued support with help from the EPA has been given to the University of Virginia to establish and maintain precipitation chemistry at other remote sites in the world such as Australia, Amsterdam Island, and Venezuela. Preliminary results from locations have shown that the rain is fairly acid there. The ARL trajectory model has been used to interpret these data. Other activities have included the continued monitoring of precipitation acidity in the Washington, D.C., area.

Plans FY 1982

ATMOSPHERIC TRANSPORT

The perfluorocarbon tracer system will be used in a preliminary long-range dispersion study, the Cross-Appalachian Tracer Experiment (CAPTEX) involving one or more tracer releases in the Ohio Valley during August-September 1982. A major study will be conducted in 1983 in collaboration with a number of other organizations. Tracer concentrations will be measured at 75 or more sites from Ohio to the East Coast. This location was chosen because the Ohio Valley is a major pollutant source area affecting air quality and contributing to acid rain in the northeast.

Another tracer experiment will measure Kr-85 emitted routinely from the Savannah River Plant, S.C., at five sites from 300 km to 1200 km north of the plant. Twice-daily samples

will be collected for a year to provide transport and dispersion data for verification of regional-scale models.

CARBON DIOXIDE

ARL plans to measure two quantities in the air that may shed light on the contribution of deforestation to global CO_2, namely, the amount of 0_2 and the ratio of C-13 to C-12. The 0_2 concentration will be depleted in the air by any oxidation process such as rotting of wood following deforestation. The C-13/C-12 ratio will indicate the deforestation contribution because rotting wood enriches air with C-12. Instrumentation development will continue for these measurements.

Analysis of data from the flask network will continue, and the need for better accuracy will be determined. Further analysis of available records to estimate the current rate of net biospheric input into the air and to further clarify the carbon cycle will also take place.

ACID RAIN

Many of the activities in acid rain research will depend on what resources are available. Our FY-1982 initiative outlined several areas of new research. These include (1) the determination of the importance of natural sources of both acidity and alkalinity on the precipitation chemistry; (2) the study of the transport and transformation of both man-made and natural sources of acidity on a global scale; and (3) the study of both wet and dry deposition of acidic materials at special research sites.

FIELD RESEARCH OFFICE

The research of ARL's Field Research Office (ARLFRO) in Idaho is sponsored by the Nuclear Regulatory Commission (NRC) and the DOE and is directed toward current and anticipated environmental problems associated with the release to atmosphere of radioactive effluents from nuclear reactors and other nuclear facilities. These problems include the quantification of downwind atmospheric dispersion contributed by wake turbulence of nuclear-facility structures, the meander of effluent plumes under light wind and inversion conditions, the effect of surface roughness and complex terrain, the measurement of the vertical profile of plume concentration, and the dispersion rates to distances of 100 kilometers. Tracer gas techniques are used in full-scale field experiments to address these problems and provide the necessary data for transport and diffusion model verification.

Accomplishments FY 1981

An intermediate range field dispersion experiment to distances of 50 km from the tracer gas release point was carried out in southeastern Idaho during the period July 15 to 31, 1981. Nine tests were completed, each test consisting of an 8-h release of SF_6 tracer gas. Hourly samples were taken at about 110 locations for a 12-h period to determine concentrations within a radius of about 16 km from the release point. In addition, 24-h samples were collected at 100 other locations out to about 50 km from the source. Numerous samples aloft were also taken by aircraft. Plume trajectories were determined both by visible oil fog plumes and radar-tracked tetroons. Meteorological measurements were provided by 22 mesonet wind stations, a 60-m instrumented tower, pibals, rabals, and radiosondes.

A real-time emergency response capability has been developed for the 80 x 130 km area encompassing the Idaho National Engineering Laboratory. Existing computer and data collection facilities provide initial and ongoing analysis of meteorological and radiological information from a 22-station network.

Plans FY 1982

The staff in Idaho will carry out a second intermediate-range field dispersion test at a location yet to be decided. The aim of this research is to evaluate transport and diffusion

calculation assumptions and practices currently used to assess environmental consequences of routine and emergency discharges of effluents into the atmosphere.

ATMOSPHERIC TURBULENCE AND DIFFUSION LABORATORY

The Atmospheric Turbulence and Diffusion Laboratory (ATDL) in Oak Ridge, Tenn., is partially supported by DOE and NRC. ATDL 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. Major funding is from DOE/OHER's Pollutant Characterization and Safety Research Division. ATDL 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.

The goal of the ATDL 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 1981

A major field experiment was conducted in northern California, as a contribution to the DOE "ASCOT" program. A team of ATDL field personnel operated a tethersonde sounding system and associated equipment during the July 1981 ASCOT study of cooling-tower plume behavior in the California Geysers region. Earlier investigations in the same area have led to the development of a nocturnal drainage model, suitable for investigating plume dispersion in complex terrain.

Analysis of wind tunnel observations of plume dispersion have been completed; comparisons between alternative techniques for interpreting plume characteristics show that similar results are obtained from tracer concentration studies and from optical density analyses of visible plumes. Following these verifications of photographic techniques, a series of plume dispersion experiments was conducted at Idaho Falls, Idaho, as part of a more extensive study of atmospheric diffusion conducted by ARL under NRC sponsorship.

Two handbooks on atmospheric diffusion have been completed, one for the World Meteorological Organization and the other for DOE. The modification of the usual pollutant dispersion relationships required in the vicinity of buildings continues to attract special attention. Wind tunnel modeling studies and extensive theoretical analysis have culminated in a detailed report, recently finalized by NRC.

At the Walker Branch Watershed field site, detailed diffuse radiation distribution data were collected to test a model developed at the University of Nebraska for determination of the vertical distribution of woody forest biomass. Sub-canopy distributions of incoming and outgoing fluxes of solar and terrestrial radiation have been determined for all seasons and for major phenological phases of the forest to provide data suitable for tests of canopy radiation transfer theory (developed largely for canopies of agronomic interests) in a forest canopy.

Turbulence measurements at the Walker Branch field site have been used to demonstrate the utility of eddy correlation techniques in nonuniform surroundings. After application of coordinate rotation techniques to three-dimensional wind data, measured eddy fluxes can be corrected for the effects of local site inhomogeneities. The corrected fluxes retain some memory of terrain effects that apparently cannot be completely eliminated; however, preferred

wind directions are easily identified and hence acceptable operating conditions can be identified. These same turbulence data have provided a basis for a detailed investigation of eddy correlation techniques, as they might be applied in complex terrain.

Theoretical examinations of processes that limit the exchange of atmospheric contaminants with natural surfaces have led to the development of several improved formulations, suitable for evaluating wet and dry deposition rates of selected pollutants. Numerical models now used by EPA to assess downwind effects of emissions from power plants and other industrial sources are being modified to include deposition processes.

Workshops were organized and conducted on several topics. During February 1981, a meeting was held at Pennsylvania State University to discuss Vegetation Impacts on Building Microclimates. In April, a workshop on Plant-Canopy Structure was held at Oak Ridge, Tenn. In July, a workshop on the Representativeness of Meteorological Data was conducted at Boulder, Colo.

Plans FY 1982

Collaboration with the DOE-ASCOT program will continue, with new emphasis on the northern Colorado area of oil shale development. Extensive site surveys will be conducted in the near future, and preliminary plans for initial field experiments and modeling studies are already being drawn up. Work on flow and diffusion in complex terrain will be closely tied to related work in other ARL laboratories, and will be coordinated with studies conducted under the sponsorship of other agencies.

The effect of complex canopy structure on dispersion of air pollutants in the lower atmosphere will receive attention, in parallel with the complex terrain studies but with the intent of combining these areas of independent research in order to address the natural circumstances in which complex terrain is indeed forested.

Turbulence studies in and above forest canopies will be conducted, focusing especially on sub-canopy turbulence, on frictional effects on sub-canopy flow, and on the turbulent transfer of air pollutants to natural surfaces. Initial measurements of dry deposition rates of selected pollutants will be made at the Walker Branch Watershed. Tests of the eddy accumulation method and other potential techniques for dry deposition determination will be conducted. Plans are being prepared for a dry deposition monitoring program, to be initiated at the Walker Branch field site.

Tests will be conducted of existing models describing radiation penetration and emittance in canopies, partly in support of defense-related concerns involving camouflage and target obscuration, and partly to provide basic information on the thermal properties of canopies and the methods by which these can be included in dynamical models.

Models used for assessment purposes by EPA will be improved further, by incorporating more detailed descriptions of deposition processes.

A series of wind tunnel studies of dispersion downwind of arrays of obstacles will commence, and parameterization techniques developed in earlier studies will be tested. A program of routine monitoring of the structure of the planetary boundary layer will be initiated at Oak Ridge, to describe the average behavior in the lower atmosphere of critical quantities (such as depth and intensity of the nocturnal inversion) as a function of season.

Methods and instrumentation to measure dry deposition of appropriate pre-acidic, acidic, and alkaline materials in the air will be developed. A number of approaches that might be used in research or in network monitoring will be explored.

METEOROLOGY LABORATORY

Meteorology Laboratory (ML) support and services to the EPA include theoretical and experimental studies of the physical processes affecting the transport, diffusion, transformation, and deposition of air pollutants; the 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.

ML 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 1981

Major emphasis during FY 1981 continued to be the development and evaluation of air quality simulation models, including the collection of critical data bases. A small-hill-impaction field study was conducted on Cinder Cone Butte near Boise, Idaho, during October and November 1980. Scaled physical modeling of plume dispersion over Cinder Cone Butte was simultaneously performed in the ML Fluid Modeling Facility. Detailed meteorological and tracer gas measurements from the hill study were used to evaluate existing dispersion models and to aid in the development of new models for defining stable plume impact in complex terrain.

The description of the turbulent wake of an automobile as determined by measurements in the wind tunnel was incorporated into an existing numerical model. Comparisons of model results with General Motors Corporation field data showed a substantial improvement in the model. A completed study examined the effects of an abrupt change in surface roughness on dispersion from a point source. Also, a preliminary study was conducted on the flow over ridges and valleys for various atmospheric stabilities.

Processing and analyses were begun of the data collected during the Northeast Regional Oxidant Study (NEROS) and the complementary Northeast Corridor Regional Modeling Project (NECRMP) field studies conducted during FY 1979 and FY 1980. The data will be used to test and improve the NEROS regional model.

The NEROS regional model underwent further development during FY 1981. Enhancements included a finite difference representation of the horizontal advection-diffusion equation that is unconditionally stable; a numerical technique for solving chemistry rate equations in their differential form, and an algorithm for treating the vertical transport and turbulent fluxes among the model's layers.

Work was completed, and a final report was written on further tests of the Eastern North American Model of Air Pollution (ENAMAP). The tests studied the variability of the model's seasonal calculations of sulfur concentrations and depositions due to changes in annual wind and precipitation patterns.

Air Quality simulation models are made available to the general user community through user's guides and magnetic tapes with FORTRAN source codes and test data available from the National Technical Information Service (NTIS). Version 4 containing 21 models was prepared and forwarded in March 1981.

Plans FY 1982

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 related meteorological models on all temporal and spatial scales. Major emphasis will be on model evaluation and verification utilizing the available data bases; on the use of the data base obtained during the NEROS field program to evaluate and modify a regional photochemical oxidant model; on the conduct of 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; on the development and evaluation of long-range transport models; and on the development of planetary boundary layer models. 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 1981

The primary standard instrument, an absolute cavity radiometer, was compared with other standard instruments at the Fifth International Pyrheliometer Comparison (IPC V) held at the World Radiation Center, Davos, Switzerland, in October 1980. Results showed that the NOAA standard was within 0.06% of the IPC V reference.

During the year, 144 pyranometers were calibrated for 31 different users. This number does not include instruments calibrated for the NOAA solar network, which comprises 39 stations making 88 solar measurements.

The facility participated in a round-robin comparison and testing of 21 pyranometers from Europe, Canada, and the United States that are part of the International Energy Agency solar-collector testing program.

Considerable progress has been made in a continuing effort to describe and understand the factors that affect the accuracy of solar radiation instruments. The objective of this effort is to reduce the inaccuracy of pyranometer measurements from the current level of ±5% to about ±2% for time scales as small as 1 hour.

Plans FY 1982

Global radiation measurements with both the old and new style pyranometers will be made at 10 of the NOAA solar network stations in an attempt to relate the old solar data base (years 1952-1976) to measurements made since 1977. These data will be analyzed in cooperation with the Solar Energy Research Institute in Golden, Colo.

The facility will continue working with national (ASTM) and international (ANSI) groups that are writing industry standards for solar radiation measurements.

GEOPHYSICAL MONITORING FOR CLIMATIC CHANGE LABORATORY

The Geophysical Monitoring for Climatic Change (GMCC) program of ARL operates four observatories that measure atmospheric constituents important for climate change. These observatories are located in remote clean-air sites to measure background levels and concentrations of trace gases and particulates in the atmosphere. The observatories are located in Point Barrow, Alaska; Mauna Loa, Hawaii; Cape Matatula, American Samoa; and South Pole, Antarctica. Long-term surveillance of the atmosphere is the research objective at these observatories. 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 affect climate.

Accomplishments FY 1981

Mauna Loa started two new solar monitoring activities: measuring direct solar intensity by using an active cavity radiometer (to detect long-term solar intensity variations) and measuring humidity by using a dual-challenge precision solar infrared hygrometer (to detect precipitable water vapor of the upper troposphere and lower stratosphere).

Arctic haze episodes detected at the Barrow observatory were analyzed for radiation characteristics. The analyses showed that 4% more of the incident radiation was absorbed or backscattered in the atmosphere on cloudless, hazy days than on cloudless, haze-free days. The arctic haze is apparently caused by long-range transport of middle-latitude pollution aerosols.

The annual decreases of atmospheric transmission and increases of light-scattering aerosol particles in spring and early summer, superimposed on longer secular variations at Mauna Loa, were identified as effects of long-range aerosol transport from the Asian continent. Chemical analysis of the aerosols at Mauna Loa shows that concentrations of crustal material are highest in spring.

From analyses of the Mount St. Helens ash cloud over Boulder and Mauna Loa we obtained absorptive/refractive index, single-scatter, and backscatter-to-total-scatter values. This information is useful to assess the effects of such ash clouds on incident solar radiation and to correct Umkehr ozone vertical profiles.

Analyses of CO_2 measurements at Mauna Loa, at Barrow, and on ship Papa showed that an early growing season followed by a severe drought in the U.S.S.R. during 1975 caused a change in the annual CO_2 cycle; the CO_2 drawdown in spring advanced by 10 days, and the CO_2 rise in autumn advanced by 15 days. Another analysis of data for the three stations showed a temporary decrease in the measured annual increase of CO_2 loading in the atmosphere during 1976, possibly because of below-normal North Pacific ocean temperatures. Both studies showed that the annual increase in global CO_2, measured since 1958, can temporarily be affected by factors other than increasing consumption of fossil fuels.

Stanley, in the Falkland Islands, became the twentieth station in the global flask-sampling network for measurement of CO_2. Data from the network's stations, along with the analyzer CO_2 data obtained at the GMCC observatories, showed a continuing increase of atmospheric CO_2 of 1.0 to 1.5 ppm per year. The global mean CO_2 concentration was about 338 ppm. A study of the CO_2 latitudinal distribution, based mainly on 1979 data, indicated a north-south annual mean CO_2 gradient of about 3 ppm; a primary maximum occurred in the Northern Hemisphere at 65°N latitude, and a minimum occurred at South Pole, Antarctica. A secondary maximum in CO_2 occurred in the Northern Hemisphere at 5°N to 10°N. A study of CO_2 annual cycle variations indicated a maximum peak-to-peak value of 16 ppm in the Northern Hemisphere at 55°N.

Transition from CO_2-in-N_2 to CO_2-in-air as a reference gas for calibrating infrared CO_2 analyzers was completed. Currently, all ARL CO_2 measurements are compatible, being expressed in the 1974 WMO CO_2-in-air calibration scale.

A procedure using traveling CO_2 standards for intercomparison of air samples was established to improve the intercomparability of CO_2 measurements from the GMCC program and the Scripps World Calibration Center program.

Total ozone observations with Dobson ozone spectrophotometers continued at Bismark, N.Dak.; Caribou, Maine; Tutuila Island, Samoa; Mauna Loa, Hawaii; Wallops Island, Va.; Barrow, Alaska; Nashville, Tenn.; Boulder, Colo.; White Sands, N. Mex.; Huancayo, Peru; and Amundsen-Scott, Antarctica. Preliminary results were archived at the World Ozone Data Centre (WODC), Downsview, Ontario, Canada.

A least-squares-fit autoregressive trend model was tentatively used to derive data concerning ozone trends for North America from 1961 through 1980. The data used as input were provisional monthly mean total ozone values published by WODC. Results of the analysis confirmed earlier findings that ozone increased over North America during the 1960's, and showed that ozone decreased over North America during the 1970's.

A possible 5% systematic error in ozone measurements by Dobson instruments was investigated. The existence of this error was inferred primarily from differences between total ozone measurements and ozone amounts derived from simultaneous electro-chemical concentration cell (ECC) ozone soundings. A possible source of error is use of an erroneous ozone absorption coefficient for the short wavelength of the Dobson instrument A-wavelength pair. In related research, the effect of interfering trace gas pollutants on the accuracy of Dobson instrument ozone measurements was studied. SO_2 and NO_2 were identified as potentially significant interferences; N_2O_5, H_2O_2, HNO_3, acetaldehyde, acetone, and acrolein were identified as trace gas species having absorption spectra at the Dobson instrument wavelengths, but presenting insignificant interference.

GMCC continued maintenance and intercalibrations of the World Standard Dobson ozone spectrophotometer with secondary Dobson standards from participating countries in the WMO ozone monitoring network. WMO designated GMCC as the central laboratory for Dobson spectrophotometer calibrations. To date, nearly 40 instruments have been directly calibrated, and 40 other instruments have been indirectly calibrated relative to World Primary Standard Dobson Instrument No. 83. These 80 instruments represent a substantial fraction of the approximately 110 existing Dobson spectrophotometers, about 73 of which are currently in use for observations.

Development of an automatic Dobson ozone spectrophotometer for Umkehr measurements is nearly complete, and testing will begin soon. The automated spectrophotometer will be used to monitor stratospheric ozone changes.

The ECC balloon ozonesonde was adapted and tested for high-altitude soundings, i.e., up to 2-mb-pressure altitude. The adaptation entailed improving the sonde pump's efficiency at pressures above 10 mb, checking instrument performance characteristics such as the sensor background current, and developing a reliable, inexpensive balloon vehicle for attaining flight altitudes of 40 km. Current tests are using lightweight (0.23-mil-thick wall) plastic balloons capable of bearing the sonde flight packages to 40 km altitude.

An important aspect of ozone trend detection is the delineation of long-term changes in tropospheric, as contrasted to stratospheric, ozone. Data for 6 to 8 years are now available from surface measurements at Barrow, Mauna Loa, Samoa, and South Pole. The 1973-to-1980 Mauna Loa record, in particular, is believed to be representative of ozone variations in the middle troposphere. This record shows no significant change in tropospheric ozone concentration in recent years.

A commercially produced version of the frost-point hygrometer and a reliable balloon platform were developed for regular stratospheric water vapor measurement. Regular balloon soundings started at Boulder in January 1981. Preliminary analysis of the 1981 data indicates that the stratosphere from about 16 to 24 km altitude is currently somewhat drier than it was in the past; mixing ratios approach those measured in the mid-1960's at Washington, D.C. An international intercomparison of stratospheric water vapor sounding instrumentation was held at Palestine, Tex., in May 1981. Agreement of results from a variety of in situ measuring techniques was generally good.

Chlorofluorocarbon-11 (CFC-11), CFC-12, and nitrous oxide (N_2O) have been monitored since 1977 at the GMCC observatories. Tentative analyses of the data showed CFC-11 to be increasing in the troposphere at an annual rate of about 12 parts per trillion by volume (pptv), CFC-12 to be increasing annually at about 18 pptv, and N_2O increasing at about 0.8 parts per billion by volume (ppbv). The preliminary analysis, furthermore, yielded estimated minimum tropospheric lifetimes of 41 and 65 years for CFC-11 and CFC-12, respectively. During FY 1981, a technical report was prepared that presents detailed information about the measurement program as well as measurement results through December 31, 1979.

The atmospheric baseline measurements of CO_2, ozone, chlorofluorocarbons, aerosols, and solar radiation continued at Mauna Loa (1958-1981), Barrow (1973-1981), American Samoa (1974-1981), and South Pole (1974-1981). Data are archived in Asheville, N.C., at the National Climatic Center. **ARL**

Fabrication and testing of improved sunphotometers neared completion in Boulder. These instruments will be used to upgrade turbidity measurements at the GMCC baseline observatories and at cooperating Dobson spectrophotometer total ozone sites.

Plans FY 1982

- To initiate a limited field study of the arctic haze at Barrow, Alaska, during the winter-spring of 1981-82.
- To broaden the solar radiation measurements at Mauna Loa Observatory to include spectral measurements of the atmospheric transmission at Mauna Loa and to determine its relation to long-range transport of aerosols and other trace gases.
- To deploy upgraded sunphotometers at the GMCC baseline observatories and Dobson spectrophotometer sites to measure atmospheric turbidity and its relationship to atmospheric aerosols and Umkehr ozone measurements.

- To expand to 22 stations the global CO_2 flask-sampling network. Logistical arrangements are being coordinated to begin CO_2 measurements at San Cristobal in the Galápagos, and Easter Island in the South Pacific. Processing of the data will emphasize correcting of past data to account for calibration gas concentration changes with time and pressure broadening errors. Research will be conducted to obtain improved information on year-to-year changes in CO_2, latitudinal gradients, annual cycle amplitudes, and CO_2 sources and sinks.

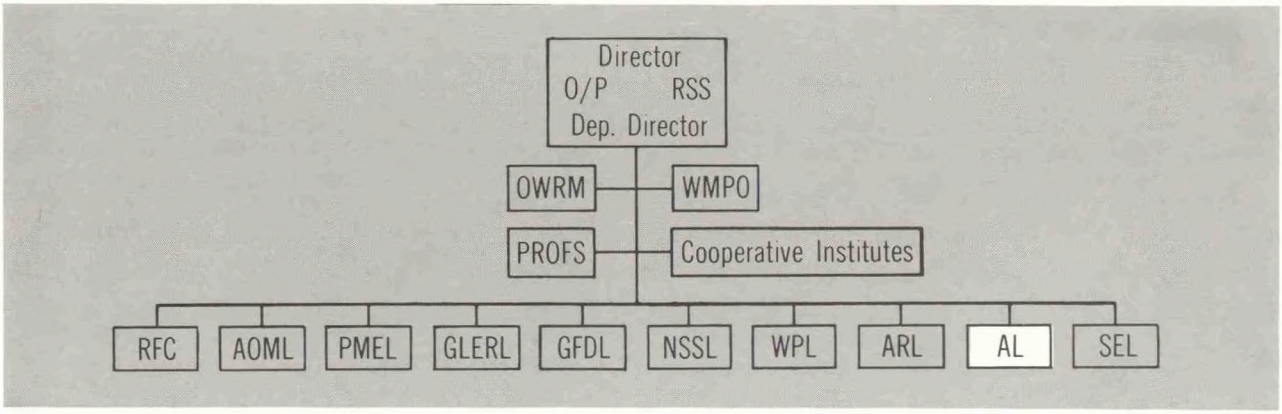
- To continue Umkehr observations in Boulder. Tests will be conducted to evaluate the performance of the automated Dobson instrument for such observations.

- To continue tests on adaptation of the ECC ozonesonde for balloon ozone soundings to 40 km. Simultaneous and accurate air temperature soundings to 40 km altitude will begin.

- To continue CFC-11, CFC-12, and N_20 measurements at the GMCC stations and at Niwot Ridge, Colorado. Final analyses will be undertaken to estimate their abundances, growth rates, and lifetimes.

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 atmosphere. The research concentrates on the stratospheric region of the atmosphere but also involves the troposphere, the ionosphere, and occasionally the magnetosphere, 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 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 groups 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 recently, the use of chlorine-containing halocarbons has been attacked as also being hazardous to stratospheric ozone. In addition to the effects of ozone loss on biological systems, climatic changes may also be precipitated by change 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 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 ion composition measurements to determine the concentration of critical trace compounds such as sulfuric acid in the stratosphere.

Accomplishments FY 1981

The reaction of hydroxyl radicals (OH) with nitric acid has been studied with a new apparatus equipped with resonant fluorescence detection of radicals and diode laser detection of stable compounds. An upper limit was established which indicates that negligible amounts of hydrogen peroxide and nitrogen dioxide are formed in this reaction. The temperature dependence of the rate constant was also measured and found to be smaller than the accepted values.

The reaction of chlorine atoms with hydroperoxyl radicals has been studied using a laser magnetic resonance (LMR) spectrometer. This work is the first direct measurement of the rate constant for this important stratospheric reaction. A major finding of this study is that the reaction has a second major product channel, forming hydroxyl and chlorine monoxide (ClO) radicals. The previous data on this reaction indicated that this channel was not significant and that the only path led to the formation of the chemically inactive hydrogen chloride (HCl) molecule.

An argon ion pumped ring dye laser system has been acquired and set up to detect nitrogen trioxide (NO_3) radicals. NO_3 radical chemistry is a major uncertainty in stratospheric models.

The chemistry of sodium, magnesium, aluminum, and silicon ions has been investigated. These studies help to explain the observed atmospheric abundances of the metallic ions derived from meteors and improve our knowledge of the thermochemistry of some metal compounds. An important conclusion derived from this work and in situ ion composition measurements is that most of the metal atoms deposited in the atmosphere are taken up in condensed-phase particles before entering the stratosphere.

Laboratory studies of negative ions have shown that the superoxide ion hydrates, $O_2^-(H_2O)_n$, are not expected to be abundant in the troposphere. This finding contradicts conclusions by biologists who believe that this biologically active ion is important. This work also leads to new insights into the nature of the electron transfer process, a fundamental process in biology and chemistry

Plans FY 1982

The reaction of OH with ClO will be investigated as a function of temperature, using the optically pumped LMR system. This reaction represents an interaction of two important stratospheric radicals and may be an important source of HCl. The reaction products will be determined.

The temperature and pressure behavior of the $HO_2 + HO_2$ reaction will be studied with the water vapor laser system. This reaction is also important in the stratosphere as a radical termination process. Recent studies in other laboratories have produced conflicting results.

The kinetics of NO_3 radicals will be studied using the newly constructed dye laser system. Measurement of NO_3 in the stratosphere and troposphere by the Optical Aeronomy group has demonstrated that the current kinetic data on NO_3 radical chemistry are inadequate. The reactions of NO_3 with other atmospheric molecules will be studied.

The reactions of proton hydrate ions, $H^+(H_2O)_n$ with N_2O_5 will be measured to see if such reactions play a role in conversion of N_2O_5 to HNO_3 in the stratosphere.

An understanding of the ion chemistry of the upper ionosphere during maximum solar activity will require measurements of the reactions of O^+ with vibrationally excited N_2 as a function of ion kinetic energy. Such measurements now seem feasible, by using the newly

developed mass-selected ion injection techniques for O^+. This ion source will be adapted to the flow-drift system in order to facilitate these measurements.

The role of solvation on charge-transfer reactions in the gas phase will be studied. These processes are important in determining the ion composition of the atmosphere, and knowledge of such processes can make an important contribution to understanding solution chemistry phenomena.

ATMOSPHERIC DYNAMICS

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 frequency of measurement and great altitude range, Doppler radars are well-suited for studying phenomena that vary rapidly in time, such as gravity waves, turbulence, and, at greater altitudes, 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 megahertz at all locations, and that, with a sufficiently powerful radar operating below ~70 megahertz, measurements can be made at all heights, from near the ground up to about 100 kilometers. On the basis of these studies, during FY 1979 construction funded by NSF began on a large MST radar at Poker Flat, Alaska. The partially completed radar has operated almost continuously since February 1979.

Accomplishments FY 1981

MST radars can measure two parameters of turbulence: the turbulence energy dissipation rate ε and the turbulence structure constant C_n^2 of the radio refractive index. In the past 4 years we have compared measurements of these two parameters with each other, with optical measurements of turbulence, and with aircraft observations of clear air turbulence. As in previous years the agreement has been satisfactory in every case.

In FY 1977 we developed a model for the occurrence of turbulence that permits calculation of profiles of C_n^2 and ε from routine radiosonde measurements of profiles of the background wind and temperature. In FY 1981 we greatly improved the conceptual basis of the model.

AL

With VHF MST radars, signals received by looking vertically are considerably enhanced compared with signals received by looking obliquely. This enhancement is attributed to quasi-specular reflection from stable regions of the atmosphere. We have used this effect to detect stable regions. In previous years we showed that the altitude of the tropopause measured by this technique agrees with the conventional balloon-determined altitude, and we developed a model that quantitatively relates the magnitude of the specular echoes to the gradient of atmospheric temperature. The model involves a new approach to the reflection of radio waves from stratified irregularities of refractive index. It permits the determination of temperature gradients in stable regions from the magnitude of the specular echoes. During FY 1981 we have successfully tested the model by comparing it with data from several VHF radars. We have also used the model to develop an objective technique for radar determination of tropopause height.

During FY 1981 the sensitivity of the Poker Flat radar was improved by increasing the peak transmitted power by a factor of 3 and by increasing the usable antenna aperture by a factor of 4. From continuous observations made by the Poker Flat radar for approximately 30 months, important new results were obtained on winds, tides, and wave motions in the mesosphere and lower thermosphere; the effect of magnetic activity on winds in the lower thermosphere; long-term vertical winds in the stratosphere; and gravity waves in the stratosphere.

During FY 1981 the Sunset radar was modified to make it steerable in the E-W and N-S planes and to increase its sensitivity.

The Platteville VHF pulsed Doppler radar near Boulder was put back into continuous operation as a joint project of the Wave Propagation Laboratory and the Aeronomy Laboratory. The principal purpose of the Platteville radar will be to explore the unity of wind profiles for operational forecasting, but the data will also be scientifically valuable.

Plans FY 1982

During FY 1982 the measurement capabilities of the program will be further increased. The sensitivity of the Poker Flat MST radar will be increased by an additional factor of 20. This will bring it up to its design specifications.

These improved capabilities will contribute substantially to our ongoing program to improve understanding of clear-air turbulence. The increased sensitivity of the Poker Flat radar will enable turbulence to be studied at all heights, from near the ground up to 100 kilometers. The new steerability of the Sunset radar will enable us to study the anisotropy of meter-scale turbulence, to observe the growth and decay of turbulence following a parcel of air, and to map the intensity of turbulence in the vertical east-west and north-south planes. This latter capability will be particularly important in downslope windstorms, since one theory of such storms involves the distribution and intensity of turbulence. Further comparisons with aircraft observations and further observations of turbulence associated with thunderstorms will be made.

The nature of refractive index structures that give rise to quasi-specular echoes will continue to be studied intensively, using the Poker Flat radar to study the phenomenon versus altitude and the Sunset radar to study the angular dependence of the echo and the tilt of the layers. The theoretical model that relates the magnitude of the echoes to the atmospheric temperature will be further refined on the basis of comparisons with observations. The value of radar measurement of tropopause heights in improving radiometric temperature profile retrieval will be studied in cooperation with WPL.

The existing array of microbarographs at Sunset will be replaced with new absolute instruments. The steerability of the Sunset radar will be used to make a detailed study of the air flow and turbulence structure in mountain lee waves, which are common in the Boulder area in winter.

The continuous data from the Poker Flat MST radar will be used to extend the preliminary studies on tidal variations throughout the atmosphere; energy coupling processes between the troposphere, stratosphere, and mesosphere; the generation and propagation of atmospheric waves; Sun-weather relationships. Some of these studies will be undertaken as cooperative programs with other institutions, including Boston College, Air Force Geophysics Laboratory, University of Alaska, Cornell University, University of Illinois, UCLA, Control Data Corporation, and NASA-Ames.

Additional observations will be made using the Jicamarca (Peru) and Chatanika (Alaska) radars to answer questions about the geographical, latitudinal, and frequency dependence of the scattering and reflection mechanisms, atmospheric wave generation, etc.

In addition to the reactivation of the Platteville radar mentioned above, the program is continuing to study the development of an operational radar that could profile winds in the troposphere and lower stratosphere. Such a radar would be configured to operate unattended and to be rugged and portable.

The program will continue to collaborate with Rice University and the Arecibo Observatory to study the effects of ionospheric heating on ionospheric irregularities.

The program will also study mesospheric irregularities in the auroral zone using data from Anchorage, Alaska. Additional experiments are planned to study equatorial F-region irregularities in conjunction with rocket launches in Brazil and to study gravity wave generation in southern France during the ALPEX program.

ATMOSPHERIC SAMPLING

The present Atmospheric Sampling program is a recent amalgamation of Aeronomy Laboratory programs that have common aims. The research goals of the combined 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. This research program develops new techniques for the measurement of trace atmospheric species and the field application of these techniques using balloon, aircraft, ship, and ground station platforms. In the past few years, the program's global research activities have included studies in tropospheric nitrogen photochemistry, eddy-diffusion transport coefficients, multidimensional model validation, stratospheric-tropospheric exchange mechanisms, origins of tropospheric ozone, seawater photochemistry, and acid rain.

Accomplishments FY 1981

Four years of stratospheric chlorofluoromethane (CFM) and N_2O measurements with balloon-borne instruments have been assessed for temporal and latitudinal trends. The CFM concentrations in the atmosphere have clearly increased with time, whereas the N_2O concentrations do not exhibit such increases. These data sets, because of their global stratospheric coverage, are invaluable input not only to answer questions regarding potential anthropogenic stratospheric ozone destruction, but also to provide a general understanding of stratospheric vertical and horizontal transport processes.

Stratospheric water vapor concentrations have been measured at middle and equatorial latitudes, using a fast-response detector. These data reveal the important role of water vapor as a tracer of stratospheric-tropospheric exchange processes. A new water vapor instrument designed and built for use with a U-2 aircraft was used first in Panama during summer 1980 to map the water vapor and hence transport patterns in the important tropical upwellings.

The fast response of the instrument has revealed a rich structure in the vertical distribution of water vapor, which should provide considerable insight into microdynamics. Both the balloon and U-2 instruments participated in a water vapor instrument intercomparison during 1981. Further U-2 flights have probed the latitudinal distribution of water vapor.

The chemiluminescent nitrogen-oxide measurements in the troposphere have been used as a basis of a new photochemical theory on the origin of ozone in the undisturbed upper troposphere. Collaborative calculations with Geophysical Fluid Dynamics Laboratory (GFDL) investigators have shown the likelihood that upper tropospheric ozone is made photochemically in this region of the atmosphere, rather than transported there from the stratosphere, and have identified a potential ozone-altering role of subsonic aircraft.

Nitric acid measurements have been continued at the Niwot Ridge atmospheric-chemistry research site. These data, which are the results of a collaborative effort with Colorado College, Metropolitan State College, and the University of Colorado, reveal that a sizable fraction of the annual acidic burden deposited in this mountain area is likely to be transported there from the heavily populated areas immediately to the east. The prevalence of winds from the west at Niwot Ridge led scientists earlier to believe that the acidic burden may have traveled from distant sources to the west. Furthermore, correlative tests have been made of the nitric acid sampling methods at clean-air levels. Both field and laboratory tests have verified the technique at levels appropriate for the study of clean-air nitric acid chemistry.

During the winter of 1980-1981, nitric acid and aerosol measurements were made during snowfall activity at Niwot Ridge. The observations show rapid decrease in the atmospheric concentrations of nitric acid at the onset of snowfall and potentially can yield considerable insight into scavenging by snow.

A new technique has been developed for enhancing the sensitivity of gas-chromatographic electron-capture detectors for gases that these instruments previously could not detect reliably. This technique has allowed the study of several atmospheric trace constituents, both naturally occurring species and pollutants: carbon dioxide, hydrogen, vinyl chloride, and a variety of hydrocarbons. During 1981, the detector was shown to be applicable also to carbon monoxide, and field tests of the instrument were begun.

A new ultraviolet-absorption ozonesonde has been developed and flown on one test flight. Being an absolute instrument, it shows great promise as a highly accurate ozone detector to accompany atmospheric-chemistry flights, or to be considered as a monitoring ozonesonde.

Plans FY 1982

To expand the knowledge of the distribution of the chlorofluoromethanes and eddy diffusion and other transport phenomena, the grab-sampling system will continue to accompany other balloon-borne experiments to a variety of global locations. Similar combinations may also prove desirable for the balloon-borne water vapor instrument.

The U-2 water vapor instrument will be flown on missions designed to trace water vapor transport patterns. The plans at present include a flight into the arctic winter.

A new technique for measuring carbon monoxide in the stratosphere will be laboratory tested. Carbon monoxide provides an insight into stratospheric transport and chemistry. The detector uses resonance fluorescence to detect CO with fast response.

The NO-NO_2 chemiluminescence-photolysis balloon-borne system has been completely rebuilt to avoid the problems that plagued earlier flights. 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. The later flights in the series are intended to examine the total odd-nitrogen profile as well. The approach will be to pyrolyze these species into NO, which is then detected by chemiluminescence. The first flight is scheduled for the fall of 1981.

A state-of-the-art diode-array detector is being incorporated into a monochromator-computer system. Initial tests are in progress, and the necessary changes that these have identified are being made. Once operational for field use, this system is expected to provide absorption measurements of the atmospheric species like NO_2, NO_3, and SO_2 (sulfur dioxide) with heretofore unobtainable quality.

The U-2 and balloon-borne water vapor instruments will participate in the next round of instrument comparisons sponsored by NASA and FAA. The goal of this series is to improve understanding of the capabilities and limitations of each type of water vapor instrument currently available.

Development will continue on nitric acid detectors, with the goal of a fast-response detector that could supplement the currently used filter-collector technique. This work is a collaboration with the Department of Chemistry at the University of Colorado and the Cooperative Institute for Research in Environmental Sciences. The feasibility of laser-induced photofragment fluorescent detection of nitric acid will be explored.

The measurements at Niwot Ridge research station will continue, with the emphasis on odd-nitrogen (e.g., nitrogen oxides and nitric acid) chemistry. Pending the acquisition of a dual-column ion chromatograph, the precipitation will be analyzed for total ion content, the goal being to trace the nitrogen-related acid rain from its precursor, nitric oxide, to its acid nitrate. These measurements will rely heavily on PROFS meteorological data to trace the origin of the species involved.

Gas-chromatographic techniques will be applied to determining the levels of hydrocarbons present in the atmosphere at ambient levels less than 1 part per billion. The emphasis of this work is on establishing the accuracy and possible interferences associated with present cryogenic and sorbent trapping techniques and the role of these species in atmospheric chemistry. This study is being conducted in collaboration with the Department of Chemistry at the University of Colorado and the Cooperative Institute for Research in Environmental Sciences.

The hydrogen-α-induced photofragment fluorescent detection of hydrogen peroxide will be pursued. This species is one of the major oxidants believed to be involved in the formation of acid materials in the atmosphere.

ATMOSPHERIC WAVES AND TURBULENCE

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.

Large turbulent 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 group during the past decade.

Accomplishments FY 1981

Theoretical studies have been made of several wave and turbulence problems that currently need attention. These studies include (1) a theoretical calculation of the off-diagonal pressure-velocity term needed for numerical models of the boundary layer and numerous engineering applications; (2) determination of the vertical diffusion coefficients in oceans and atmospheres for weak stratification and large Cox number; (3) a proof that the thickness of CAT (clear air turbulence) is determined by its intensity and is approximately equal to the buoyancy length; (4) explained and predicted observations from balloons and rockets of a strong correlation between wind shear variance and turbulence layers in the troposphere and stratosphere; (5) solution of a complex integro-differential equation that determines the height profile of diffusion caused by gravity waves from 20- to 100-km altitude and that determines a coupling mechanism between the troposphere and the mesosphere; (6) use of the comprehensive theory of stably stratified turbulence to determine the interaction between gravity waves and turbulence in oceans.

A liaison with NEPRF (Naval Environmental Prediction Research Facility) has been set up that includes financial support of our program to develop models of the boundary layer.

Plans FY 1982

Studies planned of current turbulence problems include (1) a major program to develop and improve equations used for modeling turbulence in the atmosphere and for pollution studies and other engineering application; (2) calculation of the diagonal pressure-velocity correlations needed for such models; calculation of the annual average of energy dissipation in the troposphere; (3) derivation of a formula to predict the average of energy dissipation in the troposphere; (4) derivation of a formula to predict the kinetic energy for CAT from measured eddy dissipation rates; (5) deduction of turbulent transport parameters from Sunset radar data; development of a nonlinear theory of shear instabilities in the atmosphere; (6) application of a comprehensive theory of stably stratified flows to determine turbulent transport in the ocean and atmosphere.

AL

Studies planned of gravity waves include continuation of the modeling of eddy diffusion from 30- to 100-km altitude, coupling of the stratosphere 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.

In addition, exciting new insights into the importance of gravity wave heating and Rayleigh friction in the middle atmosphere will be developed. The heating 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 atmospheric processes such as energy balance, composition, and dynamics. In the past the program has focused primarily on atmospheric emissions associated with the airglow and aurora. Although ground-based study of atmospheric optical emission continues to be a concern, the program has expanded into related areas such as measurement of chemically active minor constituents in the lower atmosphere, optical studies of other planets, and optical effects associated with tropospheric aerosols.

Accomplishments FY 1981

Studies of stratospheric nitrogen dioxide by absorption spectroscopy have continued, with increasing emphasis on the influence of transport. Dramatic changes in NO_2 content accompany breakdown of the stratospheric polar vortex, such as those associated with sudden-warming events. We have completed a several-year-long study of the relationship of stratospheric NO_2 and circulation in the polar stratosphere.

Extension of the absorption spectroscopy technique to nitrogen trioxide (NO_3) has led to considerable information on the behavior of this important atmospheric intermediate species, whose existence had been suggested on theoretical grounds but had not been directly observed before these measurements. Both stratospheric and tropospheric NO_3 have been detected, and both have shown unexpected features. Stratospheric NO_3 maximizes in the spring, contrary to expectations, whereas tropospheric NO_3 is much less abundant than had been expected, and strong evidence indicates that it is attached by an unidentified scavenger. Recent work shows a fivefold increase in stratospheric NO_3 to occur in less than a day over a large part of North America in spring, in association with the final stratospheric warming; no explanation yet exists for this quite unexpected discovery.

In 1981 a new and very sensitive optical method was developed for measuring NO_2 in the clean lower troposphere. Very low values for NO_2 density were found in the mid-Pacific region that confirm and extend earlier measurements by the Aeronomy Lab made at sea surface.

A long series of stratospheric OH measurements has been completed and has been submitted for publication. We have detected OH in the troposphere using an artificial light source and an interferometer.

Studies on the "ring" effect (filling in of Fraunhofer lines in sky spectra) have been completed; they confirm that in clean air the effect is entirely due to rotational Raman scattering by air with some contribution from fluorescence by snow in winter. We have now begun to study the effect in polluted environments.

High-resolution interferometric studies of thermospheric winds have continued; they show the connection of wind wth auroral electrojet activity. A new collaborative program has been set up in conjunction with the University of Alaska and with the University of Michigan working in Calgary; this will provide a chain of wind measurements connecting middle and high latitudes.

Aircraft measurements of stratospheric NO_2 continue. Our picture of the global and seasonal changes in NO_2 derived from these measurements is now receiving confirmation from numerous other workers.

Plans FY 1982

The technique of absorption spectroscopy will be exploited further in continuing studies of the trace constituents of the stratosphere and troposphere. The major departures of the observed behavior of the odd nitrogen species from that expected on the basis of known photochemistry will be intensively studied. The coupling between chemistry and dynamics in the middle atmosphere will be further investigated. Absorption spectroscopy will be applied to new atmospheric trace constituents as the opportunity arises. The demonstrated ability to measure tropospheric OH opens up an entirely new area in tropospheric chemistry.

Data on the climatology of thermospheric winds will be obtained and analyzed in cooperation with other institutions, and the coupling between the thermosphere and the lower atmosphere will be studied.

THEORETICAL AERONOMY

The objective of this program is to undertake theoretical studies of important atmospheric problems, to construct and utilize computer models of the photochemistry and dynamics of the atmosphere, and to analyze atmospheric data collected by the experimental programs of the Laboratory or through collaboration with other institutions. A secondary function is to provide assistance to other Laboratory programs on problems that require advanced computer programing techniques. In addition to this direct service function, strong scientific coupling exists in several areas, and the objectives of the program are continuously approached and developed in collaboration and cooperation with the Laboratory's experimental and observational programs.

Until fairly recently, the principal concern has been with the region known as the middle atmosphere (the stratosphere and mesosphere, extending from the tropopause to the mesopause), in which ozone is the dominant minor constituent, but there is now an increasing involvement in the chemistry of the troposphere itself, in the mechanisms of transport of trace gases through the tropopause, and in the influence of chemical species generated above the mesopause and in the upper mesosphere on middle-atmosphere composition. There has also been an increasing involvement in the problems of global climate and the influence of time-varying solar radiation on time scales ranging from a year through thousands of years. Future years should see an expansion of these exciting areas.

The ultimate goal of the program as a whole can best be described as that of attaining a sufficiently detailed understanding of the composition and energy budget of the atmosphere that accurate predictions of future trends can be made. To this end, the program serves the function of placing the experimental and observational results obtained by the other programs within the overall framework of the atmosphere as we now understand it. The computer models are the basic tools for accomplishing this, and are used to generate predictions of quantities and trends that cannot yet be measured.

Accomplishments FY 1981

The simplest models of atmospheric chemistry are the one-dimensional (1-D) models in which height is the only independent variable, and whose usefulness is confined to predictions of global averages. Restricted though they are, the 1-D photochemical models have provided a number of important results, including estimates of future concentrations of fluorocarbons in the stratosphere. Comparison of the 1-D model results with measurements of odd-hydrogen, odd-nitrogen, and odd-chlorine species still show unresolved differences that may be due to a mixture of measurement errors, uncertainties in chemical reaction rates, and shortcomings in the models themselves.

Currently the 1-D steady-state and time-dependent models are being used in conjunction with a 1-D radiative model. The coupled models predict that chemical damping of gravity waves is not nearly as important as had previously been thought. This has led to a new approach to the problem, and the results now predict a larger amount of damping, consistent with observations, but basically from radiative effects rather than chemical.

The 1-D combined steady-state and diurnal model has been used to compare theoretical values for the concentrations of NO, NO_2, HNO_3, O_3, and H_2O with those measured in a balloon flight of the University of Denver group. Agreement is very good for NO, NO_2, and HNO_3 even though in the lower stratosphere the measured water vapor concentration is much higher and the measured ozone concentration is lower than a 1-D model would predict. This is probably a dynamical problem arising from transport of H_2O and O_3, which are both long-lived in the lower stratosphere.

Over the past year, a two-dimensional (2-D) model that couples photochemistry and dynamics has been developed in collaboration with NCAR. Absorption of ultraviolet radiation by ozone is the main source of heat in the stratosphere, and the atmospheric ozone distribution therefore plays a major role in determining the meridional circulation of the stratosphere.

It is therefore desirable to couple the dynamics and the chemistry in a self-consistent manner. In most 2-D photochemical models of the stratosphere, this is not done--the possible response of the circulation to changes in stratospheric ozone is generally neglected.

The model currently extends from the tropopause to about 118 kilometers. It considers the photochemistry of O_x, NO_x, HO_x, H_2, H_2O, HNO_3, N_2O, and CH_4. The circulation is calculated by evaluating the sources and sinks of heat and solving the stream function equation, in a manner similar to that described by Schoeberl and Strobel or Holton and Wehrbein.

Studies of the production and transport of NO_x in the atmosphere have been continued. The goal of this work is to evaluate the possible impact of thermospheric NO_x production on the NO_x in the stratosphere, and its possible effects on stratospheric O_3.

The photochemistry of near-surface air over the equatorial Pacific was studied by comparing the distributions of NO_x, HNO_3, and O_3 observed by the Atmospheric Sampling program to model calculated results. It was shown that the in-situ photochemical destruction of ozone dominated the photochemical production of ozone because of the observed low ($\sim$10-pptv) concentrations of NO_x. It was concluded that the tropical marine area could be an important photochemical sink for tropospheric ozone if this low NO_x concentration prevails. In comparison the destruction of ozone at the sea surface is about a factor of 3 smaller. The model calculations also showed that the net photochemical loss of ozone is practically independent of the concentrations of CO and nonmethane hydrocarbons and the inclusion of heterogeneous reactions for soluble gases.

Analysis of the NO_x and HNO_3 observations made at Niwot Ridge by the Atmospheric Sampling program showed that the heterogeneous removal of NO_2 and NO is probably not important.

A study of the budgets of the odd-hydrogen compounds in the troposphere and stratosphere has been completed with the aid of the 1-D model. This has resulted in a clarification of the role of odd hydrogen in the stratospheric ozone cycle, and has emphasized the importance of obtaining more direct information on the concentrations of these highly reactive species.

Work has continued on the problem of the origin of tropospheric ozone; our results indicate that it arises from NO_x that is transported downward from the stratosphere, and not from locally produced NO_x. A lively debate on this topic is under way, and the issue has not yet been completely resolved.

Development of a full three-dimensional (3-D) model incorporating photochemistry in a self-consistent way has continued in collaboration with GFDL. The long-range goal is to reach an understanding of the ways in which the composition of the atmosphere influences global climate, a subject of great current interest and importance in view of human potential for altering the composition by introducing pollutants into the atmosphere.

The study of the annual variation in the height of the tropical tropopause has been continued. The annual variation is such that the tropopause is about 1 kilometer lower at its minimum level in August than at its maximum in March-April. The theory that has been developed explains the variation as a spatially averaged response to the annual variation in surface insolation in the tropics, which produces corresponding variations in sea-surface temperature, in the intensity of convective activity, and in the potential temperature of the upper troposphere. This latter variation combines with the oppositely phased variation in lower-stratosphere temperature to cause the observed changes in tropopause height.

Plans FY 1982

Problems in the general area of chemical coupling between the thermosphere and the stratosphere will be explored using a 2-D model that extends from the Earth's surface to the lower thermosphere. This model has been used to show that NO_x produced in the thermosphere can reach the stratosphere, where it participates in the catalytic destruction of ozone.

Current stratospheric models do not include this potentially important sink for ozone. The implications for a solar-cycle dependence of stratospheric ozone concentrations will be examined.

Another 2-D model is currently being developed in collaboration with NCAR, and will include coupling between photochemistry and dynamics throughout the middle atmosphere. By employing a diabatically-driven circulation, the model will avoid the problems arising from cancellation of eddy diffusion and advective transport that exists in conventional stratospheric models. Eddy transport occurs only for photochemically active species and can be appropriately parameterized.

We have also developed a 2-D model that treats both the ion and neutral chemistry in the D-region. We plan to examine the effects of latitudinal variations in the neutral composition on the ion composition, and particularly to consider possible chemical effects that may contribute to the winter anomaly.

Collaboration with GFDL will continue in both the 3-D studies of transport and deposition of soluble gases such as HNO_3 and H_2SO_4 in the troposphere and the stratospheric photochemistry. Tropospheric ozone problems will also be investigated with the 3-D tracer model.

In collaboration with the Sampling program and Optical Aeronomy program, we will continue the study of the interactions between tropospheric O_3, CO, OH, NO_x, and HNO_3. Focus will be on the photochemistry of NO_x, O_3, and OH. The photochemistry of non-methane hydrocarbons in the clean ambient atmosphere will be studied with the collaboration of the Atmospheric Chemical Kinetics program.

Two studies will be carried out in collaboration with the Atmospheric Dynamics program. One involves an investigation of the mechanisms responsible for the mesospheric radar echoes seen by the MST radar at Poker Flat, Alaska. The role of turbulence in the neutral atmosphere and of steep gradients in the concentration of free electrons produced by particle and X-ray ionization will be investigated. The other will be a continuation of the work on the variation in height of the tropical tropopause, with increasing emphasis on the long-term variations that will be caused by changes in the effective solar radiation at the Earth's surface. The linkage between variations in the tropical Hadley-cell circulation and middle-latitude climate will be investigated using a combination of theoretical studies and analysis of existing climatic data.

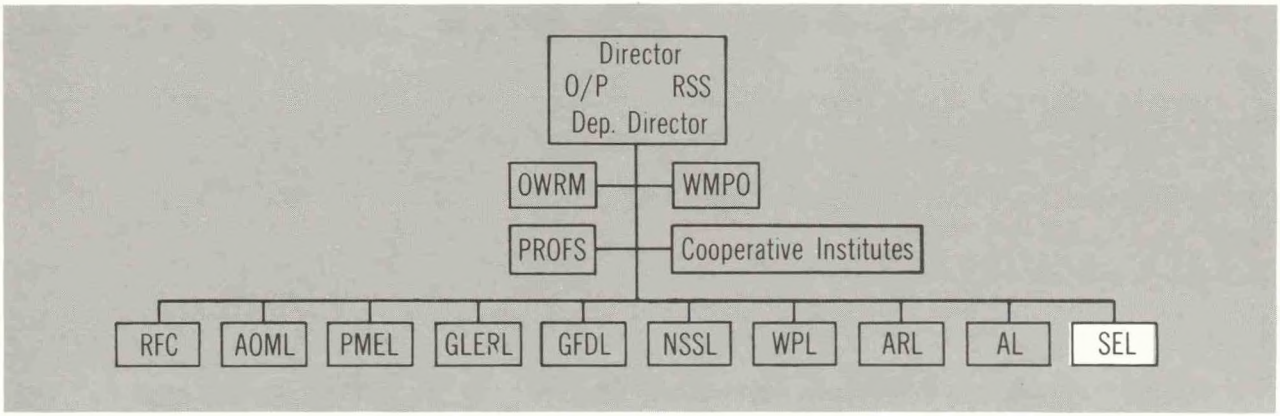
COOPERATIVE PROGRAMS

Accomplishments FY 1981

AL work in conjunction with the CIRES program related to the development and field application of a UV ozonesonde and the collaboration on NO_x balloon experiment; meteorology at Niwot Ridge, and the air mass movements that transport airborne chemical compounds to this site; the development of a data reduction program on a group minicomputer that allows automatic processing of Niwot Ridge data.

SPACE ENVIRONMENT LABORATORY
Boulder, Colorado

Harold Leinbach
Acting Director



The Space Environment Laboratory (SEL) conducts research in solar-terrestrial physics, develops techniques for forecasting solar disturbances and their subsequent effects on the Earth's environment, and provides real-time space environment monitoring and forecast services. The Laboratory also provides ERL with expertise and advice concerning satellite instrumentation and interface techniques in solar-terrestrial physics.

SEL has three divisions: Research, Support, and Services. The Research Division consists of Interplanetary, Magnetospheric, and Ionospheric and Atmosphere-Ionosphere-Magnetosphere Interactions Research Branches; the Support Division consists of Numerical Analysis and Instrument Development Branches; and the Services Division consists of the Real-Time Data Services and the Space Environment Services Center.

SEL personnel study the solar-terrestrial environment (the Sun-Earth system) as a set of several subsystems with strong interactions that produce significant environmental effects. For instance, at the Earth's surface, induced currents and accompanying geomagnetic storms produce adverse effects on electric-power distribution systems and telephone lines at high latitudes. In the atmosphere there appears to be a relationship between solar activity and weather. Recent findings also indicate that the ozone layer, which protects the Earth from solar ultraviolet radiation, may be affected by protons from solar flares. In the ionosphere, there are undesirable effects on high-frequency communications, on communications from Earth to satellites, on radar systems, and on navigation aids at very low and high frequencies.

SEL conducts theoretical and experimental research studies on the fundamental physical processes responsible for the observed energy release of electromagnetic and particle radiation from solar flares; the propagation of this energy through the interplanetary medium to the near-Earth environment; the transfer of this energy from the near-Earth interplanetary medium into the Earth's magnetic field, the magnetosphere; and the behavior and subsequent effects of this energy within the magnetosphere, ionosphere, and upper atmospheric regions. Information gathered from these studies is used to develop prediction techniques that can, with the extensive real-time data service maintained by the Laboratory, forecast solar events and their ground-based effects. Early-warning and real-time information concerning the solar-terrestrial environment, especially the near-Earth environment, is provided to a variety of users.

RESEARCH DIVISION

The aim of the Research Division is to conduct long-term research into the phenomena that affect the solar-terrestrial environment. This involves 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. Research includes the significance to climate of the intensity and time scales of variations in solar ultraviolet radiation.

INTERPLANETARY PHYSICS

The principal activity in the interplanetary studies is the development of magnetohydrodynamic models of the solar wind.

Accomplishments FY 1981

Work was completed on the modeling of solar coronal plumes which makes it possible to study magnetic field structures low in the corona. The results show that plumes are magnetic features with magnetic field strengths two to three times greater than the background field strength. The relationship of coronal hole size to magnetic field strength was successfully modeled, and it was shown that the coronal-hole size is weakly dependent on field strength and varies with the geometry of the photospheric magnetic field. This eliminates one variable blocking interpretation of the solar cycle variability of solar wind structure and, hence, of geomagnetic activity.

The principal activity of the solar wind physics research is the development of magnetohydrodynamic (MHD) models of the transfer of plasma, mass, momentum, energy and magnetic flux from the Sun to the Earth's neighborhood. This study will provide a scientific basis of the evaluation of power transfer into the Earth's magnetosphere under both quiet and disturbed conditions. The basis for the most advanced fluid equations (but with no magnetic field) was established for a nonequilibrium, multicomponent solar wind plasma. This important development will enable extension of existing codes to include a multispecie and turbulent solar wind, with realistic heat flux and skewed energy distributions.

Transient activity (with magnetic field) in the lower corona (flares, prominences, etc.) has been numerically simulated. A previous two-dimensional MHD model has been extended to include an accelerating solar wind in the highly restrictive case of a radial magnetic field. Work was initiated to extend the coronal two-dimensional simulations to include the third-dimensional component both of plasma velocity and magnetic field, resulting in a nonplanar, quasi-three-dimensional MHD coronal model. Coronal transients were simulated, phenomenologically, by a synthesis of various kinds of observations. This work indicates an association of the expanding shock wave with the enhanced density near the Sun, observed by coronographs and by use of satellite probes in the interplanetary medium. By use of the nonplanar MHD model, the solar flare of 29 June 1980 (~1800 UT) is being simulated as part of a Solar Maximum Year project in which the input conditions (density and temperature as a function of time) at the flare are provided from an X-ray polarimeter experiment.

Substantial progress has been made in extending the two-dimensional model of the solar wind to include all three components of velocity and magnetic field in the interplanetary medium--starting at the Sun and extending to the Earth's orbit. This model, which calculates the propagation of an interplanetary magnetic field feature, will be the principal model to be used for the calculation of the energy flux from the Sun to the Earth's magnetosphere, providing a predictive tool for geophysical disturbance.

The analysis required for a one-dimensional hydrodynamic model (no magnetic field) of the solar wind was successfully implemented. A very successful comparison of observed (Pioneer 10 and 11 spacecraft) data with one-dimensional model calculations indicates that the model has potential as a predictive tool.

The structure of the magnetosphere of Mercury has been studied to gain insight into particle access from the solar wind to the Earth's magnetosphere. This study showed that the helium exosphere of Mercury is derived almost entirely from the solar wind.

Plans FY 1982

Codes will be written for the NOAA Cyber-750 for the time-dependent magnetohydrodynamic model of the solar wind. Higher moment fluid equations will be formulated for future inclusion into models.

The nonplanar two-dimensional model of the solar wind will be programed for the NOAA computer. The model will be used to simulate a special Solar Maximum Year Study of Travelling Interplanetary Phenomena event of 29 June 1980 based on solar X-ray observations. Coronal and transient model simulations will be compared with observations (in Hα and Fe X) made by the NCAR High Altitude Observatory coronograph-polarimeter team.

The operational utility of using the solar wind plasma measurements from Pioneer-Venus-Orbiter at 0.7 AU to predict the same parameters at ISEE-3 (or IMP-8) will be examined.

The one-dimensional coronal model will be used to analyze coronal energetics, conductive damping of coronal motions, coronal stability, etc. The model will be developed to improve its applicability to solar-terrestrial relations and to extend its use to more complicated situations.

Participation will continue in national and international programs such as Solar Maximum Year Workshop, the Scientific Committee on Solar-Terrestrial Physics, and bilateral India-United States projects in solar and interplanetary physics.

MAGNETOSPHERIC PHYSICS

Studies in magnetospheric physics include 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 involves the analyses of satellite data sets obtained both from research and operational satellites.

Accomplishments FY 1981

Multisatellite studies of magnetospheric dynamics continued with particular emphasis on the analysis of data from the Medium Energy Particle Experiment of the ISEE (Interplanetary Sun-Earth Explorer)-1 and -2 spacecraft launched 22 October 1977. This set of data, comprising complete three-dimensional scans of the particle distributions over an energy range of 24 kiloelectronvolts to greater than 1 megaelectronvolt, has been merged with data from several correlative experiments aboard the spacecraft.

Conventional wisdom in the magnetospheric research of the past decade has looked to the so-called collective behavioral characteristics in trying to explain the dynamics of the magnetosphere. Although certain progress has been made in our understanding of magnetospheric processes such as the structure of the radiation belts and some significant effects of wave-particle interactions, progress toward and understanding of the principal energization processes operating in the magnetosphere has been halting. The success of the modeling of the dayside magnetosphere boundary through the remote-sensing technique developed by laboratory scientists, and the modeling of an auroral particle acceleration mechanism, has stimulated an aggressive interest in reexamining the single-particle dynamics approach to magnetospheric dynamics. This approach has also been encouraged by some rather exciting and productive analytical and theoretical accomplishments this year.

Studies of the ISEE-1 particle data as well as those at other institutions had shown that particle acceleration in the geomagnetic tail occurred primarily in a thin layer adjacent to the plasma sheet. Imaginative analysis of the ISEE data by laboratory scientists has indicated that the apparently complex behavior of these bursts of energetic particles observed near the plasma sheet could be explained and understood by invoking single-particle dynamics. A further theoretical study has realistically modeled the plasma sheet configuration and, using single-particle dynamics, has shown that transport of magnetospheric particles into the plasma sheet, and their subsequent acceleration by electric fields known to exist there, produces in this model the fluxes of energetic particles observed to precipitate into the auroral regions of the Earth. There is a strong indication that this process represents a major mechanism for the transport of solar-wind energy into the auroral atmosphere, and may also represent a significant source for the maintenance of the particle populations of the Earth's radiation belts.

SEL

Further studies have been directed to the elaboration of wave structures on the magnetospheric boundary. Preliminary analysis has indicated the possible presence of standing

waves on the boundary. Studies continue as well, of the characteristics of the boundary at all observable local times, and of the more complete description of the dynamics and morphology of the trapped radiation belts.

Plans FY 1982

Continued analysis of data relevant to the elaboration of acceleration processes in the geomagnetic tail.

Further characterization of the magnetospheric boundary and associated boundary regions and wave structures.

Further characterization of the particle populations of the inner magnetosphere (trapped-particle population and ring currents).

Initiation of a study of low-energy electron and ion entry into the Earth's polar-cap region.

Initiation of a study of solar proton cutoffs in relation to the observed auroral zone.

ATMOSPHERE-IONOSPHERE-MAGNETOSPHERE INTERACTIONS

The two objectives of the research in atmosphere-ionosphere-magnetosphere interactions are to understand the transfer of energy from the magnetosphere into the Earth's upper atmosphere by treating the atmosphere, ionosphere, and magnetosphere as a single coupled system and to understand the consequences of this energy input upon the ionosphere and upper atmosphere.

Accomplishments FY 1981

During FY 1981 a major effort was the reduction and analysis of data from the Total Energy Detector (TED) which, since November 1978, has been part of the Space Environment Monitor (SEM) on board the TIROS/NOAA series of spacecraft. This instrument measures the energy input to the upper atmosphere by precipitation of auroral particles over the polar regions. The energy input by particle precipitation represents about 30% of the total energy input to the upper atmosphere from the magnetosphere. The remaining 70% results from Joule heating by electric currents flowing in a dissipative ionosphere. For a point of reference, the total energy input to the polar atmosphere above 90 kilometers by magnetospheric processes regularly exceeds, by a large margin, the energy input into the same part of the atmosphere by solar irradiation. The dynamics of the ionosphere and neutral upper atmosphere is controlled largely by the energy input from the magnetosphere into the auroral zone, and large disturbances may propagate to middle and low latitudes.

The total energy measurements give the magnitude, location, and geographical extent of the energy input, providing an excellent guide to the level of geophysical activity, which is of direct use to the Space Environment Services Center (SESC). Furthermore, a long-term, continuous measure of particle energy input to the polar atmosphere will be of considerable value to understanding the response of the atmosphere to this highly variable source of energy. The processing of the TIROS/NOAA data tapes for 30 months was completed during the year, and data processing is being done on a regular basis.

During FY 1981 preliminary analyses of the TED data have been made. The location of the equatorward boundary of auroral particle precipitation has been correlated with the magnetic activity index K_p showing that higher K_p values are associated with movement of the boundary to lower latitudes. Once the relevance of this boundary position is established it can be used by SESC as a measure of solar-terrestrial disturbance and for extrapolation of auroral disturbances to local times and longitudes not sampled by the spacecraft.

The total energy measurements provide an estimate of the power input to the entire polar cap by the particles. The method uses measurements from an entire pass over the polar region (taking about 25 minutes) and suitably weighting the magnitude, location, and

geographical extent of the energy input while assuming that the precipitation was independent of longitude. This power input has been determined for each of 28 to 29 passes per day. This power measurement correlates with the magnetic A index. The daily average power input to the polar region is routinely calculated for each available satellite; the results have been published monthly by SESC since October 1980.

The energy input measurements have been used in several research activities both within the Space Environment Laboratory and in collaboration with external groups. One example is the calculation of ionospheric electrical conductivity resulting from the ionization produced by the precipitating particles. Given the electrical conductivity and the electric field, the Joule heating, the major energy input from the magnetosphere to the atmosphere, can be calculated.

A model has been developed that simulates, globally, the interactions between the thermosphere, ionosphere, electric fields, electric currents, etc. The model shows that a major part of the electric current system in the quiet ionosphere is driven by winds created by local solar heating but that tidal winds were also important. This model has been used to simulate quantitatively a large ionospheric/magnetic storm of 13 April 1981 when the gas temperature at 200 kilometers over Boulder doubled. Increase of atmospheric density caused the atmospheric drag on shuttle orbiter Columbia to be unexpectedly large.

Plans FY 1982

By use of the TIROS/NOAA particle precipitation measurements the global pattern of enhanced ionospheric conductivity will be determined.

Modeling of the three-dimensional ionospheric (electrical) current system will be directed toward understanding the current system that links the ionosphere to the magnetospheric source of electromotive force.

Analyses of the TIROS/NOAA total energy deposition will be carried out in collaboration with the academic community to obtain a physically meaningful geophysical activity index.

Research will be conducted to make possible construction of a model of the generation and propagation of auroral infrasonic waves (with period $\lesssim$ 2 hertz).

IONOSPHERIC RESEARCH

Ionospheric studies consist of theoretical and experimental research into the processes that govern the ionosphere such as production and loss of plasma, plasma motion, and the effect on the ionosphere of the neutral atmosphere and the plasmasphere. The experimental research included measurements using modern digital radio sounders and satellite radio beacons.

Accomplishments FY 1981

Ionospheric observations were made at the NOAA field station at Brighton, Colo., and at the Cleary, Alaska, site (near Fairbanks) operated by the University of Alaska. In June and July a field campaign was conducted in Puerto Rico. In Alaska, simultaneous digital ionograms, conventional photographic ionograms, and incoherent scatter radar data from Chatanika, Alaska, showed good agreement. The digital ionosonde was operated at Cleary in a phase-coherent partial reflection experiment for studies of the auroral-zone D-region (50-90 km) of the ionosphere and as a multifrequency riometer for the measurement of radio noise. At Brighton, Colo., the sounder was used in the partial reflection mode to investigate the mechanism of radio scattering by irregularities in the D-region. The measurements suggested that the scattering irregularities were associated with atmospheric waves. SEL

As part of a coordinated program of ionospheric measurements organized by Rice University, the NOAA sounder was moved to Arecibo, P.R., in the summer of 1981. Additional experiments included wind measurements from (Doppler) airglow observations and ionospheric modification by high-power radio transmissions. A major emphasis was on the comparison of high-frequency (HF) sounder measurements (e.g., winds, electron density profiles) with

similar observations using the Arecibo incoherent scatter radar. Particularly important are the drift observations and the comparison with neutral winds and electric fields, both during normal and during disturbed conditions. The experimental campaign was very successful, and preliminary analyses of selected data have commenced.

Plans FY 1982

Because of insufficient funding of salary increases the SEL management requested a major programmatic reduction in force with the termination of the Ionospheric Physics Branch. This was granted and was effective on 1 November 1981.

SOLAR ULTRAVIOLET RADIATION

The long-term objective of the new NOAA-ERL Solar UV Radiation Program is to determine the intensity and time scales of variations in the solar ultraviolet radiation as a function of wavelength in the 100- to 400-nm range in terms of their significance to climate, molecular dissociation, atmospheric chemistry, upper atmospheric heating, and measurements of minor atmospheric constituents. The temporal scales range from a day or so to the 22-year sunspot magnetic cycle. The research activities include analyses of existing solar UV irradiance data observed by Nimbus-4 and -7, development of models that represent the observed UV variations in terms of spatial structures and the full-disk chromospheric flux observed on the ground in the CaK solar absorption line, development of new techniques for analyses of data from the NOAA-NASA solar-backscatter ultraviolet (SBUV)/2 instrument, and development of a new improved instrument for measurement of solar UV spectral irradiance.

Accomplishments FY 1981

The Nimbus-7 SBUV data are the first to show the existence of variations in the 210- to 300-nm UV flux caused by solar rotation (~27 days) during the period November 78 through April 1979. It is concluded that the active-region contribution to UV variability is a major component of the solar-cycle variation. The observations of solar-rotation variations illustrate the importance of having satellite spectral UV irradiance measurements to supplement occasional measurements from shuttle and rocket flights. The latter measurements are too short in duration and too infrequent to establish the solar rotation effect. The solar rotation variation may be comparable in magnitude with the long-term variations that are of interest to climate research and, therefore, must be taken into account in ascertaining the long-term trend.

A model of solar UV spectral irradiance has been extended to include spatial information on the evolution and rotation of active regions around the Sun, and a term representing long-term variations in the chromosphere has been incorporated. The results already achieved include a great improvement in estimating the observed solar-rotation variations in comparison with the previous model. This model will be helpful in deciding what portion of the observed UV temporal variations can be explained in terms of current knowledge of solar physics.

The Solar UV Satellite Observations program has been designated an official user of the solar UV spectral irradiance measurements to be made by the SBUV/2 instrument in the joint NOAA/NASA program for ozone and solar UV operational monitoring from TIROS/N satellites. The problem with satellite measurements alone is that they are insufficient for long-term solar UV variations because of instrument drift.

In order to achieve rocket-flight measurements of the solar UV spectral irradiance with accuracies consistent with the required-accuracy goals, a program has just been initiated to design and develop a new spectroradiometer. Higher accuracy measurements are needed to recalibrate the Nimbus-7, Solar Mesosphere Explorer (SME), and SBUV/2 measurements and to intercompare rocket-flight and future shuttle measurements, where in the latter case the effect of space contamination from the shuttle on high-accuracy UV measurements remains to be determined.

As a first step in studying the long-term variation of solar UV irradiance an analysis was conducted of the long-term temporal variations of soft solar X-rays (1-8 A) which are

dominated by active-region emission and which were already available from SMS-1, SMS-2, and GOES-1, -2, and -3. Two atlases of X-ray data were published in 1981. The relationship between solar soft X-rays and the daily 10.7-cm solar radio flux was found to depend on the solar location (central meridian distance) of the prominent regions of solar activity. This results from the fact that the corona is optically thin for soft X-rays, which is not the case for 10.7-cm radio noise. A daily index of solar soft X-ray emission, based on the daily average X-ray flux, was developed for use with concurrent Nimbus-7 solar UV measurements and concurrent measurements of the solar constant.

Plans FY 1982

There will be active participation in the SESC Workship on Satellite Drag which will try to identify the reasons for unsatisfactory satellite drag predictions and start work on an alternative (improved) model.

The results of the research on solar UV variability observed with the Nimbus-7 satellite will be published. A comparison will be made of solar UV variability with the variability of the solar constant.

The solar UV irradiance model will be refined and compared with all available UV data.

Time series (spectral) analyses of the daily solar background soft X-ray flux will be carried out. Research will be completed on the long-term solar soft X-ray flux during the period over which Nimbus-7 observed solar UV, and on the central meridian distance dependence of the relation between the solar 10.7-cm radio flux and the (1- to 8-A) X-ray flux.

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 research and services are the development of ground-based and satellite instrumentation for experimental and service-related data collection and in the analysis of data used in research publications.

ANALYSIS BRANCH

The Analysis Branch provides computer programing support to the rest of the Laboratory. It maintains a large library of data tapes from satellite and ground-based experiments, which are routinely processed and analyzed. Members of the Analysis Branch combine expertise in computer usage with general knowledge of the scientific endeavors of the Laboratory and therefore provide advice and assistance to the scientists in the use of computer techniques to further their research.

Accomplishments FY 1981

International Sun Earth Explorer-1 (ISEE-1) data have been archived through 11 September 1979 when the Energetic Particle Detector became inoperable. Archiving for the ISEE-2 satellite has continued, and archive tapes have been generated for data through April 1980. ISEE Quick-Look Line Plots have been produced for all the data that have been archived as well as a complete set of ISEE-1 flux, magnetic, and spectral plots. Programs have been written to generate ISEE-1 pitch angle plots, gray code plots of ISEE-1 particle data, color plots of spectrograms and unit sphere displays, and plots of ISEE-1 plasma flow. Additional programs have been written to write ISEE data to magnetic tape in a standard format for data analyses and to transfer ISEE data to cassettes so scientists can analyze the data on stand-alone microprocessor systems.

Work has continued to support the SEL HF-radar (ionosonde) system with software. A more complete and flexible operating package has been designed. The Analysis Branch directly supported the field campaign in Puerto Rico.

Archive production continues for the TIROS series, the IMP-J satellite, and the IMS satellite. The analysis branch supported the solar UV radiation research project by providing computer access to the Nimbus-7 data tapes sent by NASA Goddard Space Flight Center. Display of, and access to, SMS/GOES satellite series data continues, Design of a system for measuring soft X-ray bursts has begun.

The Branch has been actively supporting the 1982 ERL computer initiative both with representatives and in organizing the package of computer benchmarks.

Plans FY 1982

With the exception of the HF radar activities, the FY 1981 projects are expected to continue into FY 1982. ISEE-2 archiving will continue as long as the experiment is operational. Backup tapes will be written for all the Boulder archive tapes. ISEE display programs will be run at the request of the scientists, and new display programs will be generated as they become defined.

Programs to model the solar wind and the effects of solar-flare-induced transients will be converted to the local Cyber-750 computer. These models will be expanded and improved.

INSTRUMENT DEVELOPMENT BRANCH

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, continuing through design, fabrication, and test phases, to support in field deployment or launch operations and often involving continuing evaluation and consultation during data reduction and analysis. Program management and technical supervision of contractors are provided for larger programs.

Accomplishments FY 1981

OPERATIONAL SPACE ENVIRONMENT MONITORS (SEM)

NASA approved the IDB proposal to provide maintenance support for the TIROS SEM instruments. A clean room for use in the maintenance of existing space flight instruments and fabrication of new instruments was completed. Two instruments were repaired.

NOAA-7 was launched on 23 June 1981, and GOES-E was launched on 22 May 1981. Each subsystem was functionally checked for proper operations and calibration data were taken. Except for the HEPAD (High Energy Particle Detector) on NOAA-7, which is exhibiting an unexplained anomaly, all sensors appear to be operating as predicted.

SOLAR X-RAY IMAGER FEASIBILITY DEMONSTRATION

Preliminary laboratory tests have been completed on the CCD (Charge Coupled Device)-based X-ray Imager prototype and TV display system using conventional white-light optics. Excellent image spatial resolution was obtained, approaching very nearly the Nyquist limit for the 256-by-320 pixel array in use. The feasibility of electronic image despinning was demonstrated using a revolving mirror to simulate a spinning object field. Resolution for the despun image was not perceptibly degraded from that for the static case.

A cryogenic image array mount was under test at the end of this period. Preliminary results show that very significant background noise reduction and virtual elimination of dark current defects occur with cooling to -50°C or more.

HF RADAR

In addition to general background technical support of the systems in the field, the IDB provided several new hardware developments.

A 1/20 scale model of a new log periodic transmitting-antenna design was built and tested at Table Mountain. The Boot Lake antenna was modified according to the new design.

A parallel data interface was designed and built for the Boot Lake HF radar receiver to allow expansion of the number of receiving antennas used with the receiver.

The Boot Lake HF radar receiver was modified so that it can be switched between wide and narrow bandwidth during soundings. An extra low-power transmitting circuit was also added to give quadrature RF outputs for transmitting circular polarization.

The design of a serial data interface for the HF radar was begun. This interface will allow the radar computer to switch antenna relays or control other devices at a distance of up to 1 kilometer.

GALILEO ENERGETIC-PARTICLES DETECTOR

The launch of Galileo satellite has again been delayed, now until April 1985. During FY 1981 the IDB continued to provide program management to the Galileo EPD (Energetic Particles Detector) team. Fabrication of the engineering model time-of-flight (TOF) system within the IDB was completed, and the system was integrated into the EPD experiment test assembly at Johns Hopkins University Applied Phyics Lab., Laurel. Md. Following a successful integration, work was begun on the flight TOF unit.

As a program cost reduction maneuver, the EPD team has dropped the completion of the EPD engineering model as a total system and is proceeding as directly as is feasible toward the flight unit instrument. Fabrication of this unit is well under way and should be completed early in FY 1982.

Plans FY 1982

OPERATIONAL SPACE ENVIRONMENT MONITORS

Continuing support will be provided to the TIROS and GOES projects for SEM activation and checkout after launch, as required by the TIROS and GOES launch schedules.

IDB has committed to providing an instrument repair capability for the TIROS SEM and the GOES HEPADS. The in-house thermal/vacuum facility will be completed this fiscal year as part of the program.

IDB will continue to provide technical and project management support for the GOES SEM procurement.

SOLAR X-RAY IMAGER FEASIBILITY DEMONSTRATION

In November, the Imager will be integrated with the X-ray optics that were developed through Marshall Space Flight Center. Extensive resolution and sensivitity measurements will be made in white light, followed in January by tests in the X-ray source chamber at Marshall Space Flight Center. In addition to X-ray resolution and sensitivity tests, multiple frame integration for low photon signal-to-noise ratio improvement will be investigated. SEL

GALILEO ENERGETIC-PARTICLES DETECTOR

The Galileo EPD Team should complete the EPD flight unit in early FY 1982 and perform flight acceptance test and instrument calibration in the latter half of FY 1982.

ION COMPOSITION INSTRUMENT

A detailed investigation into the timing characteristics of microchannel plates will be conducted. This effort is aimed at developing an improved ion composition measurement instrument employing an ultrathin solid-state detector and using microchannel plates to collect

secondary electrons from the ion interaction at the detector surfaces. This effort, funded by NASA, is expected to yield a sensor design for use on the NASA Origin of Plasmas in the Earth's Neighborhood (OPEN) Program and other research and operation programs.

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 Real-Time Data Services Branch and the Space Environment Services Center (SESC) 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.

SPACE ENVIRONMENT SERVICES CENTER

The Space Environment Services Center (a joint operation of NOAA and the USAF Air Weather Service) continued to provide predictions, alerts, and data for a variety of users whose systems 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, DOE, FAA, universities and research foundations, and industrial and commercial users.

Accomplishments FY 1981

In the second year following the sunspot maximum of Solar Cycle 21, solar flares and the other manifestations of solar activity remained at levels typical of the intense post-maximum years. SESC operations reflected these levels.

A major scientific research campaign, the Solar Maximum Year (SMY), was devoted to the study of solar activity and the release and propagation of disturbances from the Sun through interplanetary space. SESC was closely involved through forecasting and monitoring activities in Boulder, communications coordination of the observing programs throughout the Western Hemisphere and much of the rest of the world, and especially in operating a dedicated forecast center on contract from NASA at the Goddard Space Flight Center, location of the control center for the Solar Maximum Mission (SMM) satellite. The Solar Maximum Year (SMY) concluded in February, and the SMM Control Center closed in June. NASA is considering a rehabilitation and reuse of the SMM satellite in 1983 using rescue capabilities of the Space Transportation System (STS) (Shuttle).

FORECAST CENTER

Operations were extended to 24 hours at the beginning of the fiscal year to meet service demands. New products were initiated, including an early morning forecast and activity summary intended to serve daytime users.

Shuttle support began with the STS-1 flight in April. Predictions and summaries of radiation levels were provided to the Johnson Space Center according to previously negotiated procedures. A solar flare just prior to launch produced both a geomagnetic storm and a small proton event. Neither was strong enough to affect the mission, but the effects were sufficient to be measurable. The entire experience provided a good learning exercise for both NASA and SESC.

As the forecast center has matured, new data sources have been added, there are more forecasters, customers have increased, and new products have been introduced. As a result, there is an increasingly apparent need for standardization of procedures and programs. During the past year, the first steps were taken to develop standard procedures and analysis and provide for uniform user documentation of all new programs.

A major improvement in detection and alert capability was introduced in the form of a shock detector operating on data from the ISEE-3 satellite, located about 1 million miles in

front of the Earth in the direction of the Sun. As disturbances propagate outward from the Sun, they are detected by the ISEE-3 as sharp discontinuities in the solar wind. The new automatic detector gives a 20- to 50-min alert before the disturbances reach the Earth and cause a sudden commencement, the normal beginning of a geomagnetic storm.

The launch of GOES-4 and -5 satellites, with a capability of monitoring very-high-energy, (100-MeV to 1-BeV) solar flare particles, significantly improves the ability to monitor hazardous radiation at high aircraft altitudes.

These alerts were issued during the year:

Solar flares	Magnetic disturbances	Radio disturbances	Proton events	"Presto" messages
193	186	404	19	142

COMMUNICATIONS CENTER

The SESC Communications Center was established to provide communication services to the Boulder Laboratories as well as handle data flow into and out of the Forecast Center. The general communications function has continued to rely on standard teletype operation while the SESC data flow has become increasingly automated, using computers as interface with the external networks. In order to improve both types of service while better utilizing available personnel, a contract was let with a commercial company to handle the general-purpose communications and leave the Civil Service staff free to handle the increasingly heavy and specialized SESC data flow.

OBSERVATORIES

Working relationships for real-time data continued with Kitt Peak, Marshall Space Flight Center, Mt. Wilson, and Culgoora solar observatories. These data fill special-purpose needs and are in addition to the data received from the Air Force SOON (Solar Observing Optical Network), which provides the basic patrol and continual reporting functions required for real-time services.

Satellite data sources include GOES and NOAA weather satellites as well as the ISEE-3 satellite mentioned previously. The Total Energy Detector (TED) output from the NOAA polar orbiting satellites came into its own this year. The completion of routines that made the data available in near-real time and contributions from staff of the Research Division assisted greatly in determining formats, content, and use of the data in the services function.

The International Magnetospheric Study magnetometer network was used on several occasions when special processing made possible access to the data in real time, to support research campaigns and rocket launches. The same data are used in preparation of a Substorm Catalog included in the weekly publication Preliminary Report and Forecast of Solar Geophysical Activity.

TECHNIQUE DEVELOPMENT

SEL

Projects to improve services included the following: Use of large-scale solar maps to anticipate areas of development of solar active regions; use of an automated routine for geomagnetic-disturbance forecasting to record the basis for each forecast and provide continuity between forecast shifts; development of solar active-region indices as an aid in flare prediction; short-term (30- to 60-min) flare forecasting; use of interplanetary data in short-term geomagnetic forecasting; increased information as to the probability of magnetic storms based on solar flare characteristics; longer range solar-cycle forecasting; use of NOAA TED data for services; use of coronal-hole information for geomagnetic forecasting.

SELDADS II

SEL, received an increase of base in early FY 1981, to improve the services offered by the Services Division, particularly those of SESC. The majority of these funds are being committed to acquiring a new SEL Data Acquisition and Display System (SELDADS II). The SESC staff has documented some 250 products that this new system must support. Documentation of the Requirements Study based on these product definitions was completed, and along

with a Management Plan, was submitted through NOAA to the Office of Procurement and Automatic Data Processing Management, DOC. Work began on the request for proposals (RFP). The Source Evaluation Board and its Technical Review Committee were appointed.

Plans FY 1982

Plans include maintenance of current services; preparation for bringing in the SELDADS II, including extensive documentation of current routines and procedures; development of an RFP for a new video system to take, transmit, store, retrieve, and process solar images; an RFP for design of a new forecast center layout; further technique improvement in many of the current areas; implementation of new data communication systems; and integration of the communication operators into the forecast center operation.

REAL-TIME DATA SERVICES BRANCH

Real-Time Data Services (RTDS) operates systems that provide data from various solar and geophysical sensors for supporting the Space Environment Services (SESC) operations. RTDS has three operational components: (1) the Data Display System (DDS) in the Radio Building at Boulder, Colo., (2) the Table Mountain Observatory (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.

Accomplishments FY 1981

The Space Environment Laboratory's Data Acquisition and Display System (SELDADS) consists of facilities to acquire, process, and display a wide range of solar geophysical data for use by the SESC forecaster for relay over a dedicated data link to the USAF Air Weather Service at Offutt Air Force Base, Neb., and for direct use by a number of industrial, governmental, and scientific groups. Data from this system are also supplied to the National Archives.

The Astrogeophysical Teletype Network (ATN), operated by the Air Weather Service, supplies 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 Space Environment Monitors on three GOES satellites were routinely received and sent to SELDADS where they were processed, displayed, and archived. Data from GOES-4 and GOES-5 compare favorably with data from GOES-2. GOES-2 data are being recorded and sent to EDIS for archiving, and GOES-4 and -5 data are being recorded for future reference.

Data from the NOAA-6 and NOAA-7 polar orbiting satellites are received at Boulder from NESS. The data are stored in a data base, displayed by the SESC, archived, and sent to the Global Weather Center (GWC) at Offutt Air Force Base, Neb.

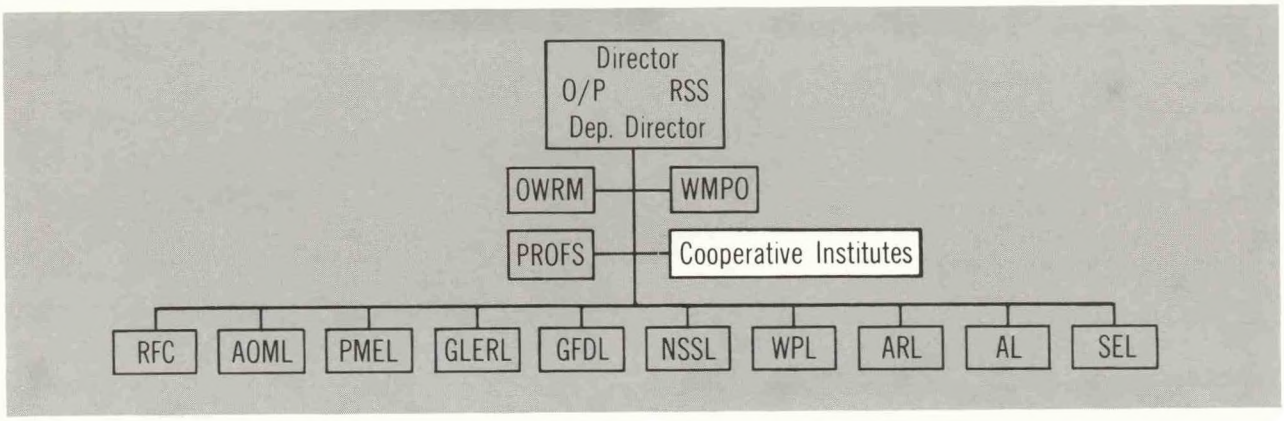
SELDADS receives, processes, displays, and archives the IMS (International Magnetospheric Study) magnetometer data from the U.S. magnetometer network via a satellite communications link. Because the data are received at SELDADS, there is a considerable amount of system monitoring and communication with the USGS, University of Alaska, UCLA, and University of New York, which maintain the magnetometer sites.

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 data.

Plans FY 1982

The routine data acquisition and processing will continue. The development of the SELDADS II system will be supported.

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) enables NOAA and university scientists to collaborate on problems of mutual interest, and facilitates the participation of visiting scientists.

Accomplishments FY 1981

The primary activities in CIMAS during FY 1981 occurred in support of climate-related physical studies.

A significant level of effort was devoted to planning activities relating to Atlantic studies. This involved preparatory work for STACS and participation of international planning activities in POMS and in the proposed CAGE experiment to measure poleward heat flux in the Atlantic region.

Participation in the EPOCS program included oceanic tracer studies, with main results being a clear indication of a very sharp limitation in the vertical of the cross-equatorial water mass exchange. More samples are being analyzed, and quantification of the intensity of the lateral exchange between the tropics and sub-tropics as well as across the Equator will be forthcoming from this work.

Model studies included the joint adjustment problem for atmospheric and oceanic boundary layers. The model considered advection effects and stratus cloud formation. These studies provided significant new insights into the persistence of effects of upstream boundary conditions and into factors controlling the dominance of stratus cloud decks in eastern ocean margins.

Studies by visiting scientists included the following:

- Plans for an Atlantic climate program, including preparations for a NATO-sponsored workshop on oceanic heat storage.
- Work on problems related to tropical aerosol distributions.

- Work on boundary layer processes.

- Plans for workshops related to ecology of fisheries.

During the past year, CIMAS was host of two important conferences: the Seasat Storms Colloquium and the U.S.-U.S.S.R. meeting of Working Group VIII--Influence of Environmental Changes on Climate.

Plans FY 1982

CIMAS activities related to climate will be split approximately equally between continued work on EPOCS-related proglems and support of the beginning STACS program. One focus will be on surface layer adjustment processes.

A substantial effort will be devoted to a series of workshops on physical aspects of fisheries ecology and their relation to climatic variability. These activities will support objectives of the National Marine Fisheries Service.

Significant interest in the problem of coastal storm surge prediction appears to be developing. Further active cooperation in storm surge prediction is expected, with emphasis on the effects of local bottom-sediment characteristics on the damping of long waves.

Discussions are being conducted toward the establishment of cooperation between the Atmospheric Programs Office (NOAA Headquarters) and CIMAS in the area of program assessment and planning.

Activity in the sediment dynamics area will be reduced because of the departure of the principal investigators involved.

CIMMS

The Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) is a joint venture of the University of Oklahoma and NOAA/ERL through the National Severe Storms Laboratory. CIMMS received first funding in late FY 1978 and began major efforts during FY 1979. CIMMS is modeled after other NOAA joint institutes on university campuses. The program objectives and activities of CIMMS complement and supplement those at 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 the University of Oklahoma. During 1980, Dr. Yoshi K. Sasaki, George Lynn Cross Professor of Meteorology at O.U., was appointed Acting Director and subsequently Director. The present Council of Fellows, which consults with the Director concerning ongoing matters of policy, numbers four: two members from NSSL, both of whom hold adjunct appointments at O.U., and two members from O.U. One former O.U.-NSSL staff member is an Associate Fellow. The Advisory Council meets annually and includes several officials of NOAA, officers of the University of Oklahoma, and representatives of other government agencies and the academic community.

During 1981, four significant reports were published, and other works are in press in the peer-reviewed literature. Topics include structure of the planetary boundary layer, retrieval of transverse winds from single-Doppler radar data, variational analysis, and a nonhydrostatic axisymmetric hurricane model with prospects for adaptation to the three-dimensional mesoscale. During April-July 1981, CIMMS sponsored a series of nine special lectures presented by leading meteorologists from various places in the United States. During FY 1981, 13 students were employed in CIMMS, and there were 10 Postdoctoral Fellows and research associates from the United States, Japan, Taiwan, Republic of China, and Finland.

CIMMS's base funding provided through NSSL continues at the starting level of $100,000 per year, and additional funds through NSSL to support employment of students amounted to about $150,000 during FY 1981. Salaries of some Fellows from foreign countries are supported wholly or in part by their governments; these persons represent very little impact on

the CIMMS budget while they bring fresh viewpoints, active minds, and healthy personal interactions to CIMMS.

The financial base is small, but CIMMS has attracted some additional funds from NASA. This is a bright sign, especially in view of funding cutbacks in government. Two of several promising postdoctoral researchers have received appointments to CIMMS tenable during FY 1982, and it seems certain that CIMMS will continue to be characterized by a staff of high quality, though small in number.

A meeting of the CIMMS Advisory Board was convened on September 21, 1981. An important topic was the projected new Energy Center at The University of Oklahoma, to be endowed with both private and State funds. It was proposed that this include a Weather Center inhabited by the O.U. Department of Meteorology, the Oklahoma Climate Survey, CIMMS, and the research side of NSSL. Sharing of certain basic facilities could represent significant savings to the participating organizations, and opportunities for improved flow of ideas. Since CIMMS and the Meteorology Department are inadequately housed at present, the Energy Center also offers the enticement of markedly improved office and research space for those organizations.

CIRA

The Cooperative Institute for Research in the Atmosphere (CIRA) is jointly sponsored by Colorado State University and NOAA. Since its establishment in October 1980 CIRA has had a close relationship with ERL in Boulder.

Research performed by CIRA scientists concentrates on the scientific problems of observation and analysis related to climate dynamics, local-area weather forecasting and evaluation, cloud physics, weather modification, and VISSR (satellite) Atmospheric Sounder Research. Currently the National Earth Satellite Service, NOAA/ERL, and the CSU Departments of Atmospheric Science, Electrical Engineering, Economics, and Statistics are conducting research under the auspices of CIRA. During FY 1982 two 12-month positions will be available for visiting fellows.

JIMAR

JIMAR, the Joint Institute for Marine and Atmospheric Research, is located at the University of Hawaii. JIMAR was formed in FY 1978 in association with the University and PMEL. JIMAR's research interests include climate, equatorial oceanography, and tsunamis.

Accomplishments FY 1981

In tsunami research, a field test of the open-ocean recording system was conducted off the Island of Hawaii. Work continues on the development of the shallow-water internally recording gage to record the time history of each tsunami at a large number of near-shore locations.

Work on a finite element model for studying tsunami propagation over variable topography is in progress.

Plans for post-tsunami surveys are being developed. Survey teams have been put together on Oahu, Lanai, Island of Hawaii, Molokai, Kauai, and Maui. Civil defense tsunami exercises were conducted in December 1980 and August 1981. A document entitled "Post-Tsunami Survey Procedures," containing specific instruction for field operations, has been prepared and distributed.

JIMAR has an active program in climate research in conjunction with EPOCS and PEQUOD (Pacific Equatorial Ocean Dynamics). Work carried out during FY 1981 included observations of the central Pacific near-tropical convergence zone from NOAA WP-3 aircraft, compilation of data on highly reflective clouds for rainfall estimation, and studies of the feasibility of calculating (biweekly or monthly) average surface winds from satellite cloud motion vectors.

A study of short-term variability of carbon dioxide concentrations at the Mauna Loa Observatory was completed. Empirical orthogonal functions were used to study the spatial and temporal characteristics of Hawaiian droughts. The Hawaii Mesoscale Energy and Climate Project (HAMEC), a joint project with ERL, collected a data set for numerical simulation of airflow and precipitation over the Island of Hawaii.

Equatorial oceanography was an especially active research area at JIMAR in 1981. Analysis of the relative current profiles made during the NORPAX shuttle continued. In September 1981, the first 3-mo series of deep absolute current profiles began as part of PEQUOD. Heat flux into the upper ocean, and the upper ocean heat storage were computed from the NORPAX Hawaii-Tahiti Shuttle. Preliminary results indicate that about two-thirds of the low-frequency variation of heat storage in the upper tropical ocean is caused by the (local) low-frequency variation of surface heat flux.

Visiting scientists are seeking evidence of remote forcing in the equatorial Atlantic ocean, are studying propagation of the seasonal upwelling in the eastern equatorial Atlantic, and are constructing a 1½-layer model for the annual cycle of the horizontal velocity and depth of the thermocline in the equatorial Atlantic, using realistic wind forcing and basin geometry. A continuously stratified model for the annual cycle of velocity and density field in the equatorial Atlantic has been developed using idealized winds and geometry to investigate the vertical and horizontal propagation of wind-forced disturbances.

Plans FY 1982

JIMAR's fiscal year is changing back to July-June, so FY 1982 will be a 9-mo period: October 1981-June 1982.

The JIMAR research in climate and equatorial oceanography will continue with the 13-mo equatorial profiling effort, work on the effect of vertical and horizontal mean flow shear on baroclinic equatorial waves, and EPOCS-supported climate studies. The effect of equatorial baroclinic waves on the tropical mixed layer will be modeled.

The tsunami observation teams and equipment will be maintained.

JISAO

JISAO is the Joint Institute for Study of the Atmosphere and Ocean, at the University of Washington. This institute, formed in FY 1978, has a strong association with PMEL. During FY 1981, JISAO sponsored or contributed to the support of 40 short-term visiting scientists (20 on topics of climate, 8 on environmental chemistry, and 9 on estuarine processes). Five additional scientists conducting research at the institute were supported for longer periods.

JISAO sponsored the annual NOAA Climate Diagnostics workshop attended by 90 scientists, including a delegation from the Soviet Union, and a smaller Arctic Workshop dealing with the uses of data on sea-level pressure and ice drift and ice extent, and with new initiatives for Arctic field programs.

JISAO has served as a mechanism for organizing collaborative research efforts between University scientists and NOAA scientists under the sponsorship of NOAA, including a major field program in the North Pacific, the Storm Transfer and Response Experiment (STREX).

The current and planned program of climate research includes three major efforts that address some important problems relevant to the long-term objectives of the Equatorial Pacific Ocean Climate Studies (EPOCS):

- Studies of the dynamics and thermodynamics of the upper layers of the equatorial oceans, with an emphasis on how sea surface temperature varies with changes in wind stress.
- Studies of the coupled atmosphere-ocean climate system in the tropics aimed at elucidating the feedback mechanisms responsible for the Southern Oscillation.
- Studies of teleconnections between tropical and extratropical regions of the atmosphere, with emphasis on phenomena such as blocking in middle and high latitudes during winter.

CIRES

The Cooperative Institute for Research in Environmental Sciences (CIRES) is jointly sponsored by the University of Colorado (C.U.) 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 Chemistry, and Solid Earth Geophysics. CIRES research on these subjects was reported in approximately 100 publications in 1981.

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 Geography and Mechanical Engineering, in addition to continuing links with Chemistry, Chemical Engineering, Geological Sciences, and Physics. There are also now formal links with the Environmental Data and Information Service of NOAA through geophysics appointments in CIRES from the National Geophysical and Solar-Terrestrial Data Center (NGSDC) and through the contractual operation of World Data Center-A for Glaciology (Snow and Ice) (WDC-A) by CIRES, following the Center's transfer from the Institute of Arctic and Alpine Research in January 1981.

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, 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 C.U.'s Mountain Research Station "clean air" site on Niwot Ridge. Experimental and theoretical studies involve a collaborative effort between scientists, faculty, and students in NOAA's Aeronomy Laboratory and the C.U. 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 C.U. chemists. New methods for separation and analysis of terpenes and other organic compounds and nitric acid in ambient air have been developed and published.

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 percent 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 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.

The data management and analysis activities of WDC-A complement and support several programs within the climate group. WDC-A arranged a workshop on Radio Glaciology in October, in conjunction with the Third International Symposium on Antarctic Glaciology; the proceedings will be published in 1982.

ENVIRONMENTAL CHEMISTRY.

One aim of this new program area is the study of 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.

SOLID EARTH GEOPHYSICS.

Observational and theoretical seismology and rock mechanics are the major concerns of this group. Seismic 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. Seismic monitoring in the Hellenic Arc may make possible detection of the foreshocks of an expected large rupture. Research in rock mechanics focuses on the processes of deformation and failure under varying environmental conditions; various test modes are used.

NEW ACTIVITIES.

CIRES has played a leading role in forming and developing a research plan for the Consortium on Energy Impacts (C.U., Colorado State University, Colorado School of Mines, University of Utah, Utah State University, University of Wyoming, and the National Center for Atmospheric Research). The aim of the research, whose planning phase is sponsored by seven major energy companies in collaboration with Federal, State, and local governments, will be to study air quality, water quality and availability, and social and economic problems associated with energy and mining activities in the Intermountain West. Atmospheric chemistry and dynamics, modeling, and meteorology are expected to become important elements of this program.

☆U.S. GOVERNMENT PRINTING OFFICE:1982—576-043 / 4