IRONMENTAL RESEARCH LABORATORIES

PROGRAMS AND PLANS

FY 1976

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Environmental Research Laboratories

ENVIRONMENTAL RESEARCH LABORATORIES

Office of Programs

Wilmot N. Hess, Director

PROGRAMS AND PLANS

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U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Environmental Research Laboratories
Boulder, Colorado

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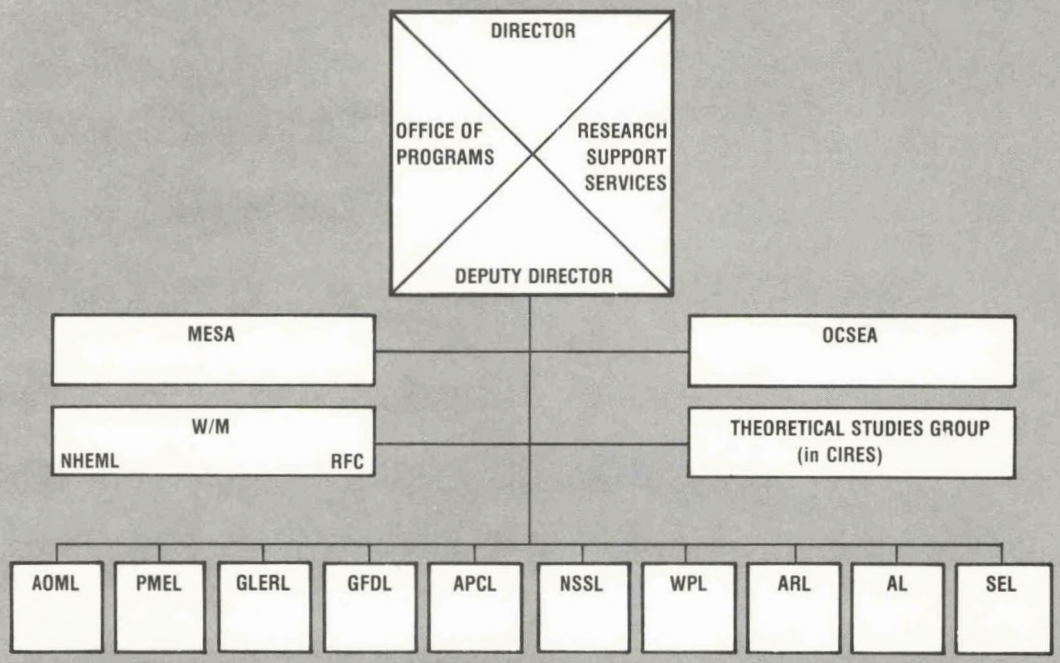
Environmental Research LABORATORIES



The mission of the Environmental Research Laboratories is to study the oceans, inland waters, the lower and upper atmosphere, the space environment, and the Earth, in search of the understanding needed to provide more useful services in improving man's prospects for survival as influenced by the physical environment. The following laboratories contribute to this mission.

MESA *Marine EcoSystems Analysis Program Office*

OCSEA *Outer Continental Shelf Environmental Assessment Program Office*

(CIRES) *Theoretical Studies Group (in CIRES)*

W/M *Weather Modification Program Office*

AOML *Atlantic Oceanographic and Meteorological Laboratories*

PMEL *Pacific Marine Environmental Laboratory*

GLERL *Great Lakes Environmental Research Laboratory*

GFDL *Geophysical Fluid Dynamics Laboratory*

APCL *Atmospheric Physics and Chemistry Laboratory*

NSSL *National Severe Storms Laboratory*

WPL *Wave Propagation Laboratory*

ARL *Air Resources Laboratories*

AL *Aeronomy Laboratory*

SEL *Space Environment Laboratory*

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
BOULDER, COLORADO 80302

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Environmental Research
LABORATORIES

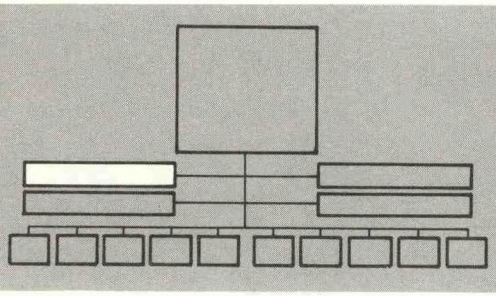
PROGRAMS AND PLANS

INTRODUCTION

The Environmental Research Laboratories are the research arm of the National Oceanic and Atmospheric Administration (NOAA). NOAA was formed in 1970 by bringing together environmentally oriented agencies from the Departments of Commerce, Interior, Transportation, Navy, Army, and the National Science Foundation for the purpose of improving man's understanding and use of the physical environment.

The research activities needed for NOAA's mission are conducted by the Environmental Research Laboratories (ERL), which are headquartered in Boulder, Colorado. ERL has facilities at locations around the country as well as at Boulder, to conduct research in oceanography, limnology, meteorology, upper atmosphere and space physics, and remote sensing of the atmosphere and ocean. These facilities are centers of science and technology to describe, simulate, predict, and in some cases to modify the environment.

The individual laboratories' and Program Offices' recent achievements and their plans for the immediate future are summarized in this report.



MARINE ECOSYSTEMS ANALYSIS PROGRAM

Boulder, Colorado
Mr. Charles G. Gunnerson, Director

The Marine Ecosystems Analysis Program (MESA), initiated in 1973, provides within NOAA a force to analyze and help to resolve environmental problems associated with territorial, boundary, and international waters. The general objectives of the Program are to assess man's impact on specific marine environments and to convey that knowledge to policy and decision makers in order to minimize such impact. The Program uses the resources of NOAA's Environmental Research Laboratories, National Marine Fisheries Service, National Weather Service, National Environmental Satellite Service, National Ocean Survey, Environmental Data Service, and Office of Sea Grants. Its activities are coordinated with the Office of Coastal Zone Management and with other Federal agencies, and it relies upon its advisory committees to assist in planning and reviewing operations and in disseminating and utilizing information.

Physical, geological, chemical, and biological research activities within MESA are focused in four major efforts: the Program Office, the New York Bight Project, the Puget Sound Project, and the Deep Ocean Mining Environmental Study (DOMES) Project.

PROGRAM OFFICE

The Program Office, located within the Environmental Research Laboratories in Boulder, Colorado, administers all MESA Projects. In addition, the Program Office conducts and coordinates studies in support of the regional projects.

Accomplishments FY 1975

During fiscal year (FY) 1975, the Program Office, together with the Maritime Administration, supported a study of the concentrations of hydrocarbons and other organics in Pacific Ocean waters.

In January of FY 1975, the Director of MESA was a member of a team of U.S. scientists representing NOAA, the Coast Guard, and the Environmental Protection Agency, that traveled to Chile to investigate and assess the impact of the METULA oil spill of 9 August 1974, in the Strait of Magellan. This event is providing an "in situ" experiment and transferable information on the fate and effects of a massive oil spill in boreal waters similar to those of the Pacific Northwest and the Gulf of Alaska where there will be increasing development and transport of the Alaskan north slope oil.

In June, MESA convened an international group of environmental scientists and managers in Boulder to discuss the observed effects of the METULA spill and to plan studies on the long-term effects of the spill.

Plans FY 1976

In addition to its administrative responsibilities, the Program Office will continue studies on hydrocarbon levels in the world's oceans and on the effects of the METULA oil spill. An atlas of organic and hydrocarbon levels in the world's oceans will also be compiled. Preliminary planning is underway for studies of the fate and effects of municipal, industrial, and/or agricultural wastes in Florida coastal waters, Gulf of Mexico estuaries, San Francisco Bay, and the Great Lakes.

NEW YORK BIGHT PROJECT

The Project (1) determines the fates and effects of pollutants on the New York Bight ecosystem, with particular emphasis on ocean dumping, and (2) identifies and describes the important subsystems, processes and driving forces in the New York Bight as a whole. The New York Bight Advisory Committee supports these efforts with the assistance of advisory panels for science and technology, for users, and for citizens and industry. MESA oceanographic studies within the New York Bight are providing an understanding of the important physical, geological, chemical, and biological processes within the Bight and effects on the fate of pollutant inputs.

Accomplishments FY 1975

Physical Oceanographic Program

During FY 1975, data from drifter and current meter studies within the Bight permitted a preliminary description of current patterns. An important result of these studies, related to mixing of waters within the Bight, is that a clockwise gyre appears to dominate inner Bight circulation during much of the year. It is not yet clear how far seaward the gyre circulation extends. Water quality studies, together with circulation studies, resulted in further understanding of water characteristics in the New York Bight.

Two permanent and several short-term coastal tide stations were installed in FY 1975 to augment the National Tide Network for the Bight area. Short-term bottom pressure measurements were also obtained on the shelf during the springs of 1974 and 1975. These pressure data have provided information on tides and on water movements associated with tides on the continental shelf, on long period waves, and on wind set-up.

Geological Oceanographic Program

An experiment to measure the transport of sand within the Bight, in waters approximately 60 feet (18 meters) deep, monitored the movement of sand tagged with ruthenium. Results of the study support the hypothesis that limited transport of sand occurs during most of the year, but that significant sand transport occurs during severe storms.

Chemical Oceanographic Program

During FY 1975, Manhattan College, through a MESA grant, estimated the sources and magnitudes of contaminant inputs to the Bight. The study measured the relative contributions of four major sources of contaminants: (1) ocean dumping of sewage sludge, dredge spoils, building and construction debris, and acid and chemical wastes, (2) municipal and industrial wastewater, (3) atmospheric fallout, and (4) runoff. Although it was determined that the majority of contaminants are contributed by the New York metropolitan area, the relative contaminant contribution of different sources varied greatly.

Under a MESA contract, the University of Rhode Island analyzed atmospheric aerosol samples for measurement of trace metals. The results of the study indicated that atmospheric inputs may account for 13 percent of the lead, 8 percent of the zinc, 5 percent of the iron, and 1 to 2 percent of the cadmium input to the Bight. In conjunction with this study, Brookhaven National Laboratory is measuring elemental and isotopic sulfur in the atmosphere over the Bight.

The decomposition rate of sedimentary organic matter within the Bight was quantified in August and December 1974, and in February 1975, by measuring rates of uptake of oxygen at the sediment-water interface. Rates of sedimentary oxygen utilization within the Bight varied with water temperature and tended to be depressed over some dumped wastes during summer and fall.

A study was started on the effects of sediment reworking and diagenesis on contaminant exchange with the overlying water. First efforts have focused on determing the rate of sedimentation and the rate of reworking by storms and bottom animals.

Biological Oceanographic Program

During FY 1975, in collaboration with other agencies (the Food and Drug Administration, the Nassau County Department of Health, the town of Hempstead—Department of Conservation and Waterways, the New York Department of Environmental Conservation, and the Environmental Project Agency), MESA measured the numbers of total coliform and fecal coliform bacteria in sediments at 20 locations south of Long Beach, N. Y. The measured concentrations were high enough to indicate coliform bacteria contamination to distances of 5 nautical miles offshore of Long Island.

Studies are being performed on the prevalence and causes of fin rot disease in some benthic fish. There is evidence that the onset of fin rot disease may not be bacterial. These findings are in contrast with evidence that bacteria do cause fin rot in some areas.

Bight waters and sediments have been analyzed for coliform and other bacteria that are resistant to antibiotics. Several locations at and near the dump sites, and near shore, yielded bacterial strains resistant to several heavy metals and to terramycin. Although the presence of these resistant bacteria in the Bight is not now viewed as a public health threat, their widespread distribution is striking demonstration of natural selection and bacterial accommodation to human contaminants.

Measurements of phytoplankton density and productivity in the waters of the Bight, Lower Bay, Raritan River, and the lower Hudson River indicated that productivity within the inner Bight is less than that measured in the Hudson and Raritan Estuaries, but larger than that measured in the outer Bight. An estimated annual phytoplankton production of 370 grams of carbon per square meter within the inner Bight is similar to that of productive upwelling areas.

Plans FY 1976

Much of the effort in FY 1976 in all disciplines will be devoted to analyses and syntheses of substantial bodies of data already gathered. Guidelines on the management of sewage sludge dumping within the Bight will be prepared for the Environmental Protection Agency (EPA). Continued studies will be performed on pollutant inputs, dynamics of phytoplankton and zooplankton in the inner New York Bight, distribution of and contaminant impacts upon benthic invertebrates, the severity and causes of fin rot disease in fishes, the distribution and sources of sewage derived sedimentary material, the release of contaminants from the sediments to the water column, and the significance of resistance to antibiotics in coliform and pathogenic bacteria.

New studies will be initiated to obtain current meter and pressure data for analysis of long term circulation features of the shelf and Hudson Shelf Valley, to determine the relative importance of meso-, regional- and macro-scale meteorological forces responsible for Bight circulation and sediment transport, and to assess the incidence of cytogenetic abnormalities in the eggs and larvae of selected fish.

PUGET SOUND PROJECT

The Puget Sound region is faced with a series of marine resource management decisions that require knowledge of marine environmental processes and an understanding of the impact of man's activities upon the ecosystems. The MESA Puget Sound Project, a 5-year study to supply this information, is evaluating the effects of primary and secondary sewage treatment plant discharges and of increased oil transportation and refining on the Sound ecosystem with special reference to the use of northern Puget Sound as terminal for Alaskan oil shipments.

Accomplishments FY 1975

FY 1975 activities, purchasing capital equipment and recruiting staff, laid the groundwork for future project activities.

The Project provided support to the Pacific Marine Environmental Laboratory (PMEL) to (a) review existing water quality and ecosystem conceptual models, (b) begin development of central basin and estuarine front mathematical models, (c) accelerate processing of oceanographic data, and (d) conduct drogue studies in the San Juan Island region.

The MESA Puget Sound Project and others supported the Oceanographic Commission of Washington in its development of a Compendium of Current Environmental Studies of Puget Sound and Northwest

Estuarine Waters. The project also supported the Northwest Fisheries Center in the expansion of its capability to conduct petroleum hydrocarbon bioassays.

PUGET SOUND PROJECT

Plans FY 1976

Data gathering will start in FY 1976. Research will focus on the central basin of Puget Sound, which receives the majority of the region's municipal and industrial wastes. Major field studies will be conducted for two summers during the low-runoff period and for one winter during high runoff. During each period, Aanderaa current meters will be used in the vicinity of West Point to measure dynamic factors influencing the dispersion of several wastewater discharges. Wind velocity, near surface currents, and STD (salinity, temperature, and density) will be measured simultaneously to permit identification of the contributions of tidal current, wind stress, and estuarine flow to advection and dispersion.

Oil transportation and refining are centered in northern Puget Sound and the Strait of Juan de Fuca. Field work will be concentrated here to determine baseline concentrations of petroleum hydrocarbons in water, sediment, and biota. Physical factors that control the transport and dispersion of spilled oil and refinery effluents will be measured.

Supporting activities will include publication of an environmental atlas and monograph series, establishment of a data management system, the interpretation of available ecosystem information, and the further development of mathematical models. The MESA Puget Sound Project Office serves as a focal point for U.S.—Canadian cooperation in ecosystem research on the impacts of increased petroleum transportation and refining in the Puget Sound—Strait of Juan de Fuca—Strait of Georgia region. A draft cooperative research protocol will be submitted to both governments in FY 1976.

DEEP OCEAN MINING ENVIRONMENTAL STUDY (DOMES)

The DOMES Project is concerned with potential environmental impacts of deep ocean mining of manganese nodules which also contain important reserves of copper, nickel, and cobalt. The main objectives of the project are to define deep ocean baseline oceanographic conditions and to predict how these conditions will be affected by the scraping of the sea floor and the subsequent discharge of fine sediments to the water column in response to the requirements of the National Environmental Policy Act with respect either to Law of the Sea negotiations, or to domestic legislation concerning mining operations in international waters. Information gathered will also be used to develop guidelines for design of industrial mining equipment and operational techniques.

Accomplishments FY 1975

A Technical Development Plan was issued in early April of FY 1975 to define: (1) alternative deep ocean mining systems and their interaction with the marine environment; (2) deep ocean environmental characteristics; (3) potential environmental impacts;

and (4) a management program to carry out the study. A technical workshop evaluated the plan.

Requests for Proposals (RFP) for FY 1976 were issued on 19 May 1975. Covering only work associated with surface waters subject to seasonal effects proposals were requested to review the literature and to study (1) phytoplankton and primary productivity, (2) zooplankton, (3) upper water column chemistry, (4) upper water column circulation and mixing, and (5) dredge head and discharge plume modeling.

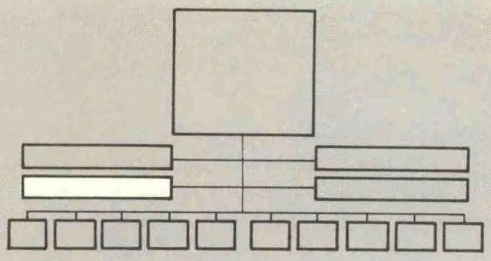
A major accomplishment of FY 1975 was the successful 44-day cruise of the NOAA Ship Oceanographer to collect baseline data at a typical mining site located at 15° North, 126° West, between 15 April and 5 June. Sample and data analyses have begun.

Plans FY 1976

A Phase II Technical Development Plan (the testing of a predictive capability during industrial prototype-mining equipment trials) will be completed in October 1975 (FY76) and RFP's issued.

The second period of field operations is planned for 90 days at sea in the period mid-February through mid-May. Near-bottom and bottom observations and sampling will support proposals accepted from the responses to the October RFP.

In August 1976 (FY 1976 extended) the DOMES Project will publish the preliminary Phase I report including preliminary predictions of biological effects of mining operations. The report will be based on analysis of the data and samples from the April-June 1975 and August-November 1975 cruises.



WEATHER MODIFICATION PROGRAM OFFICE

Boulder, Colorado
Merlin Williams, Director

The Weather Modification Program Office (WMPO) provides line management over the Boundary Layer Dynamics Group (BLDG), the Research Facilities Center (RFC), the Instrumentation Task Force (ITF), and the National Hurricane and Experimental Meteorology Laboratory (NHEML), all located in Miami, Florida.

Under the program direction of WMPO, these groups conduct research leading to basic understandings of hurricanes and their beneficial modification, and to basic understandings of convective clouds and precipitation enhancement from them, with emphasis on tropical storms.

The WMPO evaluates the social, legal, and economic aspects of the ERL weather modification programs. It provides technical advice to the Director, ERL, on other weather modification research activities in ERL, such as the lightning suppression program. It also provides advisory services on weather modification applications to U.S. Government agencies and to foreign governments.

BOUNDARY LAYER DYNAMICS GROUP

The Boundary Layer Dynamics Group (BLDG) of the Weather Modification Program Office is concerned with theoretical and experimental studies of the turbulent transfer of atmospheric properties. The Group has participated in NOAA's large field programs of the Barbados Oceanographic and Meteorological Experiment (BOMEX), the International Field Year of the Great Lakes (IFYGL), Florida Area Cumulus Experiment (FACE), and GARP's Atlantic Tropical Experiment (GATE). A main goal of these studies has been to understand and evaluate the turbulent transfer of the latent heat of condensation of water vapor, i.e., the "fuel" that drives weather systems on scales ranging from thunderstorms to hurricanes. Such studies include: weather modification studies of cumulus dynamics; air-sea interaction studies of momentum exchange, with resultant wave generation and dissipation; evaluation of evaporation coefficients for first order stations in the Great Lakes hydrological network; hurricane research involving the storm surge and modification experiments designed to lower the central wind field and its turbulent characteristics; evaluation of inadvertent weather modification such as that produced at sea by off-shore oil spills or over land by large scale irrigation; and studies of modification of extra-tropical severe storms.

Accomplishments FY 1975

The Group completed the analysis of the data collected during IFYGL, and prepared a report of data for the archives as well as formal papers for the literature and talks for appropriate conferences.

The BLDG participated in the field phase of GATE during the summer of 1974, obtaining extensive high quality measurements of the marine boundary layer under varying stability conditions. It received a NOAA unit citation for this work.

The BLDG also prepared formal papers on waves in the boundary layer, effect of waves and instabilities on astronomical observations, effects of boundary layer climatology on telecommunications and world-wide progress in radio science.

Plans FY 1976

Cooperative studies are well under way with AOML's Sea Air Interaction Laboratory (SAIL) on turbulent exchange between the sea and the atmosphere.

Completely new gust probe vane structures have been designed and fabricated in the light of the GATE experience. It is planned to test these new vanes as well as the Merceret hot film probes during the cooperative BLDG-NHEML hurricane studies in the fall of 1975.

Archiving of GATE data will be completed and an in-depth scientific analysis of the experiment will be initiated.

RESEARCH FACILITIES CENTER

The Research Facilities Center (RFC) is the aeronautical arm of NOAA's Environmental Research Laboratories. It has two major components - The Flight Operations Group (FOG) and the Scientific Instrumentation Group (SIG). The FOG has as its primary responsibilities the operation and maintenance of RFC aircraft and helicopters,and all aspects of the RFC program related to flight safety. The SIG provides technical support to operate, maintain, and calibrate research aircraft instrumentation and to process digitized sensor data into a form required by the scientific investigator.

The RFC operates a Lockheed WC-130B Hercules airplane and a Douglas DC-6A. Both airplanes are four-engined, long-range aircraft capable of carrying out a wide variety of environmental research assignments, anywhere in the world. In 1975, these airplanes will be joined by the first brand-new aircraft ever purchased by the Department of Commerce, a Lockheed WP-3D, built and instrumented with the NOAA mission in mind.

Recently the Research Facilities Center was assigned the responsibility of providing helicopter support to the Outer Continental Shelf Environmental Assessment Program. In connection with this, RFC maintains and operates two helicopters, a Bell 206B Jet Ranger and a UH-1F, from Pt. Barrow and other Arctic bases in Alaska. The Bell 206B also has been successfully operated from the NOAA Ship Surveyor in the Gulf of Alaska and the Bering Sea.

The RFC aircraft and crews have flown thousands of sorties into the world's most difficult weather. Much of the precise information that exists on these atmospheric systems and on beneficial weather modification techniques has come from those flights. RFC aircraft have also participated in the series of major international experiments aimed at obtaining an improved understanding of global weather processes. These include the International Indian Ocean Expedition (IIOE) of 1963 and 1964, BOMEX of 1969, IFYGL of 1971, and GATE of 1974.

INSTRUMENTATION TASK FORCE

The development of state-of-the-art instrumented research aircraft is perhaps the most significant development of the 1970's for advancing our measurement capability and subsequently, our understanding of severe convective storms, hurricanes, weather modification processes, and generally related meteorological and oceanographic phenomena. Powerful ground-based remote sensing systems including dual Doppler radars, lidar, acoustic radar, and conventional narrowbeam radar with high quality digital data recording systems are developed and are being exploited for atmospheric and oceanic research. Over land, the instrumented aircraft being developed are necessary as an adjunct to the ground systems to provide the cloud penetration in-situ and near cloud measurements of cloud microphysics and structure and to detail the changes and processes that result naturally and from artificial modifications. Over sea, the aircraft must provide the stand-alone systems for all measurements of the structure, kinematics, and processes, both atmospheric and oceanic.

The Instrumentation Task Force (ITF) of the Weather Modification Program Office is charged with modernizing NOAA's aircraft and aircraft instrumentation for atmospheric and oceanographic research. Additionally, ITF coordinates the instrumentation of a NASA Convair 990 aircraft for participation in joint NOAA/NASA programs.

Accomplishments FY 1975

C130B: The AWRS (Airborne Weather Reconnaissance System) developed under Air Force contract was installed in this aircraft in late FY-74 and flown in the GATE program under RFC and ITF supervision in FY-75. Additional system test was accomplished in NOAA's Florida Area Cumulus Experiment in summer of 1975. NOAA's present DC-6 and C130 participated successfully in the GATE program with data and sensor system packages that had been provided by ITF during the previous year (FY-74).

WP-3D: During FY-75, ITF received delivery of the first WP-3D aircraft (May 1975) and completed contractual agreements with the U. S. Navy for purchase of the second WP-3D, to be delivered in January 1976. Specifications, requests for proposals, and contracts were written for much of the total instrumentation and radar systems required.

NASA CV990: Specifications for instrumenting the Convair 990 high-altitude jet aircraft for STORMFURY have been prepared during FY-75 in conjunction with NOAA and NASA scientific programs.

INSTRUMENTATION TASK FORCE

Plans FY 1976

C130B: Radar hardware for improving the weather-radar capability will be purchased in FY-76; a narrow-beam antenna-radome modification to provide for STORMFURY requirements will be done in FY-77.

Air Force C130B: In FY-76 RFC will acquire the Air Force C130B aircraft with an installed prototype AWRS meteorological system. Additional cloud physics equipment and a back-up inertial navigation system will be provided this aircraft in FY-76 through ITF program.

WP-3D: In FY-76, ITF will receive delivery of the second WP-3D aircraft, and proceed with acquisition, installation, test, and calibration of instrumentation systems aboard all aircraft referenced above. Modifications of the two WP-3D's for installation of the data and instrumentation systems will be accomplished under an existing contract with Lockheed Air Service, Ontario, CA.

NASA CV990: Contracts for the engineering designs for modification as necessary for instrumenting the aircraft and for the fabrication and installation of equipment are planned for FY-76.

The initial scheduled major program to be conducted with these aircraft is Project STORMFURY, NOAA's hurricane modification experiment to be conducted in the Pacific in CY 1977-78.

Pyrotechnic Development: In FY-75 a contract was initiated with Naval Weapons Center for development of an in-board pyrotechnic flare (AgI ice nuclei for weather modification experiments including STORMFURY) and seeding dispenser. A prototype system with a few thousand flares will be delivered for RFC/ITF test in CY 1976. Dispenser systems for each of the five STORMFURY participating aircraft will be delivered in FY-77.

Omega Dropwindfinding Sonde System: The design concept for a windfinding, temperature, pressure, humidity measuring sonde, which utilizes the worldwide Omega navigation low-frequency radio signals for sonde position determination, was tested during GATE. During FY-76-77 additional "Mark II" systems will be acquired through ITF procurement and installed on the WP-3D and CV990 aircraft.

NATIONAL HURRICANE AND EXPERIMENTAL METEOROLOGY LABORATORY

The National Hurricane and Experimental Meteorology Laboratory (NHEML) was created in January 1975 by re-organization and combination of the National Hurricane Research Laboratory and the Experimental Meteorology Laboratory. The research programs of the NHEML concentrate on two atmospheric phenomena of the tropical troposphere, hurricanes and cumulus convection, together with the atmospheric environments in which they occur and with which they interact. These programs include basic research in the description and understanding of these phenomena as well as applied research in their prediction and potential beneficial modification. Special observational programs utilize aircraft of the Research Facilities Center to provide unique data. When combined with other information from more conventional sources, these data provide the basis for analytical and theoretical studies to improve the description and understanding of these phenomena. A major part of these efforts now is directed toward the development of mathematical models through high speed, large capacity computers. The models are designed to simulate the development, structure, and behavior of hurricanes and cumulus clouds, both in their natural state and when experimentally modified. These studies and models are also used to improve prediction capability.

The experimental program in hurricane modification (known as Project STORMFURY), and the program in cumulus modification (FACE), also form important and logical parts of the research programs of the NHEML. Because of the interrelationships between these modification experiments, i.e., it is the convective-scale motions within the hurricane that are modified, their combination within a single laboratory should be mutually beneficial. Within the NHEML there are four working groups: the Hurricane Group, the Cumulus Group, the Modeling Group and the Analytical Studies Group. The first two concentrate on hurricane and cumulus research; the last two support both research programs. The ultimate goal of STORMFURY is the reduction of the maximum winds associated with the eye-wall of hurricanes; the goal of the FACE is to acquire a thorough understanding of cumulus cloud behavior that will enable us to increase precipitation from cumulus clouds. These experimental programs also make extensive use of the Research Facilities Center.

The NHEML also interacts with the National Hurricane Center (NHC) of the National Weather Service (NWS) in problems of hurricane prediction, and with the Sea-Air Interaction Laboratory (SAIL) in problems of boundary layer energy transfers and the hurricane storm surge.

Accomplishments FY 1975

Hurricane Research Program

The microphysical structure in hurricanes and other tropical clouds has been examined with instrumentation that was developed by the Hurricane Group. Data collected in Hurricane Ellen (1973) with this system of instruments have verified the first link in the STORMFURY hypothesis, which states that large quantities of supercooled water exist in the hurricane where there are low ice concentrations and significant updrafts.

The proposed detailed sequence of events that should occur under the present STORMFURY hypothesis has been outlined using the variational optimization technique of the Hurricane Group. With this technique, a scheme to analyze the high energy portion of a hurricane has been developed. Results from this analysis method have been used to define a more explicit seeding hypothesis to explain and evaluate future seeding experiments.

A series of three-dimensional hurricane simulations with moving nested grids and basic currents as strong as 20 kt has been completed by the Modeling Group.

Significant progress was made in the construction of a new two-dimensional hurricane model that allows explicit representation of some cloud microphysical processes. This type of model is needed to improve upon the realism of simulations of the STORMFURY cloud-seeding experiment.

A theory was formulated, from analysis of Hurricane Ellen (1973) data, that cooling of the sea surface in the rear of a hurricane may be increased by a series of inertio-gravity waves on the ocean thermocline.

Hurricanes Carmen and Fifi (1974) were compared and the high-level wind vectors examined as a function of storm outflow and motion.

A compositing method has been completed for the study of tropical wave motion. Preliminary GATE wind data were used as a test of the technique.

A study of Hurricane Inez (1966), a small, intense storm, has been completed. Together with previously published studies of minimal Hurricane Cleo (1958), and moderate Hurricane Hilda (1964), it covers the full range of hurricane intensities.

A linear, theoretical analysis of tropical disturbance growth in response to energy released in organized cumulus convection was completed.

A diagnostic study of the air-sea exchange processes in Hurricanes Daisy (1958) and Inez (1966) revealed that the exchange rates of sensible heat, water vapor, and momentum between ocean and atmosphere in the two hurricanes could be estimated by a technique proposed for use with general circulation models.

Cumulus Research Program

The optimum system of rainfall measurement, using either raingages alone, or gage-adjusted radar, has been defined for individual showers, for the FACE target area, and for the mesonet area.

In search for covariates to be used in FACE rainfall evaluation, two shower regimes have been identified on days deemed suitable for experimentation.

Analysis of all single clouds on FACE days has revealed a factor-of-2 increase in rainfall from seeded clouds. There is strong evidence that the seeded clouds merged more rapidly than those not seeded.

It was established that seeding in Florida does not change raindrop size distributions at cloud base, thus assuring that radar measurement of rainfall is equally valid for both seeded and non-seeded clouds.

A method to estimate rainfall from satellite imagery has been developed by the Cumulus Group for use in GATE and FACE to investigate the large-scale effects of dynamic seeding.

The cloud physics system developed in NHEML was used to collect large quantities of data in the GARP Atlantic Tropical Experiment (GATE).

Analysis of FACE-1973 cloud physics observations was completed, and selected microphysical parameters were correlated. The value of radar observations for determining the mesoscale motion field was documented.

Plans FY 1976

Hurricane Research Program

An optimum hurricane seeding strategy will be sought, from both the operational and scientific viewpoints. The design of the STORMFURY experiment will be refined by evaluating aircraft and instrumentation performance in specific areas of the hurricane.

Both airborne and land-based digitized radar data will be collected during the FY-1976 hurricane season for use in Project STORMFURY research studies.

Studies of Hurricane Debbie results will continue in an effort to determine the rate at which the storm returned to its "natural" state after seeding.

The effects of hurricane modification tactics on the storm's path will be investigated by use of the existing three-dimensional, three-layer, moving nested grid hurricane model.

A multi-level, nested grid three-dimensional hurricane model with sophisticated cumulus dynamics and physics parameters will be designed and coding will be started.

The Analytical Studies Group will help to prepare for Project STORMFURY Pacific by making in-depth studies of the typoon statistics available.

New cumulus parameterization schemes have been incorporated into several versions of a two-dimensional model. This model will be developed until it is capable of simulating the growth of a weak circulation to hurricane intensity.

The compositing technique for studying synoptic-scale waves in the Caribbean-Gulf of Mexico region will be used to determine the three-dimensional structure of atmospheric fields associated with the easterly waves.

Measurements in the hurricane boundary layer and upper portion of the ocean will be made.

The planetary boundary layer and the region just above it will be studied by use of turbulence data gathered by the NOAA DC-6 aircraft.

A series of hurricanes will be examined, using satellite movie loops, to determine the extent of outflow from various sizes of storms.

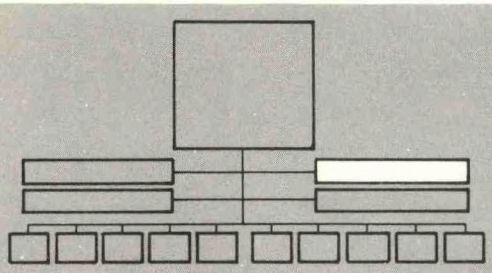
The method of estimating rainfall from satellite imagery will be used to make an A-scale rain atlas during the GATE program of 1974.

Cumulus Research Program

Major goals of the FACE program include 1) an increase in the number of experimental days, with a doubling of the days on which seeding occurs, and 2) the attainment of data that are necessary to understand cloud and environmental processes, and which are also needed for numerical models.

Research on the impact of variable cloud shielding and variable surface temperatures on the movement and intensity of south Florida sea breezes will be completed, as a preliminary to modeling studies.

A Florida area diagnostics model will be designed to provide insight into the control of cumulus convection by synoptic-scale events in this region.



OUTER CONTINENTAL SHELF ENVIRONMENTAL ASSESSMENT PROGRAM

Boulder, Colorado
Dr. Rudolf J. Engelmann, Director

Over the past two years, the Outer Continental Shelf (OCS) has taken on increasing importance in the United States movement toward energy self-sufficiency. On January 23, 1974, the President directed a three-fold expansion of the OCS leasing program, with the most intensive interest centering on the Alaskan OCS.

In May 1974, the Bureau of Land Management (BLM) requested that the National Oceanic and Atmospheric Administration initiate a program of environmental assessment in the Northeastern Gulf of Alaska (NEGOA) in anticipation of a possible oil and gas lease sale in the region early in 1976. These studies began in July 1974 under management of the Outer Continental Shelf Environmental Assessment Program (OCSEAP).

Initially, interest focused on an area of the northeastern Gulf of Alaska between Prince William Sound and Yakutat Bay, a region known to contain substantial petroleum reserves. However, because the region offers wide-ranging resources for the human economy and well-being beyond those petroleum resources, formidable environmental issues surround petroleum development there. In a report of April 18, 1974, the Council on Environmental Quality indicated that the northeastern Gulf of Alaska ranked highest in environmental risk among the areas studied, and commented that "particularly in Alaska, we have little or no information on existing marine life."

There is broad agreement among environmental scientists that environmental studies must be undertaken immediately in potential leasing areas to quantify the risks of OCS development. Without such a detailed study, the environmental impacts from petroleum development cannot be predicted or minimized.

In October 1974, BLM requested a major expansion of the environmental assessment program to encompass seven additional areas of the continental shelf of Alaska during FY 1975-1976 ranging from the northeast Gulf of Alaska on the south to the Beaufort Sea area on the north.

In March, a Source Evaluation Board, comprising representatives of the Federal government and Alaska, established program priorities and, with the assistance of four technical committees, recommended 140 investigations. These investigations are managed by the OCSEAP Office in Boulder, Colorado, and its two Project Offices in Alaska. Representatives from National Marine Fisheries Service, Fish and Wildlife Service, U.S. Geological Survey, National Ocean Survey, Environmental Data Service, and the State of Alaska, are members of the Program Office staff.

The research program objectives are:

1. To describe the distribution and general abundance of major biological components of the Alaskan marine ecosystem, as a basis for qualitative predictions of the possible impacts of major accidents.

2. To establish the baseline levels of major contaminants in the natural environment.

3. To provide improved circulation models for the Alaskan continental shelf, as well as new insights into the dynamics of ice movement and other pollutant transport mechanisms.

4. To fill some of the major gaps in our understanding of the systemic effects of target pollutants on selected arctic and subarctic biota.

5. To improve our capability for assessing special hazards that the Alaskan marine environment presents to petroleum development.

The information gathered will be used to formulate basic understanding of the interrelationships among elements of the ecological system. A comprehensive understanding of these relationships is essential in predicting the effects of petroleum development.

Accomplishments FY 1975

The environmental assessment program was designed; 140 work statements were selected from the 400 reviewed, and approximately $26 million was obligated for FY 1975-76 research. Two Project Offices in Juneau and Fairbanks, Alaska, were organized and staffed as well as the Program Office in Boulder, Colorado.

NEGOA field investigations began in July of 1974. As the program expanded, principal investigators were working in two more areas of the Gulf of Alaska and in the southeastern Bering and the Beaufort Seas by April 1975.

During the first year of the NEGOA program, emphasis was placed on assessing the physical and biological components of the environment, especially those in which the data may be perishable, and on determining the transport processes that influence the distribution of potential contaminants from OCS development. This approach was implemented by placing two meteorological data buoys in the Gulf of Alaska, deploying two current meter arrays, and carrying out simultaneous STD, CTD, biological, chemical, and sediment sampling programs.

In addition to literature searches and on-site investigations of feeding and reproducing success, marine birds and mammals were continually observed and censused during all ship operations. The intertidal biology sampling program, which required shipborne helicopter operations, was initiated, and 1757 nautical miles of geophysical trackline were taken from shipboard operations in support of the United States Geological Survey research program to locate potential hazards in the NEGOA lease area.

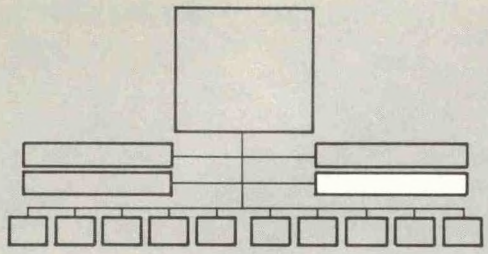
The large body of knowledge in final reports from NEGOA Principal Investigators was made available to BLM in August 1975. These findings constituted new and important information that was included in the final Environmental Impact Statement for the northeast Gulf of Alaska.

Plans FY 1976

Emphasis will be placed on the physiological and ecological effects on organisms exposed to contaminants, and on synthesizing data on environmental characteristics, transport phenomena, and hydrocarbon effects.

Research in the NEGOA region and in the southeastern Bering and Beaufort Seas will continue; in April 1976 investigations will be expanded to encompass the Norton Basin and Chukchi Sea, Lower Cook Inlet, and the northern Bering Sea.

From the findings of the principal investigators, OCSEAP will prepare input for Environmental Impact Statements (EIS) and other decision mechanisms. These impact statements - prepared by BLM - will be reviewed by OCSEAP and elements of NOAA generally.



THEORETICAL STUDIES GROUP

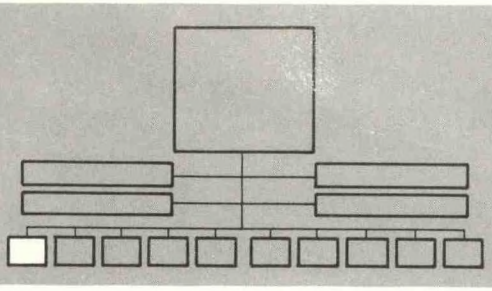
Boulder, Colorado
Dr. James R. Wait, Director

The Theoretical Studies Group is an organization of primarily NOAA-supported individuals within the Cooperative Institute for Research in Environmental Sciences (CIRES). CIRES is a cooperative effort between NOAA and the University of Colorado intended to promote interaction in research and teaching between NOAA and the university in all of the geophysical disciplines, including electromagnetic wave propagation theory, micro- and meso-scale atmospheric dynamics, solid-earth geophysics, physics of the upper and lower atmospheres, and solar-terrestrial relationships. CIRES is funded jointly by NOAA and the University of Colorado, and is manned by about a dozen permanent Fellows, either NOAA employees or University of Colorado staff, plus a number of Visiting Fellows electing to spend a period of time, normally about a year, with CIRES.

The Theoretical Studies Group, within CIRES, is primarily concerned with research on electromagnetic wave propagation theory with application, currently, to communications with miners underground, or point-to-point within mines; electromagnetic techniques for prospecting for underground mineral or coal deposits; long-distance communications at elf and vlf frequencies; radio communications through forests; plasma sheaths surrounding antennas; and electromagnetic fields associated with thunderstorms.

In 1974 and 1975, TSG authors' published articles relating to their work in electromagnetics and investigations included the following subjects:

Interaction of em waves with the Earth.
Remote probing of planar layered media.
Non-uniform Earth-crust models and geophysical probing.
Extremely low frequency (elf) phenomena.
Radio waves in forests.
Time variations of em fields in the lower atmosphere.
VLF wave propagation in the Earth ionosphere waveguide.
Trans-ionospheric transmission of vlf/lf radiowaves.
Tropospheric and lithospheric guided modes.
Particulate scattering.
EM waves in tunnels.
Interference from coaxial cables and related antenna problems.
Effect of plasma sheath on antenna pattern.
Shielding by wire grids and mesh structures.



ATLANTIC OCEANOGRAPHIC AND METEOROLOGICAL LABORATORIES

Miami, Florida
Dr. Harris B. Stewart, Jr., Director

The Mission of the Atlantic Oceanographic and Meteorological Laboratories (AOML) is to contribute to the basic understanding of the characteristics and processes of the waters of the ocean, the sea floor beneath, the lower atmosphere above, and the many complex interactions among them.

The work of AOML is carried out through the four laboratories: Physical Oceanography, Marine Geology and Geophysics, Sea-Air Interaction, and Ocean Remote Sensing.

PHYSICAL OCEANOGRAPHY LABORATORY

The Physical Oceanography Laboratory conducts investigations of physical and chemical properties of ocean waters, of ocean currents and sea level and the dynamics of their variations, of heat and mass transports, and of dispersion in the deep ocean and coastal regions. This program is broadly separable into coastal projects, regional oceanography of adjacent ocean regions, and dynamics of deep ocean circulation project components.

The long term goal is equal capability in nearshore and deep ocean research, for flexible response to national needs.

Program emphasis has been on observational studies of ocean currents and sea level, using any available methods of observation.

Program elements of the Physical Oceanography Laboratory include:

1. Coastal Process Projects

    a) New York Bight Marine Ecosystems Analysis Project (MESA)
    b) Southeast Florida Coastal Circulation Project
    c) Outer Continental Shelf Environmental Assessment Program (OCSEAP)
    d) Estuary Modeling

2. Physical and Chemical Oceanography of the Caribbean Sea and Gulf of Mexico

3. Mid-Ocean Dynamics

    a) Mid-Ocean Dynamics Experiment (MODE/POLYMODE)
    b) GARP Atlantic Tropical Experiment (GATE)
    c) Indian Ocean Experiment (INDEX)
    d) Tides and Sea Level Perturbations of the Open Sea
    e) Optical Oceanography
    f) Climate Considerations

Accomplishments FY 1975

Efforts in the New York Bight MESA Project, the largest element of the laboratory program, have been dominated by logistics and short term needs of environmental managers. Greater scientific interest and more general applicability are expected to develop.

Joint field work with the University of Miami and Nova University for an intensive investigation of the relationship of nearshore currents to the variations of the Florida Current was completed early in the fiscal year. An early finding from this work is that the mean longshore flow in the nearshore off Miami/ Miami Beach is nearly zero.

A two-dimensional model of estuarine circulation was completed and is being applied (mostly by others) to problems in San Francisco Bay and the Connecticut River estuary.

A long established study of currents and chemistry of Gulf of Mexico waters received new impetus late in the fiscal year. A major new project was initiated using both field observations and numerical modeling to develop predictive capability with application to problems arising from development of new energy resources in the Gulf of Mexico.

Processing of density data from all of the MODE ships was completed. These data, which provide the first detailed three-dimensional and synoptic description of the evolution of a mid-ocean eddy, are being prepared for publication, and already are being used by other investigators.

A post-MODE geographical exploration of the subtropical Atlantic Ocean for eddy structures indicates that features of the MODE eddy scale occur less frequently than had been believed.

An empirical model of tides in the NW Atlantic was constructed, using data from bottom pressure gauge deployments for MODE, as a laboratory contribution to the GEOS-3 satellite program.

A major study in optical oceanography was completed. Multispectral scanner data from satellite LANDSAT I were used to investigate the feasibility of observing the varying position of low-latitude ocean surface currents by means of subtle color differences during summer when IR methods fail because of disappearance of surface temperature gradients. The LANDSAT system proved unsuitable, but specifications for a suitable system were determined. The influence of sea state on upwelling irradiance was identified as a potentially important process for both detection of current boundaries and radiation balance. The latter may have a significant influence on climate.

Plans FY 1976

The New York Bight MESA Project is expected to be a major commitment of the Laboratory for several years. Some immediate objectives are to develop a statistical model relating currents in the Bight to tidal and meteorological forcing functions, and to apply diagnostic modeling techniques to extend limited observations to determine current patterns in the Bight.

Funding assistance from the Bureau of Land Management (DI) will help to continue development of predictive modeling capability for currents in the Gulf of Mexico through FY 1977.

In 1976 and 1977, field work for the joint US/USSR project POLYMODE will resume in earnest. Laboratory personnel will use shipboard, buoy, satellite, and optical tools for investigations of eddy self-interaction and meridional heat flux.

The first laboratory foray into the North Pacific begins in FY 76 with deployment of drift buoys for Lagrangian measurements of current velocities in the OCSEAP Gulf of Alaska region. Depending upon survival time, escape of these buoys from the coastal region may make us an active collaborator to the North Pacific Experiment (NORPAX) program.

Not apparent in the foregoing is the extensive relationship developed between the Laboratory and the National Data Buoy Office (NDBO). NDBO will be providing the buoy data, hardware, and/or engineering support being used in the MESA, POLYMODE, Gulf of Mexico, and Gulf of Alaska operations. In turn, the Laboratory will provide oceanographic guidance and basic data analysis functions to the NDBO drift buoy plot study for the First GARP Global Experiment (FGGE).

MARINE GEOLOGY AND GEOPHYSICS LABORATORY

The research of this laboratory is directed toward the western north Atlantic's continental margin from Nova Scotia to the Bahama Platform, the Gulf of Mexico, and selected mid-ocean areas. The emphasis in the research is on processes: sedimentary processes on the continental shelf, slope, and rise, and geophysical processes and metallogenesis on the Mid-Atlantic Ridge. The Continental Margin Sedimentation (COMSED) studies are the major program areas of the laboratory; they are concerned basically with the development and stability of bottom features, bedload and suspended transport of sand and fine-grained particulates, organic geochemical processes, and sediment geotechnical properties including clay fabric and sediment stability. The purpose of these studies is to provide geological and geophysical information for rational decision-making regarding use of the seafloor. The Mid-Atlantic Ridge research deals primarily with developing an understanding of the processes associated with tectonic movements of the Earth's crust and determining the role such processes play in mineral enrichment and deposition in mid-ocean regions.

Accomplishments FY 1975

Within the COMSED Program, the MESA studies by the laboratory have led to a basic understanding of the sedimentary and bathymetric framework of the New York Bight apex thereby making possible the determination of storms' and/or man's influence on sediment transport in the apex. These studies have provided the seasonal definition of suspended sediment transport throughout the apex and much of the Bight as a whole. Study of suspended sediment load in the New York Bight apex has resulted in defining the sources of suspended sediment as well as delineating the general current circulation in the apex. Geochemical studies of carbohydrates and organic carbon have established that abnormally high concentrations of organic carbon (believed to be sludge-derived) are being deposited with certain sediment types and that the dumped sludge is not accumulating at the dump site, but is being transported to various parts of the Bight.

Investigation of the sedimentary regime along the outer western Atlantic margin indicates that submarine canyons today are playing only a minor role in the movement of sediment from the shelf to the abyssal plain; and that transport processes down the slope are more active and effective than those of the canyons in seaward movement of sediment.

Our mid-ocean studies have revealed anomalous concentrations of manganese resulting from hydrothermal emissions on the Mid-Atlantic Ridge. These concentrations have been traced laterally from the Ridge indicating that these point source events have persisted with time to leave a trail of mineral enrichment as the seafloor moved away from the Ridge (zone of origin).

MARINE GEOLOGY AND GEOPHYSICS LABORATORY

Plans FY 1976

Near-term goals relate primarily to investigations in the New York Bight. Of prime concern is the effort to define the dynamics associated with bedload and suspended sediment transport. In the case of bedload movement we are concerned with the dynamics of the bottom boundary (0 - 100 cm) and its effect in eroding and depositing bottom sediments. Suspended sediment transport involves the dynamics of the entire water column. In association with the transport studies, efforts are being made to develop an understanding of the concentration and transformation of certain chemical constitutents (i.e., carbohydrates, organic carbon, fatty acids, and trace elements) that are bound to the sediment particles.

Our near term goal for the outer margin studies is to gain an understanding of the transport mechanism(s) responsible for movement of sediment off the outer continental shelf onto the abyssal plain through continuing studies of the role submarine canyons have in such transport.

An immediate goal for our studies of the Mid-Atlantic area is to define the hydrothermal processes causing metal enrichment in the vicinity of the Mid-Atlantic Ridge at 26°N, and to produce a series of maps and geophysical (geomagnetics, gravity, and bathymetric) profiles defining the crustal characteristics along a 300-km-wide corridor extending from Cape Hatteras, Va. to Cape Blanc, Mauritania.

SEA–AIR INTERACTION LABORATORY

The Sea-Air Interaction Laboratory is studying the boundary layers on either side of the ocean-atmosphere interface and their mutual interactions. The purpose of these studies is to improve marine predictions and to contribute to the understanding of climate. Specific areas of emphasis are the modeling of storm surges, the development of wave prediction models, and the numerical modeling of the upper ocean.

Accomplishments FY 1975

The purpose of studying the upper ocean is to describe and understand the interactive processes between the atmosphere and ocean. An upper ocean model that includes the dominant physical processes directly affected by meteorological conditions has been developed for application to typically tropical meteorological time scales. The model incorporates such fundamental processes as wave mixing, turbulence and turbulent transports, and internal waves in the thermocline below the mixed layer.

Several existing mixed-layer models have been programmed for the AOML computer. During the next year these models will be compared and critically evaluated for their applicability to the tropical ocean; the atmospheric and oceanographic data collected during the field phase of GATE will be used for comparison.

In the past year, storm surge research has been revitalized in cooperation with the National Weather Service. Two most immediate problems of numerical modeling of storm surge in bays and estuaries are: (1) calculating simultaneously in bay and shelf regions, and (2) describing a sharply curving coastline. The result has been that the most promising solution to both problems is through the use of an irregular, triangular numerical grid with variable grid spacing.

Results from such a grid have been compared with known analytical solutions and have shown good agreement. Construction has started on a triangular-grid storm-surge model (SPLASH-"Special Program to List Amplitude of Surges from Hurricanes") of Mobile Bay to study ways to calculate super-critical flows through narrow inlets and over barrier islands and peninsulas and the flooding of low-lying near-shore land.

Eventually, numerical grids will be prepared for the many bays and estuaries of the U. S. Gulf and Atlantic coastlines.

The storm surge model development is supported by an observational program that will provide the data base for testing and tuning the model.

Wave research continued during the past year with a Winter Storm Experiment (WISEX) which yielded good wave growth measurements, radar cross-section as a function of wave development for a constant wind, and S-Band passive microwave determinations of sea surface temperatures. Analysis of the data should yield improved algorithms for determination of surface wind and temperatures from satellites.

Together with NASA and the Max-Planck Institute for Meteorology of the Federal Republic of Germany, the Sea-Air Interaction Lab carried out a successful JONSWAP (Joint North Sea Wave Project) experiment that represents one of the first attempts at studying wave-wave interaction in the field and should lead to major new insights into the energy balance within the wave spectrum and its implication in the transfer of energy from the atmosphere to the ocean.

The first successful hurricane wave measurements from aircraft were obtained in June 1973 in Pacific Hurricane AVA in conjunction with SKYLAB. These data led to a simplified general wave model which has been extended to include hurricane generated waves.

Analyses of SKYLAB data have shown conclusively that both active and passive microwave systems can provide useful estimates of surface wind conditions subject to increasing error in the presence of rain.

Plans FY 1976

In theoretical studies, a "mean field" model and a "discrete fluid" model will be combined in a two-time scale mode to march forward in time and delineate the upper ocean structure evolving due to atmospheric and internal wave forcing functions.

Parallel to these theoretical studies, an instrumental system is being developed that will provide data to test the model. Initially, temperature, salinity, and pressure fluctuations will be recorded. Feasibility studies are being conducted to add suitable velocity sensors to the system.

Wave measurements obtained recently verify the parametrical approach and indicate that the model can be extended to account for the effects of hurricane forward velocity. However, for storms with very small eye diameters and large inflow angles, a more sophisticated parameterization of the directional characteristics is required. During the future hurricane seasons, therefore, it is planned to study the directional properties of hurricane waves by means of a real-aperture radar imaging system recently transferred to this laboratory by the U. S. Army.

Analysis of data sets from SKYLAB, JONSWAP, and WISEX will continue. The final analysis stage for the SKYLAB data will assess the efficacy of multi-frequency and the combined active-passive approach to improvement of accuracy of surface wind estimates.

Plans are prepared for participation in the Synthetic Aperture Radar (SAR) study to be conducted off Marineland, Florida. Measured directional wave spectra will be compared with directional wave information obtained by the SAR image in order to establish the transfer function. This effort will be a precursor to a similar study required for proper application of the Side-Looking Airborne Radar (SLAR), which will be installed on the NOAA C-130 aircraft in time for the 1976 hurricane season.

OCEAN REMOTE SENSING LABORATORY

The Ocean Remote Sensing Laboratory conducts research into such aspects of the ocean and the atmospheric boundary layer as may be carried out using techniques of remote or indirect sensing in combination with in-situ measurements.

Studies are made of surface and internal waves, sea surface temperature distributions, Gulf Stream dynamics, and distributions of near-surface chlorophyll and sediment concentrations; data are derived from a variety of Earth-orbiting spacecraft.

Active and passive microwave devices on spacecraft and aircraft are being utilized for measurements of the marine geoid, geostrophic currents, wave spectra, surface wind speed, and storm surges.

Ships carry acoustic echo-sounders, as well as more conventional oceanographic instrumentation, for probing internal waves, oceanic microstructure, and suspended sediment distributions.

Accomplishments FY 1975

A major experiment on the nature of internal waves on the continental shelf off New York was carried out by observing the waves from ship, from a NASA U-2 aircraft, and from the ERTS-1 spacecraft. The waves, which appear to be tidally excited and to propagate toward the shore, are observed along the entire northeastern North American continent. An atlas documenting the wave activity along the coast is being prepared.

An experiment was conducted on the generation of internal waves by crossing surface waves in the lee of a small island. This phenomenon, previously detected only in the laboratory, was successfully observed near Sombrero Island in the northeast Caribbean.

The acoustic echo-sounder was used on the GATE experiment along with several other shipborne observational techniques in conjunction with a Jet Propulsion Laboratory imaging radar on the NASA CV-990, to study internal waves off North Africa. The echo-sounder and radar together can give a more complete view of the three-dimensional wave field.

A sea-truth cruise was conducted in the Gulf Stream meander region northeast of Cape Hatteras shortly after the launch of the GEOS-3 altimetric satellite. Data from density sections and wave spectral measurements are being compared with sea surface topography and significant wave height observations made from the satellite.

The ability to trace low-concentration suspended sediments with 20- and 200-kHz echo-sounders was demonstrated in a dredge plume off Miami. An extension of this technique to the mapping of other foreign materials in the water column is being undertaken.

A major computional facility, the Laboratory for Image Analysis and Research (LIAR), was engineered, purchased, and partially assembled. When complete, the LIAR will accept graphical, pictorial, or taped material and manipulate it digitally to extract and enhance the information contained in it.

Considerable guidance and consultation were provided to NASA on its program on SEASAT-A, the first dedicated oceanographic satellite. Several days of NOAA RFC aircraft time were devoted to verification of SEASAT prototype instruments under winter storm conditions.

Plans FY 1976

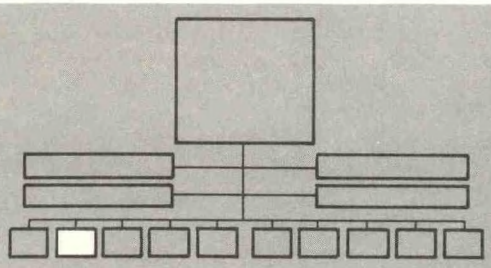
The internal wave program will concentrate on understanding the physics of wave excitation, propagation, and dissipation by continued analysis of shipborne and spacecraft data. Particular attention will be paid to the microstructure turbulence thought to accompany high-frequency internal waves. A theory for wave excitation will continue to be developed.

Analysis of GEOS-3 data will be increased as the spacecraft returns information on waves and sea surface topography. This effort will merge smoothly with the SEASAT-A program as pre-launch field activity on the latter increases. Waves, temperature, and winds at the sea surface will be the major objects of attention.

Gulf Stream dynamics in the nonlinear meander region will be studied using GOES-1, GEOS-3, and NOAA-4 spacecraft observations, as part of the POLYMODE oceanographic program.

Sediment and sludge dynamics, including advection and diffusion, will be studied in the New York Bight under the auspices of the MESA program. Microstructure and internal wave measurements will be made simultaneously; LANDSAT images will be used for synoptic scale views.

The LIAR facility will be completed through its first phase and put to work in support of the programs above. An expansion to include an optical digitizer and false color analyzer will be made.



PACIFIC MARINE ENVIRONMENTAL LABORATORY

Seattle, Washington
Dr. Robert E. Burns, Acting Director

The Pacific Marine Environmental Laboratory (PMEL) changed both its emphasis and its scope during FY-75. The principal focus became the conduct of programs associated with environmental impact assessment. Complementary research on various fundamental processes is continuing in order for there to be sound background not only for these immediate assessments but also for future needs.

Many questions relate to the potential impact of planned activities on the marine environment. Specifically, there are questions raised by the possible development of oil and gas on the outer continental shelf, by the possible increase in tanker traffic through the Puget Sound system, by the increased municipal waste discharged into Puget Sound, and by the planned mining of the deep ocean floor for manganese nodules. In each case, the impact of these activities is unknown and some estimates of kind and magnitude must be made.

Beginning early in FY-75 the existing PMEL staff prepared several proposals for work in the area of environmental impact assessment, that resulted in a marked increase in the program of the Laboratory. The increased diversity of the program resulted in internal reorganization of the Laboratory; the former estuarine research effort was divided into three components: Modeling and Simulation Studies (MASS), Studies of Coastal and Estuarine Natural Environments (SCENE), and Marine Life and Geochemical Studies (MARLAGS). The other projects remain unchanged: Deep Ocean Mining Environmental Study (DOMES), Ocean-Atmosphere Response Studies (OARS), and Joint Tsunami Research Effort (JTRE).

DEEP OCEAN MINING ENVIRONMENTAL STUDY (DOMES)

The DOMES project is concerned with potential environmental problems expected from the deep-ocean mining of manganese nodules (which also contain reserves of copper, nickel, and cobalt). The goal is to identify these problems early enough to allow a timely response to the requirements of the National Environmental Policy Act with respect either to Law of the Sea negotiations or to domestic legislation concerning mining operations in international waters. Identification of these problems will also aid in the development of guidelines for designing the equipment and devising operational techniques for the future mining industry.

Accomplishments FY 1975

Although the official beginning of the project will be FY-76, planning, operations, and data workup began in FY-75. In April 1975, a draft Technical Development plan (TDP) for Phase I was published and a workshop was held in Washington, D. C., to obtain information for use in preparing DOMES requests for proposals.

Three typical Pacific Ocean sites, representative of bottom conditions in the potential mining areas were chosen for investigation:

Site	Location
A	8°27'N, 150°47'W
B	11°42'N, 138°24'W
C	15°N, 126°W

University proposals selected for participation concerned phytoplankton and primary productivity, temporal and spatial distributions of zooplankton, nutrient chemistry, the distribution and composition of suspended particulate matter, dispersion of waste sediments, documentation of historical cases of benthic smothering, supporting physical oceanographic measurements, and a review of existing information on fishes in and adjacent to the DOMES area. Field operations took place from April 15 to June 6 at site C from the NOAA Ship OCEANOGRAPHER. The resulting samples and observations pertained to benthic fauna assessment, water column characteristics, sediment characteristics, deep ocean currents, enrichment studies, bathymetric measurements, and navigation.

A team at the Lamont-Doherty Geological Observatory of the City University of New York has completed its data report on a 1974 cruise to Site A onboard the University of Hawaii R/V MOANA WAVE.

Plans FY 1976

A draft of the Technical Development Plan for Phase II of the project will be completed in October 1975 (FY-76).

Requests will be issued for proposals dealing with the remaining activities of Phase I, associated with the biology, chemistry, geology, and physics of the bottom and near-bottom zones.

Two periods of field operations totaling 160 days at sea will be conducted at the project area aboard the NOAA Ship OCEANOGRAPHER. From August 20 to November 20, 1975, operations will support near-surface seasonal studies of phytoplankton, zooplankton, chemistry, and circulation; benthic samples will be taken also. Between mid-February and mid-May 1976, in addition to a seasonal report of the earlier work, bottom and near-bottom observations and sampling will be conducted.

In August 1976, the DOMES project will publish a preliminary Phase I report including estimates of the effects of mining operations on the biology of the DOMES area.

MARINE LIFE AND GEOCHEMICAL SYSTEMS (MARLAGS)

Accomplishments FY 1975

MARLAGS contributed to the development of three major study plans: Draft Study Plan for the Environmental Assessment of the Gulf of Alaska, southeastern Bering, and Beaufort Seas (January 1975); DOMES Technical Development Plan (April 1975); and a revised Project Development Plan for the Puget Sound MESA study. In addition, it participated in drafting a report of the Environmental Quality Monitoring Task Team Workshop sponsored by NOAA. A preliminary study was conducted in Puget Sound to determine the feasibility of using light-scattering measurements as indicators of suspended particle distributions in nearshore regions. A high correlation between suspended particle concentrations and light scattering was found when the physical and chemical characteristics of the particles were similar from sample to sample.

Although the general features of vertical distributions and migrations of zooplankton are known, there had been no previous studies regarding the effects of vertical mixing of the water on plankton stratification. During September and October 1974, with the National Ocean Survey's (NOS) tidal current survey, the effects of strong tidal mixing on vertical distributions and diurnal migrations of zooplankton in the San Juan Island region were examined. A draft manuscript reporting the initial findings has been prepared, although the samples and data require and are receiving further analysis.

MARINE LIFE AND GEOCHEMICAL SYSTEMS

Plans FY 1976

The research effort planned for MARLAGS during FY-76, will include OCSEAP investigations of (1) phytoplankton and primary productivity, (2) zooplankton, (3) suspended particulate matter, and (4) light hydrocarbon fractions. During the first year the emphasis will be on determining spatial and seasonal distributions and variability of the several parameters measured in Alaskan coastal waters. Subsequently, studies will focus on identifying ecosystem processes that affect the distribution of petroleum hydrocarbons and associated contaminants among planktonic and other populations, and on evaluating the effects of such contamination on whole populations. We will determine the distribution and composition of suspended matter in waters of the DOMES region.

MODELING AND SIMULATION STUDIES (MASS)

Accomplishments FY 1975

During FY-75 numerical modeling and simulation studies were quite natural extensions of larger, ongoing PMEL field programs. The studies are supported by observational programs within the laboratory, and we anticipate productive interaction with the other projects.

One numerical study developed a shelf circulation diagnostic model for the OCSEAP (Outer Continental Shelf Environmental Assessment Program) study in the Gulf of Alaska. The preliminary results from a test geophysical run are presented in the first annual report on the BLM contract, and some extended study cases are being prepared for the Symposium on Science and Natural Resources in the Gulf of Alaska (October 16-17) sponsored by the Arctic Institute of North America.

The second modeling study supports the MESA-sponsored observational program in Puget Sound. The study deals with the complex dynamics of the central basin and with strong tidal currents interacting with thermohaline flow. Since this work was initiated during the second half of the year, the results are only preliminary.

MODELING AND SIMULATION STUDIES

Plans FY 1976

Nine numerical models are planned, in association with five studies.

1. A Diagnostic Shelf-Circulation Model will use field data to generate (interpolate) current patterns assuming simplified dynamics and continuity constraints. The study is aimed primarily at the Gulf of Alaska and secondarily at the Bering Sea.

2. An Estuarine Circulation Model, a dynamic two-dimensional (X-Z) model of estuarine flow, is being constructed in support of an observational program in the central basin of Puget Sound.

3. A Distribution of Variables Model will be essentially a mass balance model to simulate the advection and diffusion of a pollutant. Initial efforts will look at two-dimensional surface distributions.

4. A Stochastic Advection Model will use current-meter data and a stochastic formulation to simulate time-dependent advective and diffusion effects.

5. A General Circulation Model will be used to study the response of the Bering Sea to large seasonal variations in wind-stress forcing.

6. An Ice Model Review Study will review sea-ice models in order to estimate the potential for predicting pollutant trajectories in the Beaufort Sea.

7. A Surface Current Prediction Model will compile and synthesize the information available in National Ocean Survey tidal current tables for Puget Sound in order to forecast surface currents.

8. The Finite Element Modeling Study will investigate finite modeling techniques and their possible application to environmental modeling.

9. The Triangular Interpolation and Extrapolation Study will investigate topological considerations in using triangulation routines for modeling.

OCEAN–ATMOSPHERE RESPONSE STUDIES

The OARS group conducts laboratory and field experiments primarily to investigate and describe physical processes occurring in the ocean resulting from variable atmospheric forcing.

Accomplishments FY 1975

In our investigations, as one component of the Coastal Upwelling Ecosystems Analysis (CUEA) program of the International Decade of Ocean Exploration, we determined the wind-stress curl near a coastline; we observed the response of the upper ocean to variable winds; and we estimated the mixing parameterization of the upper ocean and the role of tidal and wind-generated internal waves in the dynamics of coastal upwelling. Our findings should help to improve the management of coastal fisheries and the forecasting of local coastal weather.

Field work for the GARP Atlantic Tropical Experiment (GATE) C-Scale Oceanographic Experiment in the eastern tropical North Atlantic was completed in collaboration with many national and international oceanographic research groups. Our objectives were to define the small-scale processes occurring in the upper ocean in response to variable atmospheric forcing, and to parameterize these phenomena in large-scale ocean-atmosphere circulations. Preliminary analyses of the data indicate that the space-time variations in the thickness of the upper mixed layer were produced by oceanic forcing as well as by atmospheric forcing. This suggests that the near-surface circulation of the eastern tropical North Atlantic is more complex than originally envisioned.

Field work for OCSEAP was completed. It defined the response of the upper ocean to variable winds over the continental shelf in the northern Gulf of Alaska.

OCEAN–ATMOSPHERE RESPONSE STUDIES

Plans FY 1976

Two new research efforts, initiated during FY-75, will continue through FY-76. An attempt will be made to determine the space-time variations of sea-surface slope and its response to atmospheric and oceanic forcing over a mesoscale region of the continental shelf. Measurements of bottom pressure will be made with a prototype instrument. Findings will be used to predict ocean currents and transport of materials and to improve forecasting of storm surges. OARS will attempt also to determine the near-bottom currents and the structure of the circulation of the bottom boundary layer on the continental shelf. The analyses should facilitate decisions regarding waste disposal, dredging, and the stability of conditions on the sea floor.

STUDIES OF COASTAL AND ESTUARINE NATURAL ENVIRONMENTS (SCENE)

Emphasis of this group's studies is on understanding basic processes and on developing a sound physical basis for quantitative models that will predict the composition and distribution of biological elements of estuaries and coastal areas in general. In addition to studies of estuarine environments, there is a small program to investigate some aspects of large-scale oceanic processes. Information on advective and diffusive processes is a fundamental input in all these studies.

Accomplishments FY 1975

Puget Sound

The final proposal for PMEL's participation in the Puget Sound MESA program during FY-76 was prepared. This project begins a major investigation of the waters of the Puget Sound central basin, emphasizing the impact of wastewater and petroleum discharges.

Observations made at the central basin site in winter 1973 have been described and compared with the 1972 data, showing that the tidal averaged mean flow may reverse at depths of 50-100 m, apparently as a result of a major change in the winds. Analysis of both sets of data is continuing.

Analysis of some observations made in Port Susan during 1970 was completed. The observations are one of the only sets made during bottom-water flushing of a fjord estuary, and they indicate that direct long-term measurements of the flow on a sill will be essential for a definitive study of the bottom water renewal process in fjords or similar basins.

San Juan Island Passages

PMEL participated again with NOS in the second year of a several-year program to study tides and circulation in the vicinity of the San Juan Islands. This area is being resurveyed by NOS, partly because of the projected large increase in oil tanker traffic from Alaska to Washington.

Washington Coast and Vicinity

Efforts are continuing to assess circulation off the Oregon and Washington coasts. In July 1975, in cooperation with the OARS group, we conducted a survey aboard the NOAA Ship OCEANOGRAPHER to investigate the area from the continental slope region to about 100 m offshore. Earlier work had revealed the existence of a northward-flowing undercurrent in this region and further north.

Analysis continued of observations of the hydrographic regime across the continental shelf and offshore to depths exceeding 2000 m, which were made in autumn 1971 to investigate the possible extension of the California Undercurrent off the coast of Washington.

Alaska

The PMEL physical oceanography program in Alaska for OCSEAP has been carried out jointly by researchers in this group, in the OARS group, and in the MASS group. It is focused on direct measurement of circulation, on forming a data base to serve both as input to a diagnostic model and as a check on its output, and on providing velocity-field information to examine the fate and effects of possible oil spills or seepage related to proposed oil drilling activities. STD stations have been occupied and current meter moorings deployed. One current meter mooring has been maintained continuously for over a year.

We have collected reports of standard meteorological observations, and we have determined the average climate in this area and the transient effects of the individual cyclones and fronts. A study of the effects of air-modification processes was conducted in terms of the relationships of surface wind stress to geostrophic winds under varying conditions.

Large-Scale Oceanic Processes

PMEL continues to study the processes affecting the heat content of the upper ocean. Measurements of insolation and net longwave radiation have been made aboard the NOAA Ship OCEANOGRAPHER in order to evaluate various formulas for estimating these parameters. Recent oceanic data, plus data from selected National Weather Service coastal stations, permitted us to evaluate the various formulas for estimating insolation under clear skies.

Work on precipitation over the oceans has been revived. Collaboration with Captain G. P. Britton, who is conducting studies for the World Meteorological Organization, has allowed us to assess the various coefficients for estimating rainfall from present weather reports.

STUDIES OF COASTAL AND ESTUARINE NATURAL ENVIRONMENTS

Plans FY 1976

PMEL's field research in the Puget Sound MESA program will aim primarily at further characterizing and understanding the advective and mixing processes. This field program will include mooring a current meter for about a year at a site in mid-channel just north of West Point, a previously occupied site for which there is a large amount of data. This site is in the vicinity of Seattle's West Point plant, the largest single discharge point within Puget Sound; hence it will yield information directly applicable to managing a major discharge. Closely associated with this field program will be the development, by the modeling group (MASS), of a mathematical model of significant physical processes in the central basin.

During FY-76 we will continue to examine data pertaining to circulation in the San Juan Island passages and to participate in NOS operations in the eastern end of the Strait of Juan de Fuca. We plan to analyze data not routinely dealt with by NOS in order to obtain better descriptions and understanding of the circulation in this extremely complicated area.

We will investigate details of the circulation of the coastal waters of Washington and Oregon using the geostrophic relation and water-mass analysis. This should resolve many features inadequately described by previous surveys.

Our current efforts regarding large-scale oceanic processes are concerned principally with assessing the various cloud factors for insolation and net long-wave radiation. Plans are in progress to derive rainfall estimates for the North Pacific from the carefully edited NORPAX data tapes at Fleet Numerical Weather Central, Monterey, California.

JOINT TSUNAMI RESEARCH EFFORT (JTRE)

The Joint Tsunami Research Effort is a cooperative program of the University of Hawaii and the Environmental Research Laboratories of the National Oceanic and Atmospheric Administration. It is the Hawaiian component of the Pacific Marine Environmental Laboratory, Seattle. The two main objectives of JTRE are to improve the Tsunami Warning System and to establish tsunami hazard design criteria for coastal structures.

Accomplishments FY 1975

In order to achieve our objectives, we conducted a modest program of instrumentation and a somewhat more comprehensive program of hydrodynamics and numerical fluid dynamics. We have been involved also in an attempt to measure small tsunamis from the cable-connected gage, 5 km off the north shore of Oahu. In the past year a joint U.S.S.R. and United States experiment in the Japan-Kuril Islands region was designed and field work was begun. The objective of this experiment is to measure a small tsunami in its relatively undistorted form in the open ocean. Eleven deep-ocean tide gages were constructed, of which nine were completed in time for the Japan-Kuril cruise, and an ocean-bottom seismograph system was built; these various systems are in operation in the cooperative experiment.

Another aspect of our instrumentation program was the preparation of tsunami and tide gages for an array experiment. In this array experiment, we will observe pressure as a function of time at four locations on the sea floor. From this we will compute energy as a function of frequency and direction to identify sources of tsunami-frequency background energy that would then furnish us with a method of verifying the hydrodynamic computational techniques.

Along the line of more traditional, numerical tsunami hydrodynamics, JTRE is developing a "second-generation" tsunami-propagation model. Any given source function anywhere in the ocean will produce an output for any locationlimited principally by the quality of the depth data regarding the world ocean.

Responding to a specific request, we made a study of Honokohau Harbor on the Island of Hawaii and its long-wave response to the modifications that will result from proposed dredging.

In the absence of any major tsunami, JTRE has analyzed the large-scale water motions derived from its electric field measurement system and has produced a new set of cotidal charts for the Hawaiian Islands region of the ocean. The electric field measurement system acts as an averaging current meter, operating over a large body of water and particularly throughout the entire water column. In the event of a tsunami we would have the water motion, averaged out to a fairly large radius and averaged over the entire depth of the water.

JOINT TSUNAMI RESEARCH EFFORT

Plans FY 1976

The numerical (Green's) function technique will be applied to study of Tsunami runup. Individual numerical time-stepping studies of tsunamis will be continued with special attention to individual harbors within the Hawaiian Islands. The relative tsunami-hazard maps should be completed for the State of Hawaii; Oregon is probably the next subject for such mapping. All of the historical runup data that have been collected for the Hawaiian Islands will be presented in graphical report form. Maps showing various runup heights are being prepared.

Work on large-scale water motions derived from magnetotelluric data will continue.

An analysis and recommendation on the Straits of Magellan experiment will be completed.

Work will continue on mass transport velocity in cnoidal waves propagating steadily over a smooth horizontal bed. The result of this study should be directly applicable to tsunami problems and the dissipation of tsunami and tsunami wave energy in coastal regions. A calculation of the second approximation of the mass transport velocity within the bottom boundary layer is also being made.

Work will also continue on the differential approach to nonlinear gravity-wave problems. These are difficult problems that must be sorted out before we can understand the tsunami-shoreline interaction. We are considering a second cooperative cruise with the Russians in the seismically active area of the Kuril Islands.

BASE OPERATIONS SUPPORT SERVICES (BOSS)

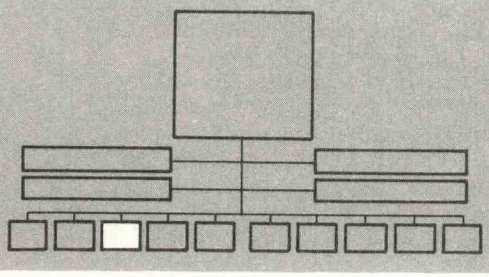
Accomplishments FY 1975

The newly organized group constructed its own shop and office space in an unused warehouse at the Naval Support Activity at Sand Point and refurbished NOAA Building 264 at Sand Point to provide temporary office and laboratory space for PMEL's increased scientific staff. It established and operated an electronic section capable of designing and fabricating new equipment as well as testing, calibrating, and repairing the many and varied electronic instruments used by the various projects. It designed and fabricated mooring assemblies, underwater camera systems, sample washers, small biological trawl frames, and other mechanical hardware requirements of the research projects.

BASE OPERATIONS SUPPORT SERVICES (BOSS)

Plans FY 1976

During FY-76, BOSS will continue to enlarge and improve its support capability.



GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY

Ann Arbor, Michigan
Dr. Eugene J. Aubert, Director

The Great Lakes Environmental Research Laboratory (GLERL) was established on April 24, 1974, to provide a focus for NOAA's environmental research in the Great Lakes region. GLERL was formed by combining the staff of the International Field Year for the Great Lakes (IFYGL) Project Office, Rockville, Maryland, with the Limnology and Computer Divisions, Lake Survey Center, Detroit, Michigan. The Ann Arbor, Michigan, Laboratory was opened in August 1974.

GLERL's mission is to conduct research directed toward an understanding of the environmental processes in the Great Lakes and their watersheds. Emphasis will be placed upon an interdisciplinary systems approach to the solving of problems in resource management and environmental services for that region. In support of this mission, the following central objectives have been established:

- To improve environmental information (e.g., statistical description, prediction, and simulation) concerning properties, processes, and phenomena of the Great Lakes and the Great Lakes watersheds;
- To develop improved environmental service tools, data, information, and consulting services to support the needs of users in government and private organizations;
- To provide an environmental advisory service, as appropriate.

The scope of GLERL's research includes field, analytic, and laboratory investigations into the limnological, hydrological, meteorological, and limno-geological properties of the Lakes, their basins, and the atmosphere.

Accomplishments FY 1975

GLERL accomplishments for FY 75 fall into several categories: organizational, scientific, and participatory. The major problem was that of building a new organization, including establishment of the present research program, program development to define GLERL research goals and objectives, recruitment of the authorized staff with the required capabilities, and development of the facilities and administrative support services required by the research program. Administrative Services and Computer Systems are organized within the Office of the Director, and the scientific and engineering staff are organized into four groups: Physical Limnology and Meteorology, Chemistry and Biology, Lake Hydrology, and Environmental Systems Engineering.

The scientific program has evolved from those of the IFYGL Project Office and the Limnology Division of the Lake Survey Center. This program is described most fully in the *GLERL Technical Plan*, a document that defines the FY 75 objectives, approach, and expected products for each of 10 component programs (or projects). GLERL scientists participated in the development and critique of that document.

Several facilities were developed during FY 75 to support the research program. The Ann Arbor, Michigan, offices and labs, and the Marine Facility at Monroe, Michigan, were opened and dedicated in late 1974. The Marine Instrumentation, Chemistry, and Biology Labs and the Computer Facility have all been set up since then and are now operational in Ann Arbor.

In order to develop future goals and objectives, GLERL hosted a workshop in October 1974 on priority Great Lakes environmental research initiatives, attended by 60 scientists working directly in Great Lakes research or in a government agency supporting that research. They identified the future Great Lakes environmental research required to provide a satisfactory state-of-the-art in environmental simulation and prediction and thereby to provide the basis for decisions on the future management of Great Lakes activities. Great Lakes environmental research accomplishments in IFYGL and in other research programs were reviewed, and deficiencies in the state-of-knowledge and needs for future research were identified and discussed. It was agreed that the state-of-knowledge is deficient in the physical, chemical, and biological processes of the nearshore region in the Great Lakes and in the exchange processes between lake and land, lake and atmosphere, lake and sediments, and nearshore and offshore. This coastal zone is a region of maximum natural variability and in addition is the region of maximum pressure on the Lakes from man's activities.

In order to develop a more coherent problem-oriented research program and to supplement in-house research capabilities, GLERL supports research grants and contracts with private institutions and other agencies. This combination of in-house and contract research allows a significantly greater capability to be brought to bear on the research problems of the Great Lakes.

Significant FY 75 research accomplishments are as follows:

- Analysis of summer and fall current measurements in the Straits of Mackinac, indicating strong oscillatory modes of the individual basins of Michigan and Huron and of the combined system with a strong seasonal dependence in the vertical structure.

- Satisfactory deployment and retrieval of 65 current meters to study the winter circulation (November 1974 - May 1975) of Lake Huron [in collaboration with the Canada Centre for Inland Waters (CCIW) and in support of the International Joint Commission (IJC) Upper Lakes Reference].

- Development of a functional model that simulates fluctuations in major components of the Lake Ontario ecosystem, e.g., several nutrients, pH, alkalinity, benthos biomass, four phytoplankton types, and five zooplankton types.

- Studies on the feeding of carnivorous zooplankton (underway with laboratory cultures).

- Development and utilization of a transient model that simulates the flow of the Detroit River (in support of the Corps of Engineers Lake Erie Wastewater Management Study and the IJC Water Quality studies).

NOAA is the U.S. lead agency for IFYGL, and the U.S. IFYGL Project Office is a part of GLERL. Results from this joint United States-Canadian multi-agency experimental field study of Lake Ontario and the Ontario basin continue to be documented. *IFYGL Bulletin No. 15* lists 26 official IFYGL publications, including 15 quarterly bulletins; a 4-volume *IFYGL Technical Plan*; 5 technical manuals; an overview report, "Two Nations, One Lake", and the *Proceedings, IFYGL Symposium, Fifty-Fifth Annual Meeting of the American Geophysical Union*. In addition, the current IFYGL bibliography now lists 204 other publications. Significant accomplishments to date are voluminous. A selection of highlights includes:

- A data archive in excess of 100 million pieces of data.

- An improved description of the thermal variations of Lake Ontario, including the seasonal, meteorological cyclone, and inertial scales.

- Identification of a major feature of the lake — that of intermittences — closely related to atmosphere-lake exchange processes.

- Identification of an intense and highly variable coastal current.

- Improved theoretical numerical circulation models.

- An improved description of the temporal and spatial variations in phytoplankton.

- Improved water quality and aquatic ecology numerical models.

IFYGL will terminate in late 1977 with the completion of eight international Summary Scientific Reports and a wrap-up workshop to synthesize and critique this major United States-Canadian project.

GLERL received and processed requests from over 100 sources for data and reports on IFYGL, in addition to the regular IFYGL distribution to more than 450 institutions and individuals. Products other than IFYGL data and reports were distributed upon request to 52 user groups covering a broad spectrum from universities and government agencies through private organizations and individual citizens. The products included reports, data, referral to information sources, presentations to civic groups, and the services of GLERL scientists on advisory boards or committees of various U.S. and international organizations.

GLERL participates for the Department of Commerce and the NOAA Offices of Ecology and Environmental Conservation in the review and critique of Draft Environmental Impact Statements (DEIS's) pertinent to the Great Lakes or the Great Lakes basin. In FY 75, some 65 DEIS's were reviewed.

Plans FY 1976

The identification of emphasis for future GLERL research comes from international, interagency, and NOAA involvements, cooperation with potential users, and an awareness on the part of the scientific staff of the research state-of-knowledge and available environmental information. GLERL plans for FY 76 and beyond are:

- To consolidate, strengthen, and carry out the evolving technical plans of present programs (or projects).

- To complete IFYGL satisfactorily in late 1977.

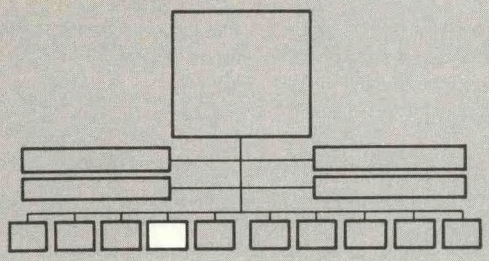
- To continue program development to further define future initiatives in Great Lakes environmental research in order to continue to provide the precise environmental information required for the decision process regarding Great Lakes resource plans, management, and environmental services.

Future research initiatives that have been identified to date include the development of research plans and Program Memoranda on:

- Great Lakes nearshore processes and properties — improved environmental information to support planning and management decisions of various activities (e.g., waste and water quality management, water supply management, power generation, fisheries management, recreation, and shipping) which utilize and impact the Great Lakes coastal zone.

- Engineering models of the Great Lakes environment — useful environmental engineering models to simulate and predict the Great Lakes limnology and hydrology to support decisions on water resources planning and management.

- Wind waves, run-up, flooding, and erosion — improved climatology and prediction to support Great Lakes resource management decisions on land use, shoreline protection, recreation, and shipping.



GEOPHYSICAL FLUID DYNAMICS LABORATORY

Princeton, New Jersey
Dr. Joseph Smagorinsky, Director

The Geophysical Fluid Dynamics Laboratory conducts fundamental investigations in the dynamics of geophysical fluids (the atmosphere, the hydrosphere, and the cryosphere) over a wide range of time and space scales. These studies comprise basic research and exploratory applications in the structure and circulations of planetary fluid systems in general, and the terrestrial oceans, troposphere, and upper atmosphere in particular. Phenomenologically they include: the dynamics of synoptic-scale evolutions; convection; internal gravity waves; boundary layer exchanges; nonadiabatic processes; and geochemical-dynamical interactions.

An understanding of these processes, mechanisms, and phenomena (which may be self-excited instabilities or forced or freely propagating modes), bears on a wide variety of potential applications for geophysical prediction. As examples there are: deterministic atmospheric forecasting for periods of several weeks to several months, the evolution and stability of climate, the dispersion of inert and interactive substances (natural or man made) in the atmosphere and oceans, mesoscale variability in the atmosphere and oceans, urban-scale atmospheric variablility and microclimate, the life cycle of hurricanes, and clear air turbulence.

Both the basic research and the exploratory applications are pursued primarily through theoretical analysis and through numerical simulation. The latter requires extremely powerful high speed digital computers. Experimentation with laboratory analogues and participation in field studies provide essential empirical augmentation.

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 a Geophysical Fluid Dynamics Program 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 1975

A reconstruction of some aspects of the global climate during the last major glaciation 18,000 years ago from deep sea cores and other geological evidence provided global distributions of the sea surface temperature, ice caps, and vegetation typical for August. A series of experiments was conducted to see what other facets of the climate and general circulation were compatible with some of

these boundary conditions. Some of the features of the climate that resulted coincided with the paleoclimatic determinations, for example, the occurrence of semi-arid climates over the equatorial continents. A more definitive study will be possible upon the availability of seasonal reconstructions.

A 30-day global prediction was completed using a 9-level 250-km resolution model. Although most of the transient characteristics lost their instantaneous predictability by the end of the period, the model succeeded in forecasting 20 days in advance the breakdown of the stratospheric polar vortex, indicating that the ultra-long waves in the troposphere were well simulated.

Global upper-air and surface data for the entire GARP GATE period from 15 June to 24 September 1974 were assimilated by a succession of several different versions of the four-dimensional analysis technique to create a definitive planetary data set for GATE. This will be used for a variety of phenomenological predictive experiments including a study of the interaction of the small-scale structure and transients in the GATE area with the planetary circulation.

An analysis of the GATE oceanographic data divulged large-scale, low-frequency waves in the equatorial tropical Atlantic. Their great stability as forced resonant waves is predicted by theoretical analysis. In contrast, instability can occur only in unusual circumstances such as in the Somali Jet or possibly in the western Pacific surface currents. The former is particularly important in the sensitive air/sea interaction characteristic of the onset of the Southwest Monsoon over the Indian Ocean.

New theoretical results indicate that the circulation of the Jovian atmosphere may be dominated by the generation of fully turbulent two-dimensional flow which is driven by the release of energy by baroclinic instability acting on relatively small scales. It appears that most of the observed features of the Jovian circulation can thus be explained, for example the quasi-axisymmetry and scale of the bands, the oval-shaped disturbances, and the waves.

Plans FY 1976

The fact that a preliminary assessment of second order effects of clouds on the radiation regime indicated great damping of the snow cover and water vapor greenhouse instabilities caused by an increase in the carbon dioxide concentration or an increase in the solar constant, renders more urgent the need of a sufficiently sophisticated cloud prediction parameterization. Special emphasis will be placed on the development of such a scheme taking full advantage of satellite data from both the visible and infrared channels in order to establish empirical relationships between cloudiness and the large-scale distribution of key parameters such as relative humidity.

A high resolution (250 km) version of the new coupled ocean/atmosphere global general circulation model will be applied to a seasonal experiment with special emphasis to be given to computationally accelerating the spin-up of the deep ocean circulation.

The new 40-level general circulation model extending into the mesosphere (80 km) will be employed in its low resolution version for preliminary tests of the feasibility of dynamically coupled ozone photochemistry.

In order to deal with predictive periods beyond several weeks, a global forecast model that reacts with the upper layers of the ocean will be developed. This will take into account the effects of salinity and vertical diffusion in determining the structure within the oceanic mixed layer and resulting sea surface temperature. This model ultimately will also have new parameterizations of the planetary boundary layer and of cumulus convection selected from several alternative methods that have been under comparative test.

A global spectral model complete with the parameterizations necessary for extended prediction will be completed together with a four-dimensional assimilation capability to be applied to one or more of several existing global data sets. Comparative tests will be made with earlier grid point model results.

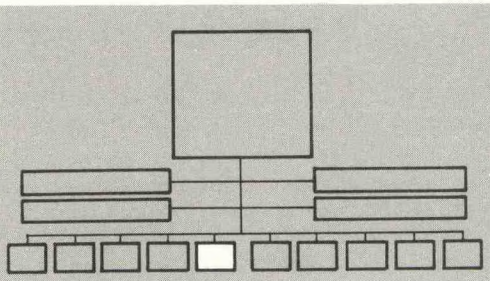
The World Ocean model will be tested with a new mixed-layer parameterization. Seasonally variable boundary conditions will be imposed since the annual cycle of the heat storage in the ocean is necessary to explain the formation of the deep water circulation.

The analysis of the 15-year global atmospheric data set from May 1958 to April 1973 will be completed. This will permit a more definitive determination of the character of interannual variability and also the mean monthly climatology of the Southern Hemisphere. An attempt will be made to relate local anomalies such as droughts to anomalies in the sea surface temperature and the snow and ice cover.

An improved version of the three-dimensional model will be applied to the study of the genesis and structure of the hurricane; for example, such characteristics as the evolution of the core structure and the spiral bands will be examined. This new model will have an improved treatment of the lateral boundary conditions to account more properly for interactions of the smaller scales within the immediate vicinity of the hurricane with the larger scale ambient circulation. Also, a new time integration scheme, which more selectively damps the high frequency noise with minimum effect on the slower moving meteorological waves, will be introduced. This model will also be capable of more properly dealing with initial adjustment of the meteorological fields.

A three-dimensional mesoscale model will be developed to study further the mechanisms of squall lines under the moist unstable conditions that may exist ahead of a frontal system. Earlier two-dimensional calculations indicated that the ageostrophic circulation transverse to a cold front is sufficient to initiate strong convection in the presence of moist instability. This convection produces a deep squall line which moves off the frontal surface because of the wind shear. Predictability studies will be performed with realistic initial conditions.

A newly developed planetary boundary layer parameterization, which was successfully tested against "Wangara" boundary layer data, will be adapted in a high resolution form for application to GATE data and for a parameterization in an urban basin mesoscale model. It will also be employed for the study of seasonal variability in the oceanic mixed layer.



ATMOSPHERIC PHYSICS AND CHEMISTRY LABORATORY

Boulder, Colorado
Dr. Helmut Weickmann, Director

The Atmospheric Physics and Chemistry Laboratory conducts a program of basic and applied research in cloud and precipitation physics, in secular changes of the chemical and particulate composition of the atmosphere, in atmospheric electricity, and in radiation and atmospheric heat transfer. The focal point of theoretical and experimental efforts is the problem of weather modification, with particular emphasis directed toward assessing the potential for mitigating the severe weather that attends extratropical weather systems. Laboratory programs include:

Program Research Investigating the Mitigation of Extratropical Storms (PRIMES)
Nucleation Chemistry
Atmospheric Electricity
Thermal Modification

PROGRAM RESEARCH INVESTIGATING THE MITIGATION OF EXTRATROPICAL STORMS (PRIMES)

The objective of PRIMES is to determine the feasibility of suppressing or mitigating, through modification techniques introduced at mesoscales, the severe weather attending extratropical weather systems. The development of numerical mesoscale models is essential to the attainment of this objective.

Accomplishments FY 1975

During FY75, a mesoscale numerical model was developed that predicts air flow over complex terrain. This model was combined with another to produce a model MESOSNOW that predicts natural and artificial snowfall by simulating cold cloud microphysical processes. A special technique for parameterization of organized mid-latitude convection was also formulated.

Diagnostic studies are also important to the attainment of the overall PRIMES objective. They support the numerical modeling effort, increase understanding of the severe storm environment and its evolution, and identify interactions between synoptic-meso-convective scales within extratropical weather systems.

Diagnostic studies in FY75 brought new insights into the interaction between mesoscale and synoptic scale systems during severe tornado events. Studies of the severe nocturnal Atlantic thunderstorms ("supernova storms") discovered during the GATE field phase showed their diurnal variation and showed also that tropical storm "Alma" originated from a cluster of six supernova storms.

PROGRAM RESEARCH INVESTIGATING THE MITIGATION OF EXTRATROPICAL STORMS

Plans FY 1976

The convective parameterization technique will be numerically tested in Model Z, a moist, 15-level Z-system, primitive equation, mesoscale model. The theoretical initial conditions previously formulated will be used. After this, sensitivity studies will be performed with Model Z to define the type of atmospheric conditions and the modification approach most likely to produce a significant effect on the mesoscale. These sensitivity studies should also yield some indication of the magnitude of modification forcing necessary to achieve a significant effect.

Further development and refinement of model MESOSNOW is planned for FY 76. Computationally stable flow fields will be generated, and several case studies will be run to validate the model. Another topographical package consisting of the terrain lying generally within 100 miles of Denver will be prepared for insertion into MESOSNOW as a prelude to an attempt to evaluate the capability of MESOSNOW to predict local snowfall distributions in the area surrounding Denver.

The development of a microphysical sub-model to simulate stable warm-cloud precipitation will also be initiated. Plans are to continue diagnostic studies to determine interactions between synoptic-meso-convective scales of motion during severe weather episodes. Emphasis will be on (1) determining the roles of horizontal temperature advection, vertical motion, and radiative processes in producing the severe convective storm sounding, (2) understanding how severe convection modifies its immediate environment, and (3) defining the important processes leading to mesocyclogenesis.

NUCLEATION CHEMISTRY

This program area encompasses several scientific fields of current interest: cloud and precipitation mechanism, air pollution, inadvertent (and intentional) weather modification, and finally, climate modification.

The following individual tasks address these broad concerns: (1) establishing source-sink relationships and spatial distribution of atmospheric nuclei; (2) developing criteria by which man-made nuclei can be distinguished from those contributed by nature; (3) improving the understanding of the mechanisms by which water vapor is converted into drops and ice crystals; (4) developing cloud seeding techniques to optimize and economize weather modification attempts; (5) determining the relationship between cloud and ice nucleus concentration on one side and the climatic distribution of precipitation on the other.

Accomplishments FY 1975

The use of a scanning electron microscope acquired in FY75, combined with an energy dispersive X-ray analyzer, increased our understanding of the chemical structure of individual aerosol particles. Studies dealt with both natural and man-made particles, including particles of the Harmattan haze during GATE. Detailed analyses of artificial ice nuclei from the Research Flight Center (RFC) generator and pyrotechnic sources were also performed. A new perspective into the mixed particle character of atmospheric aerosol has been obtained, and analyses of the individual nuclei

of snow crystals have been initiated. Reimbursable funding has been obtained for studies of (1) the Denver "brown cloud" (jointly with WPL), (2) ground truth conditions during Skylab overflights, (3) background aerosol in Montana, and (4) aerosol contaminated by the Four-Corners Power Plant.

Plans FY 1976

Existing techniques will be improved and applied to atmospheric nucleus inventories on the local, regional, and global scale. Nucleus inventories made prior to, during, and after cloud seeding experiments (e.g., for PRIMES and STORMFURY), will permit evaluation of the efficiency of artificial nucleus generating techniques, their efficiency in cloud glaciation, atmospheric residence times, and sedimentation rates. In a joint project with WPL's Atmospheric Spectroscopy Program the Boulder Valley aerosols will be investigated with regard to size and chemical composition, and their climatic impact will be evaluated. Aerosols collected during GATE will be analyzed for climatic impact evaluations of the Sahara dust cloud. The efficiency of air pollutant scavenging of ice crystals will be investigated and the feasibility of artificial "snow out" of pollutants explored. In a 5-year program funded by EPA, the Nucleation Chemistry Group will continue investigating the impact on weather and climate of the western coal and power development programs.

ATMOSPHERIC ELECTRICITY

Accomplishments FY 1975

The main projects of atmospheric electric research are lightning suppression by chaff seeding and short-time and short-range lightning warning.

The first is an in-house project, aimed specifically at suppression of cloud-to-ground discharges. In field experiments in the summer of 1974, chaff seeding was carried out inside clouds instead of below clouds as in 1972 and 1973. The physical and statistical "post-hoc" analysis of these field experiments in lightning suppression gave the interesting result that in storms seeded with chaff the lightning frequency was dramatically lower than in nonseeded control storms. Several new instruments were developed for the field experiments.

A corona detector to measure, remotely, corona discharge on the chaff fiber.

An optical lightning detector, to record lightning discharges.

An electrical lightning detector which records the electric field of lightning discharges in the range of 2 to 200 Hz.

A frequency analyzer, which automatically performs a Fourier analysis of the electric field of each lightning discharge.

Lightning warning research was carried out at the Kennedy Space Center during June and July 1975 in the joint project of NASA-KSC and NOAA-APCL to provide Kennedy Space Center with a measuring system to assess the lightning danger during rocket

launch. All of the data and results were analyzed and used to modify existing rules pertaining to atmospheric electric hazards for manned spacecraft launch. This modification resulted in less restrictive and more quantitative guidelines. Laboratory personnel advised NASA during the Apollo-Soyuz launch concerning the electrical strength of clouds, and assessed the dangers of triggered lightning, using real-time aircraft measurements and predictions based on the ground field mapping information.

The Atmospheric Electric Five-Year Measurement Program at the South Pole is now in its third year. The long-awaited opening of the new South Pole Station became a reality during the 1974-75 austral summer and the atmospheric electric surface instruments were moved to the new "clean-air" facility just upwind from the new station. This benchmark station at the South Pole will collect and maintain a data base of atmospheric electric parameters in unpolluted air and also investigate those processes that may control or influence the "global circuit" (a term used to describe the flow of electrical current between the Earth and the ionosphere which, according to the most widely accepted hypothesis, is maintained by the ever present global thunderstorm activity).

Plans FY 1976

A thunderstorm research program to obtain simultaneous measurements of important basic electrical and meteorological parameters in Florida convective clouds has been proposed by this Laboratory.

It is envisaged that the program will be a joint enterprise between government agencies and universities, each providing its own funding and using its own instrumentation under the direction of NOAA/ERL/APCL. Kennedy Space Center has been proposed as the location for the field tests because of its unique electric field mapping system and valuable meteorological support. If this concept evolves into a viable program most of FY 1976 will be occupied with preparations for a field effort in June and July 1976.

The Atmospheric Electric Program at the South Pole, which is partly supported by the National Science Foundation, will be continued at a reduced level during FY 1976 because of funding reductions.

THERMAL MODIFICATION

This program applies infrared and shortwave remote sensing observations and computer analyses to research in cloud physics, atmospheric phenomena, and weather modification studies.

Accomplishments FY 1975

During FY 75, interest centered on the refinement of a method to measure, with an aircraft-borne IR radiometer, the humidity at upper levels to study the feasibility of generating artificial cirrus. During flights on board the NASA C-141, the sensitivity of the method for use as a clear air turbulence (CAT) predictor was observed. This application is now under active investigation and could be an extremely important by-product.

A 2-layer model for ice thickness as a function of the IR line scanning ice temperature imagery, net radiation, and surface convective transport was developed and reported as a NOAA Technical Report. Results indicate that thicknesses up to 200 cm can be determined with 6 to 20% accuracy.

Summaries of one year's observations of upper tropospheric and stratospheric water vapor burdens indicated a steady increase in the relative humidity with respect to ice above background as one approaches a cirrus area. The increase began 100 km ahead of the cirrus clouds, which were subsequently encountered at 175 mb.

An IR remote water vapor burden sensing system was completed and is considered operational for aircraft.

A GATE radiation research project on the longwave radiation effects of the African Harmattan haze was completed. This resulted in the determination of a bulk total extinction coefficient amenable to inclusion in radiative transfer models with consequent improvement in the accuracy of such calculations.

Conclusions reached with the Nucleation Chemistry group, in a SKYLAB satellite-aircraft joint experiment, provided estimates of infrared and visible total absorption coefficients for modeling radiative transfer.

An analysis of latitudinal profiles of stratospheric water vapor burden was completed.

THERMAL MODIFICATION

Plans FY 1976

Plans for FY76 are:

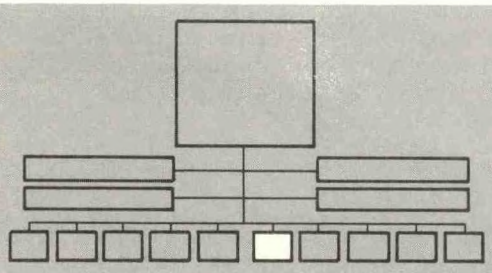
To conduct observations of stratospheric in situ water vapor and water vapor burden related to weather modification programs such as PRIMES, STORMFURY, and SESAME.

To make observations of radiance in the water vapor spectral band as a detection and prediction technique for CAT.

To apply IR and UV scanning radiometry to determine areal cloud top temperatures, surface thermal hot spots, and oil slick quantization.

To determine the capability of IR fixed field and scanning (imaging) techniques to assess the potential for cloud dissipation relative to Beaufort Sea stratocumulus and stratus clouds.

To continue analyses of the GATE radiometric data including (1) IR brightness temperature of the sea as a function of pressure, altitude, and spectral frequency, (2) radiometersonde profile analyses, and (3) analyses of water vapor burden and in situ water vapor IR observations.



NATIONAL SEVERE STORMS LABORATORY

Norman, Oklahoma
Dr. Edwin Kessler, Director

Research at the National Severe Storms Laboratory emphasizes comprehensive description and explanation of severe storm characteristics for a fundamental understanding, leading to improved warnings and forecasts. Extensive facilities for mesoscale meteorological observations are developed and managed. Data obtained on spring storms, and research activities throughout the year, aim to unite theoretical principles with observations. Topics studied include severe storm circulation and dynamics, development of weather radar including Doppler radars, flight safety in thunderstorm areas, and tornado detection and warning.

METEOROLOGICAL RESEARCH

This program emphasizes the development of a comprehensive description and explanation of severe storm characteristics, with the objective of improved understanding and forecasting. Observational, experimental, and theoretical data are merged in realistic conceptual, numerical, and laboratory models.

Accomplishments FY 1975

Fiscal Year 1975 saw maturation of dual-Doppler sensing systems earlier installed, documentation of effort that originated in collection of Doppler radar data during FY-74, detection of tornado cyclones and of tornadoes themselves by Doppler radar, and significant new insights into the life cycle of tornadoes and their place in the larger systems that spawn them. Photogrammetric determination of tornado wind speeds in several cases from high quality motion picture film provided apparently reliable estimates of tornado wind speed ($\sim$175-225 mph) in a number of documented cases. Comparable deductions were obtained from analyses of damage to structurally engineered buildings funded by a grant to Disaster Research Center, Texas Technological University, Lubbock, Texas.

Analysis of first dual-Doppler data from a tornadic storm (20 April 1974) confirmed that previously observed single-Doppler mesoscale vortex signatures represent a closed circulation of about 10 km diameter. The "hook-echo," when present, occurs around the circulation's periphery.

A new single-Doppler velocity signature consisting of extreme localized shear over a distance of about 1 km appears to identify the tornado itself. The signature was first observed in real time during the Stillwater (Okla.) tornadic storm on 13 June 1975.

A mesoscale vortex signature was also found to be recognizable in real time by single-Doppler radar. At no time during Doppler data collection did a verified tornado occur unless preceded by a mesoscale vortex signature. The average lead time before tornado occurrence was 34 minutes.

Estimates of rainfall and its spatial variability were improved by combined use of radar and raingage data.

As an extension of the AMS Monograph on continuity of water substance, working relationships among buoyancy, static stability, moisture content, mixing rate, micro-physical parameters, and vertical air motions were examined. Additionally, the density of cloud and precipitation was related by means of simple approximations to the slope, vertical air speed, and diameter of moist updraft columns, and to the fallspeed and residence time of cloud and precipitation particles. The participation of the University of Wyoming's instrumented van in NSSL's Tornado Intercept Project represented a first attempt to add data sensors to the collection procedures.

Storm penetration data from the Air Force/FAA/NSSL cooperative program are being combined with Doppler radar measurements to determine associations between velocity gradients and spectrum widths, and the occurrence of moderate or severe turbulence. Dual-Doppler observations are utilized to examine possible viewing angle dependence of turbulence detection.

NSSL scientists, participating in Florida Keys waterspout studies, documented life-cycle characteristics and scale interaction implications.

METEOROLOGICAL RESEARCH

Plans FY 1976

Theoretical, numerical, and observational studies of severe storm and tornado dynamics are expected to reveal additional knowledge on evolution and intensity of windstorms, the pre-tornado environment, and early detection of tornadic signatures.

A multi-dimensional boundary layer model using a higher-order turbulence closure scheme is under development. Turbulent kinetic energy budget measurements at the base of nocturnal inversions capping convective layers will be used further to develop parameterizations of mixing processes, to be incorporated into a model of the non-steady inversion.

There will be contined waterspout penetration work, involving the Colorado State T-28 aircraft and the newly developed WPL ground-based Doppler lidar. Cooperative efforts with ERDA, FAA, NASA, NSF, NWS, the University community, and other ERL Laboratories are expected to increase.

ADVANCED TECHNIQUES

Project objectives include observational technique development to advance understanding of severe storm morphology; and systems development for weather data acquisition, processing, and display techniques.

Accomplishments FY 1975

Dual-Doppler radar data were processed and synthesized to derive vector winds in a three-dimensional Cartesian grid. Vertical wind in excess of 25 m s^{-1} was deduced from the Doppler data.

An alpha-numeric graphic terminal at the NRO Doppler site has been programmed to display the three most significant Doppler moments for each gate, i.e., reflectivity, mean Doppler velocity, and spectrum width in each pulse volume, and portrays regions of laminar and turbulent flow.

A comprehensive comparison of five estimators of mean Doppler frequency has used Doppler spectra simulated by computer. The comparison shows both advantages and limitations of pulse pair processing weather signals' complex auto-variance function to obtain Doppler spectral moments.

Weather target direction errors and loss in resolution due to time constants of weather radar echo integrators have been predicted and experimentally verified.

The number of statistically independent data from weather radars sampling signals in time, range, and angle were related to receiver type, providing a more accurate basis for estimating reflectivity variance.

Dual polarization techniques were studied as a step toward reducing range and velocity ambiguities.

Studies defining the physical basis of electromagnetic scattering continued. These will ultimately make possible better qualitative interpretation of scattered electromagnetic signals.

Antenna sidelobe effects on weather Doppler radar data were investigated, and evidence found that sidelobes contribute to increased spectrum variance.

ADVANCED TECHNIQUES

Plans FY 1976

Extended pulse pair processors and digital integrators will be operational at both Doppler sites. This increased data handling capability will reduce time required to collect samples within a severe convective cell and increase the sampling density. The validity of stationarity assumptions will be improved and resolution of small scale features such as tornado cyclones will be enhanced.

The operational on-line mini-computer at the CMF Doppler radar site will become part of a telecommunication link providing real time dual-Doppler velocity fields and remote control of data acquisition.

High-PRF (Pulse Repetition Frequency) data will be collected when tornadoes are suspected or confirmed within PRF range. These data are required to resolve the fast speeds associated with tornadoes, and to test procedures for estimating peak wind velocities within the radar pulse volume.

NSSL's Doppler radars, and the University of Chicago/University of Illinois (CHILL) radar, will form a three-Doppler network for spring operations. Surface and upper-air stations will support this effort.

SEVERE THUNDERSTORM DETECTION AND IDENTIFICATION

The program objective is to improve techniques to detect, identify, and track hazardous weather events associated with severe thunderstorms. Detailed observations of hailfall, high rainfall rate, and strong winds on a scale commensurate with individual thunderstorms are related to scale, motion, and intensity of associated radar echoes.

Accomplishments FY 1975

During FY 75, emphasis was given to the development of calibration and quality control routines for rapid evaluation of Doppler and conventional radar measurements.

In cooperation with the Federal Aviation Administration, a unique radar data remote display system was developed and evaluated. Contour-mapped intensity fields, of quality similar to radar console, are transmitted over voice-grade telephone lines, once each 100 seconds.

A joint project with the Wave Propagation Laboratory (Boulder) explored the application of optical anemometry for direct measurement of boundary layer convergence. A special 17-station instrumented network provided comparison of wind measurement methods.

SEVERE THUNDERSTORM DETECTION AND IDENTIFICATION

Plans FY 1976

Network support for the three Doppler radars will be extended to a 32-station meso-network within the three-Doppler area. Thirteen subsynoptic stations, and nine rawinsonde sites will provide three-dimensional depiction of the environment for storms before, during, and after three-Doppler interrogation. The network plan is pre-SESAME (Severe Environmental Storms And Meteorological Experiment) oriented.

Methods to provide subsynoptic and mesoscale meteorological fields for real time analysis with radar data will be studied.

Cooperative efforts with other ERL Laboratories will continue to explore new probes for severe storm surveillance.

SUPPORT

NSSL programs are supported by Computer and Data Processing (CDP). CDP develops and operates NSSL computer systems, archives and distributes processed data, evaluates computer capability related to need, and advises management concerning requirements.

Accomplishments FY 1975

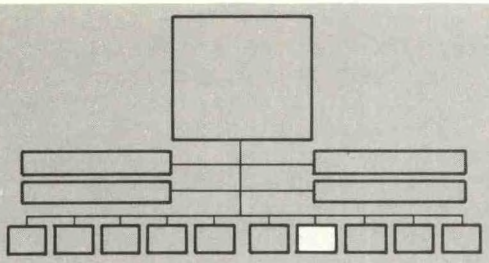
A two-day symposium on NSSL data and their applications was held at NSSL with support from NSF's Atmospheric Sciences Section. NSSL's Doppler radar data were emphasized.

Data collected and processed at the National Severe Storms Laboratory are being used in basic studies and in University course work. Thirty-four organizations received NSSL data and/or computer programs during the past year.

SUPPORT

Plans FY 1976

Growth in computer memory and peripheral capability will support increased requirements associated with multi-Doppler radars and supportive data acquisition.



WAVE PROPAGATION LABORATORY

Boulder, Colorado
Dr. C. Gordon Little, Director

The Wave Propagation Laboratory (WPL) was created to serve as focal point within NOAA for the development, and research application, of new methods for the remote measurement of geophysical parameters.

Remote sensing is achieved through the interpretation of observations of some form of wave interaction with geophysical media. The wave may be an electromagnetic wave (typically at optical, infrared, or radio frequencies), or an acoustic or gravity wave. Each kind of wave may be used passively (i.e., through studies of the emission, absorption, or propagation of waves of natural origin) or actively (in which the propagation of man-made waves is studied). From the point of view of remote sensing, passive and active systems of each kind of wave have their own unique sets of advantages; the Laboratory seeks to understand and exploit these advantages, and therefore includes an exceptional range of activities covering passive and active studies of radiowaves, optical waves, and acoustic gravity waves.

Throughout FY 1975, WPL operated with seven program areas, six devoted to remote sensing of the atmosphere and the seventh to radio oceanography. The accomplishment highlights that follow, by program, show that the field of remote sensing of geophysical media is a rapidly expanding one, already providing much richer data sets than have ever been available in the past.

Of particular importance in FY 1975 was ERL and NCAR acceptance of the WPL-initiated plan that ERL and NCAR join together in the creation of a Joint Meteorological Observing Facility, to be located some 25 km east of Boulder. This joint facility is to be fully instrumented with remote-sensing and in-situ instrumentation (including a tall meteorological tower) and will be used as a major atmospheric field site for the development of meteorological instrumentation, and for the conduct of atmospheric research of many types.

OPTICAL PROPAGATION

The objective of this program is to develop techniques for the remote measurement of wind, precipitation, and atmospheric temperature inhomogeneity, based on optical and infrared intensity variations measured on line-of-sight paths.

Accomplishments FY 1975

Earlier work by this group has shown that the average wind speed across an optical line of sight can be derived from measurements of the optical diffraction patterns produced by the atmospheric turbulence. During FY 75, this work was extended in several directions. A new version of the single-beam wind sensor

uses a conventional incandescent light source instead of a laser and is designed to be unaffected by saturation of the scintillations (which, in strong turbulence or over long paths, adversely affected the earlier versions). The need for an artificial light source at the far end of the path was eliminated by using the illumination of a natural scene, and resulted in a new, passive optical sensor of average crosswind. A new method of measuring the distribution of crosswind along the optical path (rather than only its average value) was successfully developed; it is based on two lines of sight intersecting at very small angles of a variable position along the path. The theory of measuring height profiles of transverse wind and the intensity of the scintillation-causing irregularities was also published.

The above work all relates to scintillations in clear air. Theoretical and preliminary experimental studies of optical scintillations produced by rain indicate that path-averaged rainfall rate and path averaged drop-size distributions can be measured using vertically spaced measurements of the scintillation patterns.

Plans FY 1976

Our theory of rain measurement by use of optical scintillations will be applied to measurements of rainstorms in Colorado. Development and testing of theories of rain and wind measurement will continue. As an application of the theory for remote sensing of wind by optical means, a prototype wind profiler that will permit remote measurement of wind at places inaccessible to direct measurement (as above a canyon or lake) will be constructed and tested. The new saturation-resistant crosswind sensor will be used in an attempt to measure average low-level convergence associated with convective activity over a 6-km triangle.

At the request of the National Weather Service, a research instrument has been designed and built for experimentation with automatic optical identification of hydrometeors and other obstructions to visibility. This instrument will be delivered to the NWS test station at Sterling, Virginia, by November 1975.

An instrument developed and built at the request of USAF and ARPA will be used at the ARPA observatory on Mt. Haleakala, Hawaii, to observe star scintillations, and to determine the refractive-index turbulence continuously at various levels in the upper atmosphere. With this information, the USAF will be able to determine how much of the degradation of astronomical images taken through the ARPA 60-inch telescope is due to atmospheric conditions and how much can be attributed to inadequacies in the image-restoration scheme being used.

ATMOSPHERIC SPECTROSCOPY

The objective of the program is to develop laser and other optical techniques for remote geophysical sensing, and to apply them in cooperation with other remote and in-situ techniques to atmospheric science problems relevant to NOAA's monitoring, forecasting, and warning services and weather modification studies.

Accomplishments FY 1975

The program has developed an infrared Doppler lidar system that measures remotely the wind component along the line of sight, using small, naturally occurring aerosols as scattering centers for the infrared and thus as flow markers. The system has been tested and shown capable of remote measurement of vortex velocity in dust devils.

Valuable information on cloud and precipitation processes has been obtained with the lidar facility, a complete remote sensing system consisting of multiple-wavelength laser transmitters and receivers with polarization-sensitive detectors, a microwave radar, an infrared radiometer, and an acoustic sounder. Transition rates of ice forming in water clouds, leading to snowfall, have been determined from observations of clouds at Fraser, Colorado.

The lidar equipment was used, in cooperation with APCL, to monitor aerosols of the Boulder Valley for study of their role in climatic change. For the EPA and for the National Science Foundation, data on air pollution levels and insolation were gathered at Colstrip, Montana, to establish baseline conditions prior to power plant operations expected in October 1975.

Theoretical calculations of drop-size distributions and laboratory tests of mathematical inversion methods gave results that will be used in aerosol and cloud particle-size determination in the field.

ATMOSPHERIC SPECTROSCOPY

Plans FY 1976

The existing infrared Doppler lidar will be used in the measurement of one- and two-dimensional wind and turbulence profiles, to assess its applicability to boundary layer research. The feasibility of using the Doppler lidar system to measure winds transverse to the axis of the system will be explored, and an FM/CW technique for the measurement of aerosol profiles will be investigated. For the Nuclear Regulatory Commission, the Doppler lidar will be used to study waterspout and land/sea breeze in the Florida Keys, to determine potential dangers from pollution by proposed offshore nuclear power plants.

For the EPA Colstrip studies, follow-up measurement for characteristic periods will be made for the next two years to provide information on the effects of the power plants on air pollution. Analysis of solar flux data will determine for the National Science Foundation the feasibility of measuring the effects of hydrometeors and lithometeors on solar flux.

The lidar system, supplemented by radiometers (IR and microwave) and by spectroscopy heliometers, will be used to make simultaneous measurements of emission, backscatter, and extinction measurements of clouds. The data will be used to determine the radiation properties of clouds, of importance in climate studies.

A 5-year program for optical characterization of aerosols will begin, funded by EPA pass-through money, with the goal of identifying pollutants remotely by their scattering effects, and determining their locations and concentrations. The program will start with ground-based and aircraft sampling.

ENVIRONMENTAL RADIOMETRY

The program's objective is to develop passive radiometric techniques for use in meteorological remote sensing, including remote sensing of tornadic storms.

Accomplishments FY 1975

A two-wavelength, passive microwave technique for the simultaneous measurement of atmospheric water vapor and cloud liquid content was demonstrated.

Methods were developed for inferring layer-averaged temperature profiles from radiometric data, and for correcting for the effects of non-precipitating clouds. A theoretical study showed that, when temperature profiles are retrieved from angular scan radiometric data, the horizontal spatial variations of temperature are usually too small to affect the measurement, but temporal variations may be significant.

A generalized inversion program was produced for retrieving information from the integral equations so often encountered in remotely sensed geophysical measurements.

Both the omnidirectional and the sector-directional tornadic storm detectors were modified to incorporate further improvements; 4 omnidirectional and 14 sector-directional detectors were reactivated at National Weather Service stations to obtain additional semi-operational experience.

Studies of lightning processes, partly funded by NASA, produced circuitry for an azimuth-elevation display of vhf electromagnetic signals from intracloud lightning discharges, with accuracy in both azimuth and elevation of one degree.

ENVIRONMENTAL RADIOMETRY

Plans FY 1976

Evaluation of methods of measuring atmospheric water vapor and liquid will continue, including comparison with lidar data. A liquid-sensing radiometer will be acquired for installation on the NOAA P-3 aircraft.

Techniques for inferring layer-averaged temperature profiles will be applied to clear and cloudy model atmospheres over the ocean to establish expected accuracies for ocean data buoy application. A joint WPL/Jet Propulsion Laboratory field experiment will test these technqiues under cloudy conditions.

Field tests of the tornadic storm detectors will continue through the 1975 season and on a very limited basis in 1976. The analysis of 1974 and 1975 data will be completed.

The lightning direction-of-arrival display system will be tested in the field and supplemented with a vlf system for real-time tracking of thunderstorms.

Already completed calculations and studies will be used in a preliminary analysis for NASA of methods of measuring rain with multi-frequency satellite radar.

METEOROLOGICAL RADAR

The program's objective is to develop radar techniques for measuring the structure of the atmosphere and to apply them in ways that increase our knowledge of atmospheric processes, to improve the forecasting of mesoscale atmospheric events.

Accomplishments FY 1975

A breakthrough in meteorological radar has been achieved with the addition, for the first time, of a Doppler wind sensing capability to the clear-air FM/CW radar. This gives the ability to expand the wind measuring capabilities of microwave radar from regions of precipitation into clear air, and for the first time offers possibilities of an all-weather wind and turbulence measuring system.

The FM/CW radar was also used successfully to sense stratification of the atmosphere that controls the concentration of air pollutants and confines them near the ground.

To exploit the capabilities of dual-Doppler radar to contribute to understanding of dynamic processes controlling local weather, a theory was developed relating wind variance as measured by a Doppler radar to the turbulent dissipation rate measured at a single point.

Dual-Doppler techniques were applied to studies of clear-air convection, and, in experiments for the Nuclear Defense Agency, were used to determine the effectiveness of precipitation in scavenging pollutants from the atmosphere.

For the first time, triple-Doppler radar data were collected in severe storms, for improved interpretation of the velocity fields observed.

METEOROLOGICAL RADAR

Plans FY 1976

The FM/CW radar with Doppler capability will be tested to determine its value for measuring wind profiles in the clear air.

Dual-Doppler data will be collected in conjunction with ongoing interagency experiments. Program area personnel will also participate in the National Science Foundation's Metropolitan Meteorological Experiment (METROMEX) and prepare for participation in SESAME in 1978.

In a continuing effort to relate chaff diffusion to velocity fields under various stability conditions, we will analyze 1974 data acquired from injection of chaff into the turbulent layer from a point source, and continue to analyze past snowstorm and NHRE data. Such investigations will improve knowledge of the microphysics of hail formation and of the way the diffusion of air pollutants is affected by thermal stability, and will aid the forecasting of small and mesoscale severe weather events.

GEOACOUSTICS RESEARCH

The program's objective is to improve atmospheric pressure-measurement techniques and apply them to study and monitor severe weather and atmospheric waves and turbulence; to develop physical models of the planetary boundary layer and of turbulence and wave dynamics in the atmosphere.

Accomplishments FY 1975

A study was initiated on the role of atmospheric gravity waves in modulating or triggering severe convective storms, involving a large-scale (50 km) array of sensitive microbarographs in the vicinity of Norman, Oklahoma. Completed and submitted for publication was a theoretical analysis of the operation of the noise-reducing pipes we have used with microbarographs for detecting acoustic waves in the presence of turbulent noise. Another theoretical study established the feasibility of using microbarographs outfitted with such pipes to detect aircraft wake vortices near runways. By use of microbarograph arrays in Boulder and Fraser, Colorado, it was found by triangulation that strong airflow over the Rockies generates infrasound. We carried out a second-generation experiment to study such infrasound generation by airflow, and gravity wave generation by shear instability, over the Rocky Mountains.

We completed statistical assessment of the potential of infrasound signatures for detection/warning of severe weather, finding that two-thirds of such emissions come from storms spawning tornadoes, and that, on the average, the onset of the emissions precedes the onset of the tornadoes by an hour.

A book Waves in the Atmosphere was published that should provide a useful introduction to students and researchers entering the field. A final report to the Air Force Technical Applications Center summarized 25 years of infrasonic research under their sponsorship, which terminated at the end of FY 1975.

GEOACOUSTICS RESEARCH

Plans FY 1976

One theoretical effort will analyze the errors introduced into pressure measurements in an airflow by the presence of an in-situ sensing instrument. On the basis of the findings, a pressure probe, designed to introduce minimum error into in-situ measurements of wind flow, will be fabricated. Another theoretical effort will extend our maximum entropy spectral analysis capability to array processing, as an alternative to currently used procedures.

The near-infrasound detection system will be refined to provide greater sensitivity, better noise suppression, real-time readout, and telemetry. The large-scale gravity wave detection system will be made less sensitive to temperature changes. A gust-front detection device that was first built in the laboratory several years ago will be further developed and tested for the FAA.

Data will be gathered on acoustic emissions from the airflow over the Rockies. Data on acoustic emissions from dust devils, and data from the Oklahoma arrays will be gathered and analyzed

for analogs of the severe-storm wave emission mechanism, and for evidence of gravity wave/severe storm interaction, respectively.

Models of acoustic emissions from natural aerodynamic sources such as airflow over mountains, rotating columns (the simple idealization of a tornadic storm), auroral arcs, and wind shear will be completed and published.

The Geoacoustics research group will work with NCAR in a joint study of the development of the convective boundary layer, and will help the FAA and the Dept. of Transportation in their efforts to monitor wind shear and reduce its hazard to air traffic.

ATMOSPHERIC ACOUSTICS

The program's objective is to develop acoustic sounding techniques, in order to improve research and service capabilities in the atmospheric sciences.

Accomplishments FY 1975

The principal accomplishment was the successful installation at the South Pole of a monostatic echo-sounding system, which has operated with a minimum of down-time throughout the polar winter, giving new information on the atmospheric boundary layer at high latitudes.

A sounder to obtain measurements of temperature inversion heights for use in air pollution meteorology was installed in St. Louis as part of the Regional Air Pollution Study sponsored by EPA; nearly continuous records from February through June were evaluated and provided to EPA. Other sounders were provided to the Dept. of Interior's Forest Service and the Atomic Energy Commission, and a sounder is being constructed for the Naval Surface Weapons Center in Dahlgren, Virginia. The Weather Service Forecast Office has requested that experimental use of one of our sounders in Los Angeles continue for another year because of its value in monitoring the mixing layer depths and incipient stratus breakup in the Los Angeles basin.

In efforts to establish the feasibility of low-frequency acoustic devices, investigations with echo sounding techniques have obtained low-level echoes at both 85 Hz and 250 Hz (unusually low frequencies for echo sounding).

A multi-receiver steerable-beam antenna has been designed and tested for the Doppler wind-profiling system. Fabrication of an underground bunker to shield this antenna is complete and is undergoing operational tests.

ATMOSPHERIC ACOUSTICS

Plans FY 1976

Capabilities of the monostatic sounder at the South Pole will be expanded if Navy aircraft support is available. Bistatic operation will open the way to studying mechanical dissipation of turbulence in the atmosphere. . Digital data logging will provide quantitative storage of data for later assessment.

With FAA support, testing and deployment of Doppler windshear sensors at Dulles International Airport, in a test-operational mode, will be completed. Operational testing will continue for 9 months and, if successful, will lead to engineering specifications for similar systems.

A joint test with NCAR will use a sounder for monitoring the modification of the planetary boundary layer in early morning convection. The feasibility of a higher acoustic frequency short-range sounder for temperature-inversion formation studies will also be investigated.

Data gathered with a shipboard sounder during GATE will be analyzed to determine sensible heat flux over the tropical Atlantic. The data will also yield vertical velocity profiles in convective plumes over the ocean, and in storm outflow currents as well.

SEA STATE STUDIES

The program's objective is to develop and perfect new methods for the remote sensing (from Earth's surface or from space/air) of ocean properties.

Accomplishments FY 1975

Project Sea Echo, a joint NOAA/Navy program, has developed a theory for using radar signals reflected by the ionosphere to obtain descriptions of the sea state over large ocean areas. Techniques have been developed and tested that use surface-wave radar data for processing reflected signals to extract wave height, direction, and velocity; a skywave facility has been completed on San Clemente Island to test the method by obtaining sea-state observations of the Gulf of Alaska; software for real-time processing of the sea echoes obtained, to produce sea-state maps, has been developed. The new skywave facility has been checked out as to its antenna and transmitter characteristics; several sea-echo data tapes have been recorded and are presently being analyzed and compared with weather-ship sea-state data.

With funding from the Bureau of Land Management, the Coast Guard, and possibly ERDA, development of a portable, self-contained radar system for mapping near-surface ocean currents in coastal waters has started. Performance predictions for the system, hardware design, and most of the digital software have been completed. Construction and procurement of the individual components is about 80% completed; overall assembly of components on hand into the field system is about 35% completed.

Analysis has begun of microwave radar altimeter echo signals from the sea measured by the GEOS-III satellite. From preliminary data tapes sent from NASA, it appears that we can confidently extract sea waveheight, and possibly wave direction or period, from the signals.

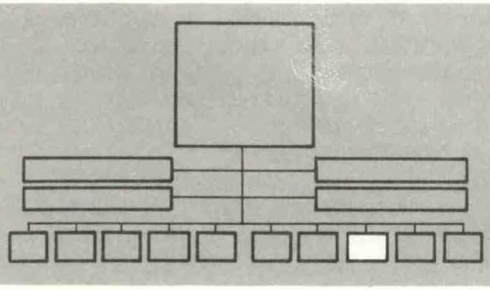
Plans FY 1976

Project Sea Echo technology will be tested in the Gulf of Alaska field experiment, to establish its capabilities and limitations for monitoring the sea state out to 3500 kilometers. The

use of the system to monitor distant storms will also be demonstrated. Techniques will be developed and tested for processing the echo satisfactorily in the presence of ionospheric distortions of the echo. When the development and the testing of these routines is completed, it will be possible to process skywave sea-echo data digitally and display them as sea-state maps within an hour after the radar observations are made.

For current mapping, construction of the first pair of radar units will be completed by March 1976. The system will first be checked out in Florida coastal waters and data compared with actual "sea-truth" data. Measurements will begin off the southeastern Alaska coastline in the summer of 1976, with the objective of obtaining predictions of the trajectories of surface-borne oil spills before oil drilling is begun.

Further GEOS-III satellite radar altimeter data forwarded from NASA will be reduced, and sea waveheights obtained therefrom will be compared with those from other sources. Techniques for extracting other sea-state parameters will be developed and tested; also methods for estimating accuracies and minimizing noise and distortions will be examined.



AIR RESOURCES LABORATORIES

Silver Spring, Maryland
Dr. Lester Machta, Director

The Air Resources Laboratories (ARL) include a headquarters group in Silver Spring, Maryland, a laboratory in Las Vegas, Nevada, the Meteorology Laboratory in Research Triangle Park, North Carolina, the Atmospheric Turbulence & Diffusion Laboratory in Oak Ridge, Tennessee, and the Field Research Office in Idaho Falls, Idaho. Almost all ARL research deals with the use of meteorology to understand and predict man's influence on his environment. General areas of study include meteorology and environmental quality, meteorology and nuclear energy, atmospheric transport, and climatology. Neither geographical areas, the layer of the atmosphere, nor the tools to conduct the research are limiting factors, although ARL does avoid duplicating the monitoring activities of other agencies. However, atmospheric monitoring plays a central role in the ARL global scale monitoring for climatic change (GMCC).

ARL research, in general, is geared to user needs, and more often than not the user is another government mission-oriented agency. Funding and guidance derive from this association. In some cases, the ARL unit under contract to another agency acts as its meteorological arm providing virtually all of the meteorological guidance it requires. This close working relationship with users insures that research conducted by ARL is relevant to real world problems.

The scope of research and other activities encompasses the study of pollutants from the time of their emission (from stacks, venting of underground atomic tests, automobile exhausts, etc.) through their transport (on all scales up to the global) and their transformation and/or removal from the atmosphere. For example, the buoyant rise of a plume from a chimney might begin the study; transport through irregular terrain would constitute the atmospheric movement to be studied, and dry or precipitating deposition would represent the loss to the air to be studied.

METEOROLOGY AND ENVIRONMENTAL QUALITY

Accomplishments FY 1975

Geophysical Monitoring for Climatic Change (GMCC)

The global nature of atmospheric contaminants such as CO_2 and particulate matter, resulting from industrialization, a burgeoning population, and accelerated urbanization, is a generally accepted reality. The absence of quantitative data on the problem has led to a variety of opinions by the public and even the scientific community, ranging from dismissal of the problem "since Nature will take care of it as it has always done in the past," to spectacular predictions of imminent melting of the polar caps due to

atmospheric warming from a "CO_2 greenhouse effect," or of the other extreme, creation of a new ice age due to the shadowing of solar radiation by particulate matter. It is the purpose of the geophysical monitoring program to provide the quantitative data that are required for predictions of climatic changes. These consist of (a) dependable measurements of presently existing amounts of natural and man-made contaminants in the atmosphere, (b) determination of the rates of increase of these amounts, and (c) measurements of the atmospheric properties that are affected by these contaminants.

NOAA, working with U.S. agencies, universities, and other groups, and in close cooperation with the World Meteorological Organization's plans for global monitoring, is conducting measurement programs at four base-line stations: Mauna Loa, Hawaii; Point Barrow, Alaska; American Samoa (all three with complete observatory facilities); and at the South Pole. A major goal was reached in November 1975 with the completion of an observatory in Samoa. Now even more of the GMCC effort will be focused on the scientific goals of quality data and its interpretation.

Data analyzed from the observatories in 1974 and, where available, for previous years have included ozone, both surface concentrations and total amounts, carbon dioxide, chlorofluorocarbons, and aerosols. Expecially interesting are the 1974 carbon dioxide data. They show that the 1973-74 increase in annual concentration is the smallest of the decade. It remains to be determined from future data if the small 1973-74 increase was a statistical anomaly or was due to physical changes.

Monitoring of the stratospheric aerosol layer with the lidar system at Mauna Loa has shown that the eruption of Fuego volcano in Guatemala added major amounts of material to the stratosphere.

From tropospheric measurements of fluorocarbon 11 and 12 (F-11 and -12) as well as carbon tetrachloride (CCl_4), it has been tentatively concluded that F-11 and probably F-12, have increased since 1970; that virtually all F-11 added to the atmosphere remains; that the atmospheric growth rate of F-11 increased in 1973 and 1974; and that the Northern Hemisphere troposphere possesses uniform concentrations of fluorocarbons and CCl_4 to the first approximation.

Meteorology of Air Pollution

Meteorology Laboratory (ML) support and services to the Environmental Protection Agency (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; studies of the effects of air pollutants on weather and climate; the preparation of air pollution climatologies; and studies to define the relationships between air quality and meteorological parameters.

ML provides direct operational meteorological support to EPA offices and activities in their abatement and compliance efforts including the provision of technical advice, the application of air quality simulation models, the evaluation of the meteorological portions of state implementation plans and environmental impact statements , the provision of expert testimony, the provision of emergency field services, and the preparation of technical staff reports and documents.

Research accomplishments in FY 75 concerned the effects of pollutants on radiation, air pollution climatology, and air quality simulation modeling.

Analyses of solar radiation measurements, taken in the fall of 1973 in conjunction with the Los Angeles Reactive Pollutant Project (LARPP), indicate that the average depletion of ultraviolet radiation due to attenuation solely by smog was 13.4%, considerably larger than the average depletion at visible wavelengths.

In air pollution climatology studies, the "urban plume" has been identified at distances of 55 km, by means of its effect on temperature and moisture. Studies of plume heights have been started.

An analysis of continuous hourly average CO concentrations at 12 urban stations in Maryland indicates that mixing height and wind speed, along with traffic count data, probably affect the diurnal variations in urban CO concentrations.

Providing technical assistance, ML applied dispersion models to a wide variety of pollution sources to determine their impact on air quality and to evaluate appropriate control tactics. The sources included smelters, power plants, and numerous types of industry.

Air quality data analyses considered the impact of meteorology conditions on non-urban oxidant concentrations and on long-range transport of oxidants and their precursors from cities in the Midwest and over the Los Angeles Basin; the impact of the 1973-74 energy crises on pollutant concentrations in New York City and Boston; and air quality trends for the period 1970-74. Approximately 30 environmental impact statements were reviewed for energy and transportation systems.

Other technical assistance has included participation in studies of particulate sulfate concentrations, monitoring for chlorine hydrocarbons downwind of an incinerator ship in the Gulf of Mexico, development of a daily mortality model for air pollution districts in the U.S., and support to New York and Los Angeles Community Health Surveillance Systems (CHESS) studies.

Atmospheric Turbulence and Diffusion

The Atmospheric Turbulence and Diffusion Laboratory (ATDL) in Oak Ridge, Tennessee, operated for the Energy Research and Development Administration (ERDA), works closely with various divisions of Holifield (Oak Ridge) National Laboratory (HNL) on environmental projects of joint interest, and also functions as a meteorological consultant and advisor to that laboratory.

ATDL completed a major field program in air transport studies, the Eastern Trajectory Experiment, during the year. Its main purpose was to determine the mesoscale wind field and typical air parcel trajectories over the eastern Tennessee Valley.

Research on atmospheric pollution included estimates of the meteorological effects of large power parks, development of a simple photochemical smog model, and comparative evaluations of several urban air pollution models.

Work on plume behavior encompassed theoretical study of dense plumes, calculation of over-water effluent concentrations, comparison of several dry deposition models, and experiments on the lift-off of a buoyant plume initially trapped in the wake of an obstacle.

Forest meteorological studies were devoted to analysis of solar radiation data obtained within a deciduous forest, analysis of wind and temperature data taken within a pine plantation, and limited smoke diffusion experiments. Instrumentation of a new forest site was begun.

Environmental Analyses

In compliance with the National Environmental Policy Act of 1969, ARL has the responsibility to review for the Department of Commerce the atmospheric pollution aspects of environmental impact statements issued by the government for facilities under their jurisdiction and control. During FY-75 54 such reviews were completed.

Climatic Impact Assessment Program

ARL completed that portion of the Climatic Impact Assessment Program of the Department of Transportation involving the monitoring of ultraviolet radiation at two National Weather Service stations, Bismarck, ND, and Tallahassee, FL. Relationships of the erythemal ultraviolet radiation (UVB) to various meteorological parameters were developed and compared with current theory; in particular, the effects of a reduction in the protective ozone layer in increasing the amount of potentially harmful ultraviolet radiation reaching the Earth were determined.

The theoretical/empirical relationships established may be applied to readily available meteorological elements in order to derive climatologies of UVB at any location with a high degree of confidence in most cases.

METEOROLOGY AND ENVIRONMENTAL QUALITY

Plans FY 1976

Atmospheric electricity measurements will be initiated at Mauna Loa Observatory to indicate changes in the atmospheric aerosol burden. This program will be rotated among the four GMCC stations.

Additional analyses of the LARPP radiation data will be made to establish the effects of Los Angeles smog on the transfer of solar radiation. Theoretical calculations of actinic irradiance (pertinent to photochemical smog reactions) will be based on radiative transfer theory, using an available computer program.

Analyses of the CO data with respect to pollutant emission and meteorological data will be expanded to include data being collected in the Regional Air Pollution Study at St. Louis. Initial emphasis will be on statistically summarizing and describing the space and time variations of pollutant concentrations over the city, to be followed by a study of the meteorological and pollutant emission data.

Development and evaluation of air quality simulation models for inert and reactive pollutants and of meteorological models will continue. Physical models will be developed and tested in the Fluid Modeling Facility wind tunnel and/or water channel/towing tank. Evaluation of existing air quality simulation and meteorological models will begin, using data from St. Louis, MO, collected by the Regional Air Pollution Study (RAPS).

Air parcel trajectories calculated from the estimated regional wind fields based on ETTEX data are being compared with observed tetroon behavior. Prediction of mesoscale trajectories of pollutant clouds subject to diffusion will begin. Sensitivity of the results to various diffusion parameters and to the nature of the underlying terrain will be examined. A model for multiple plume rise and cloud growth will be developed, for use in the study of the meteorological effects of power parks.

A large radio-controlled model airplane is being constructed to carry pressure, temperature, humidity, and acceleration sensors to altitudes up to 2 km; data will be telemetered to the ground for recording. The airplane will be used to determine diurnal variations of vertical temperature and humidity profiles and of mixing layer height, and to investigate horizontal change in temperature and humidity over terrain discontinuities such as forest edges.

A wind tunnel facility suitable for both routine calibrations of anemometers and for investigations of flow near obstacles immersed in a turbulent shear layer will be purchased, installed, tested, and calibrated. Devices to produce a suitable boundary layer flow within the test section will be fabricated and tested. Initial flow visualization studies will begin, using simple building shapes.

METEOROLOGY AND NUCLEAR ENERGY

Accomplishments FY 1975

Meteorology for Nuclear Testing

The meteorology for nuclear testing program is conducted by the Air Resources Laboratory, Las Vegas (ARL-LV). This laboratory provides ERDA with all meteorological services necessary to conduct the nation's nuclear weapons testing program safely. The laboratory's applied research program develops and improves meteorological methodologies and techniques.

In FY 1975, numerical modeling and statistical techniques were applied to improving wind predictions, which are the bases for radiological safety planning.

To determine the transport of atomic debris from possible vented underground nuclear tests, a seepage-release model was developed that uses Gaussian plume dispersion theory after Pasquill and Gifford. In addition, a Radiological Prediction Model predicts the temporal and spatial evolution of suspended airborne radioactivity that might be accidentally released to the atmosphere during an underground nuclear event.

Work was completed on the seasonal typing of 500-millibar (mb) map types for the western U.S. and on seasonal typing of Yucca Flat radiosonde soundings (Raob). Work was started on the correlation of these 500-mb map types and Raob sounding types with related weather elements at the Nuclear Testing Site (NTS). Western region of the National Weather Service has shown considerable interest in these allied projects.

Bioenvironmental studies have continued in support of the Plutonium Environmental Studies Program of the ERDA-NV Nevada Applied Ecology Group. Micro-meteorological data obtained concurrently with Lawrence Livermore Laboratory's dust and plutonium-in-air measurements were compiled for machine computation of associated statistical parameters.

A mobile micro-meteorological and airborne dust-measurement system was assembled and is being used at various locations on the NTS to study the wind erodibility of various soil types in differing vegetative areas.

The first American Meteorological Society conference on Regional and Mesoscale Modeling, Analysis, and Prediction (Las Vegas, Nevada, May 6-9, 1975) was suggested and organized by an ARL-LV staff member. Over 100 papers were presented to an audience of some 300 meteorologists from Canada, Mexico, Europe, and the United States. A summary of the conference will be published in the October issue of the Bulletin of the American Meteorological Society.

Meteorology for Nuclear Reactors

Research in this area is directed towards current and anticipated environmmental problems associated with the release of radioactive effluent wastes to the atmosphere in the utilization of nuclear reactors for power sources.

As part of an effort to determine transport and diffusion within the planetary boundary layer a number of field studies were carried out, namely, 1) a 2-month long series of atmospheric tracer tests at the proposed site of a breeder reactor in Tennessee to relate atmospheric diffusion rates and simultaneous meteorological measurements under low wind speed, inversion conditions, 2) a series of tracer tests within the wake of a reactor complex at the Idaho National Engineering Laboratory, and 3) phase II of the building wake tests conducted at Sacramento, California, at the site of the Rancho Seco nuclear power plant. Results for the latter two studies will determine the added dilution afforded by the turbulence created by large structures within an air stream.

Meteorology and Atmospheric Radioactivity

The program aims at improving techniques for predicting the distribution, transport, and deposition of trace substance in the atmosphere, with particular emphasis on nuclear debris and other radioactive tracers. Simultaneously, it uses measurements of these tracers to investigate atmospheric processes and to study intermediate and large-scale motions in the troposphere and stratosphere.

Stratospheric concentrations of radioactive debris from nuclear weapon tests continue to interest the meteorological community, especially those engaged in developing numerical global circulation models. The stratospheric distribution of radioactive debris can verify model predictions at intervals for many months

following such events as the four Chinese high yield tests of June 17, 1967; December 27, 1968; September 29, 1969 and October 14, 1970. Consistent analyses for these four events have been completed together with estimates of the initial source distribution and the depletion of the resulting stratospheric burdens. Common features of the four radioactivity patterns have been incorporated into composite pictures of the seasonal-latitudinal distribution of radioactivity following summer, fall, and winter nuclear tests.

The analysis of radioactive debris for the last high-yield nuclear test conducted by China, on June 27, 1973, is near completion. This analysis will be used to verify the composite pictures of the latitudinal distribution of radioactivity following a summer nuclear test.

Plans FY 1976

Further improvements are planned for the operational Wind Prediction Model including incorporation of noise filtering techniques and provision for additional input parameters during model initialization. Plans also include modification of our numerical Radiological Prediction Model to permit modeling of dry fallout and precipitation scavenging. Yucca Valley surface wind prediction equations will be developed with the aid of 850-mb data at surrounding radiosonde stations.

Analysis will continue on the concentration and dispersion of radioactive debris from future nuclear tests. As these tests become more infrequent, emphasis will shift to the distribution of fluorocarbons in the stratosphere.

ATMOSPHERIC TRANSPORT STUDIES

Accomplishments FY 1975

Global Modeling

The ARL operates a two-dimensional (north-south and vertical) transport model for application to environmental problems. The model is capable of transporting substances by both diffusion (flux-gradient relationship) and organized circulations. In this last year, the model has been applied to the upward transport of F-11 and F-12.

Application of a two-dimensional model to the upward transport of F-11 and F-12 has produced results that confirm the control over the concentrations of F-11 at altitudes above about 25 km by photochemical loss rather than by diffusion within the range of estimates of plausible vertical diffusion coefficients.

The model has also been applied to an inert tracer, SF_6, but no verification is as yet available for altitudes above 19 km. Both the fluorocarbons and the SF_6 exhibit patterns of lower concentration at the polar areas than at the equatorial areas at the same heights in the stratosphere.

Regional and Global-Scale Transport and Diffusion

ARL is engaged in a continuing program to develop and verify computer models to simulate local, regional, and global transport and dispersion of pollutants injected into the atmosphere, and to calculate resulting population exposures. Such models are needed, for example, to evaluate the effects of alternative sources of energy (e.g., nuclear, fossil fuel) on local, regional, and world populations.

Diffusion-deposition studies investigated the sensitivity of the model output to the assumed values of vertical diffusion coefficents, and washout and dry depositon parameters. It was found that total population exposure, on a continental scale, was not very sensitive to changes in the deposition parameter values.

At the request of the Energy Research and Development Administration (ERDA), the ARL transport-diffusion-deposition model was used to estimate total population exposure to plutonium and other transuranics for the Liquid Metal Fast Breeder Reactor draft environmental impact statement. Mean annual air concentration, deposition patterns, and population exposures over the eastern United States and Canada were calculated for a hypothetical fuel reprocessing plant in Illinois. Similar calculations were made for a plant in Colorado as part of an investigation of the effect of siting on total population exposure.

The trajectory module was used extensively during the past year. In addition to our own work, we were requested to provide trajectory calculations for a number of other groups, including five ERDA National Laboratories and eight federal agencies, and about a dozen organizations outside the U.S. Government, including three from foreign countries.

Although the ARL transport and diffusion model is being used in many studies, it has been verified against actual sampling data in only a few instances. Extensive tracer experiments are underway to provide verification data.

Long-Range Transport

The ARL trajectory program determined the trajectories of ozone, F-11, and CCl_4 measured at Adrigole, Ireland. It was shown that air arriving from the Atlantic Ocean had low values of ozone and F-11, whereas air arriving from the European continent had high values of these quantities. No similar distinction was noted for CCl_4.

Measurements of the concentrations of ozone and trichlorofluoromethane in the atmosphere over various parts of the southern British Isles provide evidence that photochemical ozone, and the pollutants from which it is formed, may be transported into the region from their origins in continental Europe. It seems likely, therefore, that even isolated areas, away from centers of industrialization, may suffer the effects of this pollution.

Atmospheric Trajectories

The Los Angeles Reactive Pollutant Project (LARPP) was carried out in September, October, and November of 1973. The experiment measured the change in pollutant concentrations following a given volume of air (Lagrangian approach) rather than at a fixed point (Eulerian approach), as done previously. Triads of constant volume balloons (tetroons) were released simultaneously from the same point on the ground in order to "tag" a particular volume of air. The tetroons, flying at a mean height of about 350 meters MSL, were followed by helicopters which did the air sampling, and were tracked with radar. The estimate of relative diffusion (the relative separation of the particles or elements of a diffusing cloud) was obtained from the rate of separation of the three tetroons making up each triad.

Conclusions based on radar tracking of 35 tetroon triads indicated that the relative diffusion was nearly twice as large in "neutral" as in "stable" conditions. Comparison with the results obtained by other investigators in other locations shows that the relative diffusion within the Los Angeles Basin is frequently unusually small, particularly with respect to travel time.

Another experiment with tetroon trajectories showed that, on non-stagnation days, air located in the Los Angeles area in the morning can pass over the Puente Hills and reach the San Bernardino-Riverside area on the afternoon of the same day. However, the vertical mixing induced by these hills should dilute any pollution present. Of greater significance is the evidence that, on stagnation days when the atmosphere is stable, air from the Los Angeles area may drift southward in the early morning katabatic flow, stagnate for 2 to 3 hours in the industrialized and high vehicle-density region north of Long Beach, and then move rapidly eastward with the sea breeze flow through Santa Ana Canyon, reaching the Riverside-San Bernardino area in late afternoon. In this case there should be much more potential for severe pollution in the latter area.

In summary, the use of tetroons in the Los Angeles Basin to "tag" a given volume of air appeared to be completely successful, and points the way to further experiments using this technique.

ATMOSPHERIC TRANSPORT STUDIES

Plans FY 1976

The ARL global model is to be tested against the observed distribution of SF_6 and carbon dioxide in order to "fine-tune" parameters such as the eddy diffusivity. The model will then be used to examine further the fluorocarbon-ozone controversy.

During the next year a "box" model will be incorporated into the ARL transport and diffusion model to permit the calculation of vertical diffusion and deposition along each trajectory. A more detailed version of the model will also be developed for more precise calculations within a few hundred km of a source. Trajectories will be started at more frequent intervals and the calculational time step will be shorter. Effects of initial source height will be incorporated (model now assumes a ground-level source).

We anticipate continued application of the ARL model to ERDA studies, particularly the coming Multi-State Atmospheric Power Production Pollution Study now being planned. The model will be an integral part of this program, both in planning and executing experiments and in analysis of results. Experimental results, in turn, will be used to improve the model. Another use will be for analysis of Lagrangian statistics of trajectories over time intervals of 10 days or greater. This study will generate some estimates of lateral dispersion.

Analysis will continue of the variation in ozone and fluorocarbon at Adrigole, Ireland, with particular emphasis on determining (through the ARL transport and diffusion model) the source of both quantities.

A careful comparison will be made between the Los Angeles tetroon trajectories and the trajectories estimated from the surface wind (again using the ARL model) with the objective of estimating the error involved in determining pollutant transport and dispersion through the use of such surface trajectories.

CLIMATOLOGY

Accomplishments FY 1975

As part of a continuing investigation into climatic trends during the last few decades, ARL has examined the variations in sunshine amount, total ozone, and tropospheric temperature.

Sunshine Amount

The annual, quasi-biennial, and long-term variations in percentage of possible sunshine (S) within six regions of the contiguous United States were examined through observations at 103 stations for the years 1950-1972. A pronounced long-term dowward trend in S during autumn, with its implication of an upward trend in albedo, represents an interesting climatological phenomenon with impact on a local and perhaps hemispheric scale. A year-average decrease in S since 1964 may be due to an overall increase in cloudiness, an increase in aircraft-induced cirrus cloudiness, or an increase in turbidity due to pollution.

Total Ozone

Total-ozone data for various regions of the world have been examined on a mean seasonal and annual basis. The increase in total ozone noted during the 1960's appears to have ended, and at United States and British stations there was a significant 2% reduction in ozone between 1970 and 1974, although the annual rate of decrease diminished from 0.8% between 1971 and 1972 to 0.2% between 1973 and 1974. In the United States the 2% reduction returned the total-ozone value nearly to its 1963 level, but in Great Britain the decrease amounted to only one-third of the increase during the 1960's.

We failed to find an unambiguous effect on the ozone shield due to the large Russian nuclear explosions in 1961 and 1962, and suggest that, on a seasonal or annual basis, these nuclear tests could not have reduced (through the production of nitric oxide) the hemispheric total-ozone amount by more than 1-2%. There is also no evidence of a decrease in total ozone over Japan during the passage of radioactive clouds following individual Chinese tests in 1968, 1969, and 1970.

The sunspot-total ozone relation was reexamined using the available data. It is concluded that there is evidence of a relationship, and that the decrease in total ozone between 1970 and 1974 may be associated with the decrease in sunspot number following the sunspot maximum in 1969. Further evidence for a solar influence results from the observation of some decrease in total ozone in north latitudes following intense solar flares (solar proton events) in 1960, 1966, and 1972.

Tropospheric Temperature

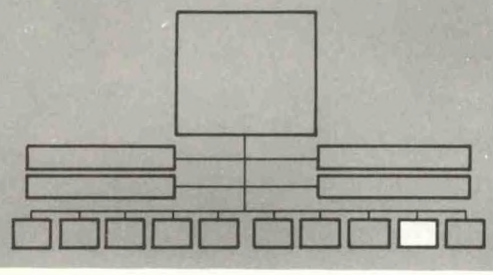
The tropospheric temperature changes during the period 1958-1973 have been estimated from the change in thickness between 700 and 300 mb at radiosonde stations fairly evenly distributed about the world.

During the decade 1963-73 there has been no real evidence of a trend in global tropospheric temperature, the slight cooling in the Northern Hemisphere having been compensated by a slight warming in the Southern Hemisphere. Thus, the large global temperature decrease between about 1958 and 1964 appears to have been just a temporary climatic aberration, and it is difficult to foretell the global temperature change that will occur during the next few decades, or the next few centuries.

CLIMATOLOGY

Plans FY 1976

It is planned to update sunshine amount and tropospheric temperature measurements at about 1-year intervals. Because of their importance to the fluorocarbon controversy, we plan to update the ozone data every 6 months. A paper relating equatorial tropopause temperature to water vapor mixing ratio in the low stratosphere at Washington, D.C., has just been completed, and these data will also be updated at yearly intervals. Finally, a study will be made of the effect of the variation in size and eccentricity of the polar vortex (12 years of data available) on surface temperatures in the United States to see if seasonal temperature foreshadowing is a possibility by this technique.



AERONOMY LABORATORY

Boulder, Colorado
Dr. E. E. Ferguson, Director

The Aeronomy Laboratory conducts research to increase knowledge and understanding of the physical and chemical processes of the stratosphere, ionosphere, and exosphere of the Earth and other planets, and of the dynamics of their interactions with high altitude meteorology, with a view toward prediction and control for the benefit of telecommunications and other space age needs. With a long tradition (in the time scale of the field) in ionospheric physics, extending back into its earlier career in antecedent organizations, ESSA and the NBS Central Radio Propagation Laboratory, the Aeronomy Laboratory has recently made a major redirection of effort into stratospheric physics and chemistry.

There are eight program areas in the Laboratory: Neutral Photochemical Processes of the Earth's Atmosphere Below 70 km, Stratospheric Sampling, Optical Aeronomy, Atmospheric Composition Studies, Atmospheric Collision Processes, Theoretical Aeronomy and Solar-Terrestrial Relations, Theoretical Plasma Physics and Turbulence, and Scatter Radar. There is a strong overlap and interplay between many of the Program Areas so that the divisions are more a matter of administrative convenience than of scientific rationale.

NEUTRAL PHOTOCHEMICAL PROCESSES OF THE EARTH'S ATMOSPHERE BELOW 70 KM PROGRAM

This program is directed towards obtaining a better understanding of photochemical processes in the stratosphere and troposphere. The stratosphere had long been a neglected region of the atmosphere even though it contains nearly all of the atmospheric ozone, one of the most important minor constituents of the Earth's atmosphere. Interest in the photochemistry and detailed composition of the stratosphere has grown explosively during recent years after the recognition that the abundance of ozone in the atmosphere could be reduced strongly by the catalytic ozone-reducing effects of nitrogen oxides emitted in the exhaust of stratospheric aircraft. Furthermore, the injection of chlorine compounds into the stratosphere through the use of industrial halocarbons, especially $CFCl_3$ and CF_2Cl_2, constitutes another threat to the ozone layer.

Present knowledge about the photochemical processes taking place in the troposphere is also limited. There are large uncertainties in present estimates of the flow of gases in the sulfur-, nitrogen-, and carbon-cycles of the biosphere-atmosphere-ocean systems, making the task of estimating man's influence very difficult. The role of tropospheric ozone on the atmospheric part of these cycles may be very important.

Accomplishments FY 1975

A detailed study was made of the possible future impact of the chlorocarbon industry on the ozone layer, with the aid of a photochemical-diffusive, time-dependent, one-dimensional model. Estimates were made of the vertical distribution of a number of important chlorine and nitrogen compounds in the atmosphere between ground level and 65 km as a function of time.

A two-dimensional, zonally-averaged, time-dependent, photochemical model of the atmosphere from ground level to 55 km was completed, and theoretical meridional distributions of a number of important minor constituents were derived to provide guidance for future observational research programs. The effect of the possible future impact of stratospheric aircraft operations was estimated with this model, and natural disturbances of the stratospheric ozone concentrations due to solar proton events were also studied.

The importance of the newly detected gas, CSO, in the formation of the stratospheric sulfate layer was postulated, based on recent measurements and a study with the aid of a theoretical model of the stratosphere. The complete origin of this gas is not known, but it is formed by coal burning. A possible industrial effect now or in the future may not be ruled out.

NEUTRAL PHOTOCHEMICAL PROCESSES OF THE EARTH'S ATMOSPHERE BELOW 70 KM PROGRAM

Plans FY 1976

The two-dimensional, zonally-averaged, time-dependent, photochemical model, which was developed to study the transport and chemistry of important constituents in the atmosphere below 55 km, will be further extended to provide estimates of the global mean distribution of several atmospheric gases. It will also be used to study the effects of possible changes in natural conditions, e.g., solar-proton events and volcanic activity. The model will be used to estimate the impact of industrial processes on the upper atmosphere, and will be validated and improved by comparisons with observations. Theoretical studies of geochemical cycles, especially nitrogen and sulfur, will be conducted.

STRATOSPHERIC SAMPLING PROGRAM

This program was started in May 1975 to combine several areas of trace constituent monitoring begun in various sections of the Aeronomy Laboratory. Its goal is to develop techniques and institute programs to monitor trace constituents of the Earth's atmosphere. An accelerating factor in this redirection was the recent interest in the possible reduction of the Earth's ozone layer by fluorocarbons and other halogen-containing compounds.

Accomplishments FY 1975

Since the original detection of tropospheric $CFCl_3$ in 1970, there have been several measurements of tropospheric $CFCl_3$ and CF_2Cl_2 concentrations. But stratospheric concentration measurements had been limited to the lowest part of the stratosphere. In June 1975, Aeronomy Laboratory scientists obtained three grab samples of stratospheric air by using balloons launched from Laramie, Wyoming. The samples were analyzed by gas chromatography and the concentrations of $CFCl_3$, CF_2Cl_2, and N_2O measured. The results were the first reported values for CF_2Cl_2, and $CFCl_3$ in the stratosphere above 19 km and the first height profiles of the two chlorofluoromethanes that showed the falloff with height. The observed falloff was consistent with the theory of photodissociation and with the predictions of models. These results tended to confirm that the only major loss mechanism for the two chlorofluoromethanes is photodissociation in the stratosphere.

In August, on a balloon flight from Yorkton, Saskatchewan, Canada, four usable samples were collected. The results from these samples agreed with the results from the Wyoming samples for the two chlorofluoromethanes, thus adding confidence to the theoretical models. The results for N_2O, however, showed a fall-off of concentration with altitude much more rapid than over Wyoming, and apparently disagree with the theory. It is expected from the theory that the N_2O concentration will have a seasonal and latitudinal variation but it is not predicted to be as large as was observed.

In September, eight samples were collected in the troposphere on an aircraft flight near Denver, Colorado. No variation with height or location was found between 6,000 and 12,000 feet.

STRATOSPHERIC SAMPLING PROGRAM

Plans FY 1976

New sampling valves are being developed and a new pressure sensor has been ordered accurate enough to give sufficient altitude resolution for samples taken above 25 km altitude. It is planned to attach a mass spectrometer to the gas chromatograph to identify the unknown constituents that appear as peaks in all the gas chromatograph records.

A number of samples, to be collected at midlatitudes from balloons, at altitudes up to 40 km, will uniquely identify the loss processes for the two chlorofluoromethanes (CFM's). Recent laboratory results from the National Bureau of Standards have shown that the photodissociations of CFM's 11 and 12 have reasonably large temperature dependences; when these dependences are put into the models, the measurement of the stratosphere distribution rate should agree precisely with the theory if all loss processes have been included in the models. The midlatitude flights, taken several times a year, will give us more information about the N_2O cycle.

As soon as feasible, two flights will be made in Antarctica at McMurdo Sound to learn more about the Southern Hemisphere distribution of the chloromethanes. Since most of the chloromethanes are released in the Northern Hemisphere, and since the mixing between hemispheres is fairly slow, less CFM 11 and 12 should be seen in the Southern Hemisphere. An N_2O profile in the Antarctic summer is expected to shed new light on the latitudinal variation of N_2O.

Several more ground-based detectors of stratospheric NO_2, similar to that installed recently at Pt. Barrow, Alaska, will be installed at the other GMCC stations in Hawaii, Samoa, and Antarctica. A detector for NO, which will have an order of magnitude increase in sensitivity over other chemiluminescent systems, is being built and tested. The increased sensitivity is needed to measure the very low concentrations of NO at ground level and near the poles.

OPTICAL AERONOMY

This program uses optical measurements of the atmosphere for studying fundamental atmospheric processes such as energy balance, composition, and dynamics. In the past, the program has focused upon atmospheric emissions associated with the airglow and aurora. While ground-based study of atmospheric optical emission continues to be of major concern, the program is expanding into related areas such as measurement of chemically active minor constituents in the lower atmosphere, optical studies of other planets, aircraft investigation of infrared aurora, and optical effects associated with tropospheric aerosols.

Accomplishments FY 1975

A technique has been developed for separately determining the stratospheric and tropospheric abundance of nitrogen dioxide (NO_2) using ground-based absorption spectroscopy. Changes in the abundance and altitude distribution of NO_2 in the stratosphere can be monitored on a routine basis; at the same time the variations in tropospheric NO_2 with changing weather patterns can be followed. The natural clean air background of NO_2 has been found to be very much lower than previously reported and a major enhancement has been found in thunderstorms. Measurements made on board a jet aircraft have revealed an unexpected major decrease in stratospheric NO_2 at high latitude in winter with a return to high values in summer. These new observations should be of value in understanding the effect of nitrogen oxides in controlling the ozone layer. Automated instruments for monitoring NO_2 are being installed at a number of NOAA GMCC stations at both high and low latitude. Those at high latitude will not only study the seasonal changes in stratospheric NO_2 but will also be in a position to detect increases predicted to result from an influx of high energy protons during PCA events.

High resolution interferometric techniques have been applied to the study of atmospheric spectral emission lines at the Fritz Peak Observatory in order to determine both temperature and wind fields in the thermosphere, fundamental quantities that cannot be determined directly by other means. The observational program permits checks on theoretical predictions of global thermospheric wind systems, atmospheric models, and thermospheric energy budgets.

All of the observations are in agreement with theory, and any discrepancies have been resolved.

In cooperation with the Air Force Cambridge Research Laboratories, a continuing program has been conducted to study infrared auroral and airglow emission, and more recently stratospheric composition, from a research jet aircraft which is fully instrumented for optical and radio studies and dedicated to arctic investigation. Such a high altitude platform permits rapid access to geographically interesting but otherwise inaccessible regions (such as the dayside auroral oval under conditions of darkness) and introduces minimal interference from absorption and extinction by the lower atmosphere. The infrared studies have yielded a unique global and seasonal picture of the ozone abundance in the upper mesosphere which could not have been observed in any other way.

A new program of twilight airglow investigation at the Fritz Peak Observatory uses the extraordinarily clear atmosphere to extract emission features from the unwanted background of scattered sunlight. The twilight enhancement of the 6300A oxygen line is used to study variations in thermospheric O_2 abundance with season, geomagnetic activity, and solar cycle. A major enhancement of near-infrared O_2 emission has been discovered in twilight and has been shown to provide a direct measurement of the ozone distribution with height between 80 and 110 km altitude; above 90 km, atmospheric ozone is unmeasurable by any other method. A large increase of ozone density during the night is evident and leads to the capability of determining the atomic oxygen density in the 100-120 km region on a routine basis. A large seasonal variation has been found in the ozone abundance above 90 km; the winter maximum is in accord with the seasonal variation in ozone between 80 and 90 km inferred from aircraft measurements. O_2 and OH emission in the nightglow can be analysed to yield a relatively direct measurement of the atmospheric temperature at 95 and 85 km altitudes, respectively. The most important discovery has been that large periodic temperature fluctuations exist at both 95 and 85 km and show a phase coherence similar to that expected from internal gravity waves originating in the troposphere as well as in the high latitude auroral mesosphere.

Techniques perfected in studies of the Earth's airglow, in collaboration with colleagues at the Smithsonian Observatory at Mt. Hopkins, Arizona, and in France, have led to the detection of infrared emission from O_2 in the Martian dayglow. From the emission intensity it is possible to infer the abundance of Martian ozone with greater sensitivity than by more direct methods employed aboard the Mariner space probes. The method permits study from Earth of the geographical and temporal changes in ozone abundance that reflect Martian meteorology.

OPTICAL AERONOMY

Plans FY 1976

A major new program in stratospheric and tropospheric measurements of NO_2 will expand to include other minor but chemically active species. Other new work deals with the composition and dynamics of the neutral atmosphere, particularly their interaction near 100 km altitude where the transition from turbulent to free molecular mixing takes place. Several current, and planned,

studies converge upon the problems associated with "odd oxygen", namely, the relative abundance of O, O_2, and O_3. Other studies will include dynamical areas such as wind, and temperature fields and their variation; here the power of ground-based observations is evident in their ability to measure, reliably and inexpensively, the time-dependent fundamental atmospheric quantities over an extended period of time from a fixed location.

ATMOSPHERIC COMPOSITION STUDIES PROGRAM

The atmospheric composition program is aimed at understanding the distribution of gases that make up the Earth's atmosphere. A number of minor constituents that significantly influence the behavior of the atmosphere are of special interest. Processes of interest include chemical and photolytic reactions, radiative transfer, atmospheric dynamics, and thermal conduction.

Accomplishments FY 1975

The first direct, convincing measurements of molecular oxygen recently demonstrated a large seasonal variation in the lower thermosphere. The study involved measuring from a satellite, at different seasons, the intensity of the solar hydrogen Lyman-alpha spectral line and its attenuation by the Earth's atmosphere as the atmosphere occulted the solar disk.

A sophisticated computer code has been written to solve time-dependent photochemical systems in the stratosphere. The code is being used to test simpler but much faster techniques than are currently being used for stratospheric modeling, and to study the diurnal variation of the nitrogen oxides.

ATMOSPHERIC COMPOSITION STUDIES PROGRAM

Plans FY 1976

Planned work will emphasize problems in the stratosphere, troposphere, and mesosphere, rather than the ionosphere and thermosphere as in the past. The remaining thermospheric program is a planned study of the major gases in the thermosphere using occultation data obtained by the Harvard University solar monitoring instruments on Skylab. Several hundred occultation absorption profiles, obtained over an 8-month period, will be analyzed.

Additional computer codes will be written to investigate specific problems, such as the sensitivity of chlorofluoromethane (CFM) 11 and 12 concentrations to temperature. One of the major planned investigations will be a comprehensive study of the odd nitrogen throughout the atmosphere. This will require consideration of production and loss not only in the atmosphere but also at the Earth's surface. An immediate consideration will be to look at various possible production processes in the mesosphere.

ATMOSPHERIC COLLISION PROCESSES PROGRAM

This program has been primarily addressed to experimental studies of atomic and molecular processes of importance in the atmosphere. Laboratory techniques developed in this group have led to most of the available data on the ion-neutral reactions that control the ion composition of the Earth's ionosphere and also the ionospheres of Mars and Venus. The principal technique developed, called the flowing-afterglow technique, is playing a valuable role in chemical kinetics, supplying reaction rate constants and thermochemical data for inorganic and organic systems. One of the laboratory flowing-afterglow systems has been fashioned to operate from 80° to 900°K, the widest range of temperature yet achieved by any method.

The flow-drift tube, an apparatus developed by the laboratory, combines the chemical versatility of the flowing-afterglow technique with the energy variability of a drift tube. This permits the study of the energy dependence of an extensive variety of ion-neutral reactions from room temperature to several electron volts relative kinetic energy, while working with a wider variety of ions and neutrals than is accessible to conventional drift tubes.

A laser magnetic resonance spectrometer combined with a flow system is being used for measuring neutral reaction rates in studies of the photochemistry of the normal atmosphere and the disturbed or polluted atmosphere. In addition to these reaction kinetic studies, there is a program in theoretical spectroscopy of atmospheric diatomic molecules.

Accomplishments FY 1975

(a) Rate constants for the reaction of electronically excited molecular oxygen positive ions with O_2, N_2, Ar, CO, CO_2, and H_2 have been measured as a function of reactant energy. The reactions with O_2 and N_2 are of importance in the ionosphere where a large fraction of the oxygen ions are produced in the excited state, and the ground state ion does not react with these neutrals.

(b) Rate constants have been measured for a number of tropospheric positive and negative ion reactions, allowing a prediction of types of ions that may be important in the troposphere, and suggesting that measurements of tropospheric and stratospheric ion compositions might lead to a very sensitive technique for determining the concentrations of some atmospheric trace constituents such as NH_3, SO_2, and HNO_3.

(c) Most of the important ion-molecule reactions in the E- and F-region of the ionosphere have been measured as a function of temperature from 300° to 900°K.

(d) The rate constants for several exothermic proton transfer reactions have been measured as a function of relative kinetic energy in the flow-drift tube. It was found that the energy dependences of the reaction rate constants are not those expected from the latest available theory.

(e) The rate constants for the reactions of O^+ with N_2, O_2 and NO were measured in the flow-drift tube using both helium and argon buffer gases in which the speed distributions of the atomic oxygen ion are substantially different. These measurements have been used to validate recent theory for calculating the speed distributions, allowing the rate constants to be obtained as a function of kinetic temperature as well as relative kinetic energy. The temperature dependence of these reactions is important in understanding the variation of electron density during natural and artificial ionospheric disturbances.

(f) The reactions of fluorocarbons 11 and 12 with the ambient ions most likely to be found in the troposphere have been studied in detail. The results show that these fluorocarbons are not removed by ions in the troposphere as had been suggested.

(g) A laser flash photolysis system has been used to study the reactions of the metastable $O(^1D)$ atomic oxygen atom with a number of atmospheric constituents as a function of temperature between 160 and 390°K. These reactions are important because they constitute a major source of free radicals in the troposphere and stratosphere, where nearly all of the active chemical processes involve reactions with radicals. The temperature variability recently measured will have a profound effect on the radical production rates used in atmospheric models.

(h) The first measurements were made, with the laser magnetic resonance system, of reaction rates of the hydroxyl (OH) radical with CO, NO, and NO_2. The reaction with CO is a major mechanism for its oxidation, and an important step in all hydrocarbon combustion mechanisms. The reactions with NO and NO_2 are important radical chain terminating steps in the photochemistry of the atmosphere.

(i) A thorough study was recently made of the reactivity of OH with a wide variety of halogenated hydrocarbon molecules. Major sources of chlorine in the stratosphere are industrially manufactured halocarbons, which are relatively inert in the troposphere, and are removed almost entirely by ultraviolet photodissociation in the stratosphere. Photodissociation frees chlorine which then attacks stratospheric ozone. The results of this study provide accurate rate constant data for modeling the atmosphere, allowing estimates to be made of the stratospheric impact of present natural and manufactured halocarbon species.

(j) Studies of the microwave spectrum of HO_2 have given enough information about its spectral structure to allow a search for the radical in interstellar space with a radio telescope.

ATMOSPHERIC COLLISION PROCESSES PROGRAM

Plans FY 1976

(a) The flow-drift tube offers the possibility of studying the role of the vibrational energy of ions in ion-molecule reactions by use of different buffer gases to vary the degree of excitation. Little is known about the effect of ionic internal excitation on reaction rates, but pronounced effects have been observed in some types of reactions.

(b) The recent successful detection of the HO_2 radical with the laser magnetic resonance system will allow the measurement of the atmospheric reactions of this radical, almost all of which have never been studied.

(c) The reactions of the OH radical with a number of sulfur-containing molecules will be measured with the laser magnetic resonance system. This work will impact atmospheric chemistry in the determination of the atmospheric sulfur balance. Sulfur compounds having natural (volcanic and biological) sources, as well as those that have industrial sources, will be studied.

(d) Use of a newly developed methanol laser will increase the number of wavelengths available for detection in the laser magnetic resonance equipment. The addition of new long wavelength lines will make detectable many heavy paramagnetic molecules, such as chlorine oxide and chlorine dioxide.

(g) The laser photolysis system will be used in a study of the chemistry of reactions of the excited oxygen $O(^1D)$ atom with a number of atmospheric trace constituents, such as the fluorocarbons. The system also shows promise for reaction studies of other excited metastable atmospheric species, important in aeronomy.

THEORETICAL AERONOMY AND SOLAR-TERRESTRIAL RELATIONS PROGRAM

This relatively small program is devoted to attacking certain problems that are of basic importance to our understanding of the upper atmosphere and of the solar-terrestrial interactions that govern its behavior.

Accomplishments FY 1975

A recent study of the effects of solar energetic particles on the stratosphere has revealed that solar-proton (PCA) events constitute a major and hitherto ignored natural source of nitric oxide in the stratosphere, and should thus exert a significant amount of control on the global ozone distribution. Solar-proton events were found to contribute much more to global NO_x production than galactic cosmic rays, whose effects have been widely studied in the literature, and very large events can contribute an amount of NO_x that is comparable with the annual production by all other known natural sources.

This discovery suggests that the Earth may have been exposed to much more severe solar-proton irradiation in the geological past, especially at times when the shielding effect of the geomagnetic field was removed. Periods of weakening of the geomagnetic field are known to have occurred in association with polarity reversals, and there is strong evidence for accompanying harmful effects on marine micro-organisms. The possibility that these harmful effects were due to enhanced levels of ultraviolet radiation, resulting from solar-proton irradiation of the stratosphere, has been investigated, and is under active study at present. If confirmed, it would have major consequences in terms of our appreciation of the importance of the ozone layer to the biosphere.

In connection with the ion chemistry of the D region, preliminary modeling efforts have suggested that the observed rapid

conversion of NO^+ into water-cluster ions of the general form $H^+(H_2O)_n$ may be understandable in terms of known clustering reactions. For several years this has constituted the main unsolved problem of D-region ion chemistry, since NO^+ was known to be the major primary species produced in the quiet D region, while the water clusters were the dominant observed ambient species. A model was constructed that tested the effects of introducing three successive stages of clustering of $NO^+(H_2O)_n$ (n = 0, 1, 2) with N_2, CO_2, and H_2O, and allowing cluster-switching reactions to take place. Results of model runs for several reasonable mesospheric temperature profiles have succeeded in reproducing the observational results reasonably well.

A model study of mesospheric ice cloud formation has been completed and the results published. The principal finding was that the observations of the optical properties of these clouds can be reconciled with current estimates of the water-vapor content of the mesosphere only if the cloud particles are thin plates or long needles, rather than the spheres that have been assumed in all previous studies. Recently, indication that the particles are probably needle-shaped has been obtained by polarization measurements of noctilucent clouds in Scotland.

THEORETICAL AERONOMY AND SOLAR-TERRESTRIAL RELATIONS PROGRAM

Plans FY 1976

Work aimed at verifying the existence and magnitude of ozone depletions associated with PCA events will be carried out in collaboration with other groups in the Aeronomy Laboratory. The collaboration will be extended to obtain estimates of the long-term importance of this source of NO_x as a factor in controlling the global distribution of ozone. The possible effects of global ozone depletion on the biosphere will be kept as an open subject, with further developments dependent on discussions with concerned biologists.

The model calculations of D-region ion chemistry will be extended to include lower altitudes and to take account of recent developments in negative-ion chemistry. Possible implications for the stratosphere and troposphere will also be studied, and the possibility of including nucleation processes involving ions will be investigated.

THEORETICAL PLASMA PHYSICS AND TURBULENCE PROGRAM

This program is devoted to theoretical studies of turbulence and waves in the atmosphere, which are relevant to many areas of geophysics, including micrometeorology, oceanography, space physics, ionospheric physics, and aeronomy. Recently, attention has turned toward theories for eddy diffusion and turbulence in the lower neutral atmosphere. Large turbulent fluctuations, sometimes called irregularities, are always present in vast regions of the atmosphere because the natural state of the atmosphere is often locally unstable, and they have a striking effect upon transport in the atmosphere.

Accomplishments FY 1975

A comprehensive nonlinear theory of atmospheric gravity waves was developed recently based on methods successfully used in plasma physics. It shows that gravity waves virtually dominate transport in the mesophere and can cause temperature fluctuations as large as 40 percent. It also shows that nonlinear effects can increase the frequencies of gravity waves by a factor of two; it explains why the amplitude of a gravity wave can never exceed a well-defined maximum value in the atmosphere, and why the enhancement of diffusion by gravity waves is extremely anisotropic with horizontal diffusion exceeding vertical diffusion by four orders of magnitude.

Also developed was a nonlinear theory of eddy transport in the atmosphere, valid for all stability conditions of the atmosphere. It shows that the three eddy transport coefficients—viscosity, thermal diffusion and particle diffusion—are related to each other in a universal and simple way, and that eddy diffusivity increases with time in the presence of a wind shear. The theory has been applied to the problem of determining atmospheric eddy diffusion coefficients from backscatter radar measurements.

A further theory proves that under certain conditions the Eulerian velocity spectrum (usually measured in experiments) is related to the Lagrangian velocity spectrum (which determines eddy diffusion) by an integral equation.

Plans FY 1976

During the next year a fundamental study will be made of turbulence in incompressible fluids (Kolmogoroff turbulence), the classic longstanding problem of turbulence theory. Other studies will include those of the role of tidal waves in atmospheric eddy diffusion, further work on the Lagrangian-Eulerian relation, and turbulence transport studies to provide theoretical support to the Sunset radar program.

SCATTER RADAR PROGRAM

The program's experimental research is based on study of irregularities in the atmosphere by means of on-line digital analysis of their radar echoes. These studies use a light-weight (<200 lb) portable radar system that consists of vhf transmitter, receiver, easily constructed antenna system, and minicomputer, and is capable of high resolution on-line spectral analysis.

Accomplishments FY 1975

Recent very high resolution studies of the equatorial ionospheric E region have shown that the irregularity structure is very similar to the structure of neutral turbulence in air. A radar study of the "interface" between the E and F regions (130-200 km altitude) recently showed that the vertical drifts in this region agree with those predicted from a theory that also predicts a meridional current system associated with the normal equatorial electrojet.

Additional irregularity studies in India, Brazil, and Jicamarca, Peru, have examined the characteristics of equatorial spread F, an undetermined plasma instability process operative in the nighttime equatorial F region of the ionosphere. Recently a theory has been developed explaining the weak echoes returned from equatorial spread F in terms of partial reflections from steep gradients in electron density that occur in the post-sunset equatorial F region.

Techniques developed in the study of the equatorial regions have been modified and used in the past few years to examine the characteristics of the radar aurora. The results showed that the radar auroral irregularities are somewhat different than those observed in the equatorial electrojet, and are not coincident with visual auroral forms as had been previously postulated. Recent results showed a striking correlation between the location of the radar auroral echoes and the auroral electrojet current system. This discovery affords the first possibility of mapping the intensity and extent of the auroral electrojet with excellent resolution, over one-quarter of the state of Alaska, with a single radar. Another recent finding has been a reasonably close agreement between electric field values in the E region obtained by the auroral radar, and values of the electric field in the F region measured by the Chatanika, Alaska, incoherent scatter facility.

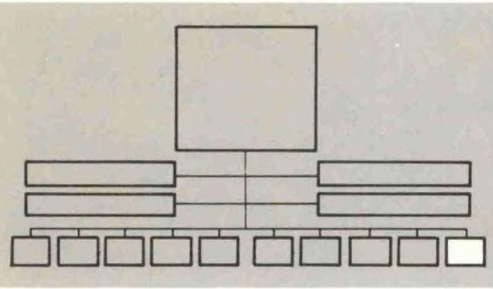
Two portable ionospheric radar systems have been completed for installation at Siple Station in Antarctica to measure ionospheric currents and electric fields, and to establish, along with measurements for others, the relationship between the radar aurora and the plasmapause, artificially induced whistlers, micropulsations, and magnetometer data.

The techniques developed by the program have also been applied to the study of the neutral atmosphere. The results of a series of experiments in the equatorial electrojet at Jicamarca, Peru, showed that it is possible to determine the east-west velocity of the neutral winds, as well as the neutral temperature, by virtue of their effect on the spectra of the radar echoes from plasma irregularities. This immediately suggested that radar echoes from irregularities in the neutral atmosphere itself could be used to measure winds and turbulence in the mesosphere, stratosphere, and troposphere. A sensitive, pulsed-Doppler vhf radar, constructed recently for such a study near Sunset, Colorado, is uniquely suited to the study of transient phenomena in the atmosphere, such as waves, because of its excellent time resolution; and its location is particularly favorable for study of mountain lee waves and associated phenomena, such as rotors, downslope winds, and propagating gravity waves. Recently, detailed observations of a rotor over the radar site showed it to be characterized by large and variable vertical winds, and unusually broad spectra, indicating strong turbulence. The radar system is also particularly suited to the study of turbulence in the atmosphere. Recent measurements have been used to estimate the mean eddy diffusion coefficient, turbulent energy, energy dissipation rate, inner and outer scale, and structure constant for the winter jet stream.

Plans FY 1976

The group plans to participate in the International Magnetospheric Study by establishing a continuous radar-aurora monitoring system over a large region of Alaska. The data obtained will be used to establish correlations between the radar aurora and other phenomena of the ionosphere and magnetosphere.

Primary experiments with the Sunset radar will be directed toward the study of waves and turbulence. During the winter, mountain and lee waves will be studied intensively and coordinated with other studies in the Boulder area. A search will be made for internal gravity waves in the troposphere. Turbulence will be measured in the vicinity of the tropopause, where it is probably caused by vertical shear of the horizontal wind which can be measured easily by radar.



SPACE ENVIRONMENT LABORATORY

Boulder, Colorado
Dr. Donald J. Williams, Director

The Space Environment Laboratory (SEL) conducts research in the field of solar-terrestrial physics, develops techniques necessary for forecasting solar disturbances and their subsequent effects on the Earth environment, and provides real-time environment monitoring and forecast services on a continuing basis. The Laboratory also provides ERL with expertise and advice concerning satellite instrumentation and interface techniques within NOAA and other agency satellite programs in the area of solar-terrestrial physics.

Within SEL there are three Research areas—Interplanetary, Magnetospheric, and Ionospheric; two Support areas—Instrumentation Development, and Analysis; and two Services areas—Real-Time Data Services, and the Space Environment Services Center.

The SEL program considers the solar-terrestrial environment (the Sun-Earth system) as a set of several subsystems with strong interactions that produce significant environmental effects. At the Earth's surface, induced Earth currents accompanying geomagnetic storms produce undesired effects in electric power distribution systems and telephone lines at high latitudes. In the atmosphere, there appears to be a relationship between solar activity and weather. Also, recent findings 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 hf communications via ionospheric reflection, communications from Earth to satellites, radar systems, and navigation aids at vlf and hf.

Theoretical and experimental research studies are conducted in order to understand the fundamental physical processes responsible for and causing

1) the observed energy release in the form of electromagnetic and particle radiation from solar flares;
2) the propagation of this energy through the interplanetary medium to the near-Earth environment;
3) the transfer of this energy from the near-Earth interplanetary medium into the Earth's magnetic field, the magnetosphere; and
4) the behavior and subsequent effects of this energy within the magnetosphere, the ionosphere and upper atmospheric regions.

The knowledge gathered from these studies is applied to the development of prediction techniques that, with the extensive real-time data service maintained by the Laboratory, are applied directly to the routine forecasting of solar events, and provide early warning and real-time information concerning the state of the solar-terrestrial and, particularly, the near-Earth environment to a wide variety of users.

INTERPLANETARY RESEARCH

Accomplishments FY 1975

The formation and propagation of non-linear interplanetary disturbances (such as stream-stream interactions and shock waves generated by solar flares) have been simulated by computer codes as a continuing development of the Solar Terrestrial Environment Model (STEM). One of the computer codes was used to analyze the propagation of a series of shock waves to the vicinity of the Earth's magnetosphere for four very large solar flares that occurred August 2 and 3, 1972. The simulation provided good agreement with observations of shock wave phenomena obtained from data that included spacecraft data and ground-based observations of solar radio bursts and interplanetary scintillations of discrete pulsar sources. This represents a significant advance toward the development of an operational method of predicting the arrival at the Earth of disturbances that produce ionospheric and geomagnetic storms.

INTERPLANETARY RESEARCH

Plans FY 1976

The effects of the interplanetary magnetic field in the quasi-steady compression and heating of a slow stream (emanating from, say, the corona above an active solar region) by a faster stream that is emitting from an adjacent inactive cooler "coronal hole," will be studied. Continuing work will also incorporate, when necessary, large variations with solar latitude of radial velocity, density, and magnetic field for inner boundary conditions. The kinematic distortion of magnetic neutral lines (sectors) will be studied since they may modify the correlations being sought in solar effects on terrestrial weather.

The study of the series of interplanetary shocks and solar wind disturbances during August 1972 will be completed.

Arrangements have been made to receive solar wind plasma and magnetic field data from 1 to 5 AU as measured by the Pioneer-10 instruments. The data will be examined for stream-stream and shock observations and will be used as tests for the numerical simulation codes. Data will also be examined from Helios A from 0.3 to 1 AU, with similar objectives in mind.

A longer range plan is to incorporate fundamental plasma physics studies in conjunction with the present fluid dynamic studies. An example would be the analysis of observed shocks, analyzed first by means of fluid theory, in terms of their morphological classification (e.g., electrostatic or ion acoustic). The August 1972 shock ensemble study will be completed with a phenomenological study of their kinematic behavior, their ability to be used for an estimation of solar flare mechanical energy output, and their eventual decay into magnetoacoustic waves.

MAGNETOSPHERIC RESEARCH

Accomplishments FY 1975

A highlight in the magnetospheric research area was the identification of the operation of the ion cyclotron instability in the hot proton plasma population composing the Earth's ring current system. This instability has been found to operate continuously and is particularly noticeable during the recovery phase of a geomagnetic storm. Growth rates are small, and resulting pitch angle diffusion of the protons is in a weak-to-moderate mode. Consideration of off-equatorial growth rates can explain why small pitch angle anisotropies such as those observed in the proton ring current distribution seemingly provide the necessary growth for this weak-to-moderate pitch angle diffusion.

Laboratory experiments of charge particle beams set up in large vacuum tanks have uncovered the generation of half harmonic cyclotron waves due mainly to counter-streaming beam-beam interactions. This result is of great interest in plasma physics generally and has many potential applications in magnetospheric physics and other naturally occurring plasmas.

Observations of large populations of heavy ions residing in the equatorial plane in the outer magnetosphere have also been a new and exciting development in magnetospheric research. The existence of such heavy ions will not only allow tests to be made of the sources of various magnetospheric particle populations but will also greatly influence which types of plasma instabilities will be able to operate in the general magnetospheric plasma.

A development of an auroral arc model including a parallel E field accelerating the ambient plasma downwards and the secondary scattering by the atmosphere has proved to be very successful. Many measured auroral arc spectra, ranging from a few electron volts to 20 keV, and their angular distributions have been successfully explained by this simple model. Comparison of magnetic data from Explorer-45 and ATS-5 satellites has shown that a non-adiabatic acceleration process within synchronous orbit at 6.6 Earth radii must be invoked in order to explain the observed particle variations.

MAGNETOSPHERIC RESEARCH

Plans FY 1976

A number of satellite programs and research with data sets will be carried out including the following:

Explorer 45 and ATS-6. At the request of NOAA/SEL, NASA extended the operational life of the Explorer-45 satellite to overlap the operational life of ATS-6. The two satellites carried nearly identical instrumentation, and data from these satellites during the overlap period from June to October 1974 will be analyzed with the objective of determining the size and region of space involved with the initial rapid energization phase of magnetospheric substorms.

ATS-6 and SOLRAD HI. In February 1976 the U.S. Navy SOLRAD HI satellites will carry NOAA/SEL instruments into an 18-Earth-radii circular orbit with the two satellites 180° apart in orbital phase. Now in orbit are NOAA/SEL instruments aboard ATS-6 in a circular orbit at 6.6 Earth radii and IMP H and J in nearly circular orbits at 35 Earth radii. Each of these NOAA/SEL instruments is capable of measuring low energy protons. It is hoped to obtain low energy proton data from NOAA/SEL instruments in each of these satellites to study whether substorms do originate in the distant tail region or deep in the magnetosphere near the plasmapause as the result of some as yet unexplained mechanism.

ISEE Satellites A and B. The International Sun-Earth Explorers (ISEE) program is a three-satellite NASA program designed to study the scale size of various magnetospheric and interplanetary phenomena. NOAA/SEL, in collaboration with the Max Planck Institute, Lindau, Germany, will have nearly identical instrumentation on two of these satellites (Mother and Daughter) which will vary their position with respect to each other. Simultaneous data from these two instruments will permit effects of space and time to be separated. A launch date in September 1977 is expected.

Electrodynamic Explorers (EE). NOAA/SEL has been selected to participate in the mission study phase of a dual-satellite NASA program designed to study the electrodynamic properties of the inner magnetosphere and ionosphere and the coupling between these two regions. Launch is scheduled in late 1978 or 1979, if approved.

ATS-6 and GOES. NOAA/SEL is playing a lead role in attempting to coordinate the shift plans of the two geostationary satellites. If they can be brought to the same location and then separated again, a Mother/Daughter type situation will exist which will permit scale sizes and phase timing to be performed on the substorm injection process.

Charge Composition Studies. Progress is being made in a cooperative program with the Max Planck Institute to develop and fabricate a third generation instrument to provide detailed charge and mass composition measurements in an extremely important energy range that present state-of-the art instruments are unable to cover. The new instrument has been proposed as part of an S^3 B satellite program and as a possible addition to the EE program also.

The satellite data base will be expanded to include a large number of sub-storms, to discriminate between the candidate electric field models and to isolate the acceleration mechanisms that act earthward of synchronous orbit.

IONOSPHERIC PHYSICS

An important aspect in understanding the physical processes that govern the ionosphere is an understanding of the coupling processes between the ionosphere and magnetosphere and between the ionospheric ionized and neutral constituents, especially the transport processes. Some of the theoretical research that has been undertaken in this area is described below.

Accomplishments FY 1975

Computer models that have been developed for the low and mid-latitudes of the ionosphere take into account the effects of vertical E x B ionospheric drifts on F-region neutral winds in the thermosphere and the westward plasma drift in the F-region produced by magnetospheric convection currents from dawn to dusk during storm conditions. The model results agree in general with ionospheric observations during ionospheric storms.

Models of solar flare X-ray and extreme-ultraviolet (EUV) bursts are being used in evaluating their ionospheric effects. SMS satellite X-ray observations have been used as input to these models for particular flare events in order to evaluate their ionospheric effects, including increases in the total columnar electron content and toward development of an automatic real-time system for the very early detection of solar flares.

The ATS-6 radio beacon experiment measurements of total electron content surpass prior measurements in absolute accuracy and phase and time resolution, permitting certain ionospheric-magnetospheric phenomena to be observed for the first time, and have provided greatly improved quantitative measurements of previously observed phenomena.

Comparisons of incoherent scatter radar and coherent ionosonde observations show that the latter can reveal motions of the neutral air at the altitude of total reflection. This results from the ability of the coherent ionosondes to detect irregularities in the ionosphere that moved along with the neutral air.

Plans FY 1976

Ion drag. It has normally been assumed in the calculation of neutral winds at low latitudes that the ions drift freely with the neutral wind along the geomagnetic field line and therefore offer no resistance to the meridional wind component near the geomagnetic equator. The pressure gradients across the equator during solstice that are present in the global empirical models of temperature and composition thus force large meridional winds at F-region heights in the vicinity of the magnetic equator. A three-dimensional equatorial ionospheric model will be used to show that the forces present in the ion momentum equation prevent the ions from drifting freely with the neutral wind component along the geomagnetic field line. The ion velocity adjustment to the neutral wind modifies the distribution of ion drag on the meridional wind at low latitudes. However, the modified ion drag alone may not be sufficient to prevent abnormally large velocities from developing in the meridional wind thereby requiring some redistribution in the empirical model pressure forces.

ATS-F Radio Beacon. During 1976 the documentation of the diurnal and seasonal variations of the total electron content, the ionospheric content (up to an altitude of about 2000 km), and the plasmaspheric content, from 2000 km out to the satellite at 6.6 Earth radii, will be completed. Until late in FY 1976, the ATS-6 satellite will provide data to the recording site in India (in cooperation with the Indian Physical Research Laboratory) to measure the equatorial total electron content and the residual plasmaspheric content near the geomagnetic equator.

In late 1976, the satellite is scheduled to return to longitudes of the U.S. At that time it is planned to move the SEL recording equipment from India to a high-latitude station in Canada near the magnetic meridian of the satellite. The measurements will be appropriate for correlative studies between ionospheric effects and particle and magnetic-field measurements on the satellite.

SMS X-ray Studies. Studies of X-ray data from solar flares observed with instruments on the NOAA/SMS satellite will be completed in FY 1976 culminating in the development of an automatic system for detecting solar flares in real-time. This will represent a significant improvement in the current space environment services.

Upgrading of NOAA Ionosondes. In response to requests from the scientific commmunity, NOAA plans to upgrade its ionosonde monitoring facilities in the period from FY 1977 through 1979, following the development of a prototype digital ionosonde during FY 1976. The prototype development will be cost-shared with the NSF, and NOAA will provide funds following the development for several additional units in subsequent years. The hardware developments will be carried out by the SEL Instrument Development Group and the software developments by the Ionospheric Research and the Analysis Groups.

INSTRUMENT DEVELOPMENT

The Instrument Development Group serves SEL programs in both the research and service areas. Activities range from major programs providing sensor and data acquisition systems through the provision of advice and physical facilities to all other SEL staff carrying out electronic work. The group also carries out projects for other ERL Laboratories and outside agencies when effort is available and the program complements SEL objectives.

Accomplishments FY 1975

Operational Space Environment Monitors. The SMS/GOES Space Environment Monitoring subsystem is now operational on SMS-1 and -2. A third system (GOES A) has been launched and will replace SMS-1 in early 1976. The SEM system is built by NASA contractors to meet requirements set by SEL.

A comprehensive particle monitoring system has been specified for the next generation low orbiting operational spacecraft, TIROS-N. SEL is acting as a contractor to NASA and will provide the instruments for the spacecraft program.

Satellite Scientific Experiments. The ATS-6 Low Energy Proton Experiment, which was largely constructed and tested in SEL, has now been in orbit for more than one year and is performing very satisfactorily.

The International Sun Earth Explorer (ISEE) experiment is currently in an advanced circuit development, breadboard, and engineering model fabrication.

Sounding Rocket Programs. SEL scientists supported by the Instrument Development Group have conducted numerous sounding rocket launches or contributed instruments to cooperative payloads. Currently, an auroral particles and fields payload is being integrated by the group with experiments coming from both SEL and other organizations. Another payload, including an electron accelerator and associated particle and field measurements for investigating electric fields parallel to the magnetic fields at high latitudes, is in advanced planning and the group will be providing a part of the particle instrumentation.

The ATS-6 Radio Beacon Experiment. The spacecraft portion of this experiment, which was built by NASA contractors under SEL general supervision, was launched in May 1975 and has performed well in orbit. The ground receiving system was built by the Instrumentation Group with NASA funding and collected one year of data at Boulder, Colorado, before being shipped to India for further ATS-6 data collection.

Other Activities. Consultant and technical management services are being provided to the Weather Modification Program for a new research aircraft data system.

INSTRUMENT DEVELOPMENT

Plans FY 1976

Planning is in an advanced stage for a new computer-based LF-HF phase and group path sounder ("Ionosonde") which is expected to become a new standard tool for ionospheric monitoring and research. In the satellite area, we look forward to a follow-on experiment to the ISEE on the Electrodynamic Explorer Satellite, which will be contractor-built, and to the opportunity, in parallel with this, to pioneer state-of-the art developments in particle measurements in space. The ATS-6 ground receiving system in southern India will continue to collect data on the equatorial anomaly region for most of 1976.

ANALYSIS GROUP

The Analysis Group of the Laboratory is involved in all aspects of the Laboratory's research and service activities that require assistance or advice in computer use. One key resource of the Laboratory, maintained by the Analysis Group, is the magnetic tape library, a vast store of information gathered from both satellite and ground based experiments over the past few years. Approximately one-third of the Analysis Group is involved in the extraction, analysis, and display of data from these tapes in support of research activities in the Laboratory.

Another third of the group is active in the design and support of real-time data systems. One such system designed by the group, the SEL Data Acquisition and Display System (SEL DADS), acquires, stores, analyzes, and displays data from the two SMS (GOES) geostationary satellites now in orbit. In late 1975, another real-time system will be installed on NOAA's new aircraft. It will provide for real-time on-board display of all data.

The remainder of the group is involved in a number of consultive and service activities ranging from the development of special numerical techniques to the operation of a complete data digitizing service.

Projects in the early development stage or planning stage include the expansion of the SEL DAD System to handle SOLRAD HI, TIROS N and the IMS ground-based magnetometer data; the installation of an SEL Remote Job Entry terminal, a false color code display system, software development for the second Research Aircraft Measurement System, processing of the data from the joint US-German ISEE (Mother-Daughter) satellite experiment, and the software system for the digital ionosonde to be developed under NSF sponsorship.

REAL TIME DATA SERVICE

The Real Time Data Service (RTDS) is responsible for the acquisition and processing of real-time solar geophysical data in support of the Space Environment Services Center (SESC) and the SEL research staff.

Accomplishments FY 1975

The RTDS maintained two observatories (at Anchorage, Alaska, and at Table Mountain near Boulder, Colorado) and continuous data flow from these two sites via teletype and computer links, to the Space Environment Services Center. The RTDS also maintained a real-time data base in the minicomputer system which is available to users via teletype. This group also supported the Air Force, Air Weather Service (AWS), via a computer data link between the SEL real-time data system and that of the AWS at Offutt Air Force Base.

Facilities for receiving data from the second SMS satellite were completed and put into operation.

REAL TIME DATA SERVICE

Plans FY 1976

Facilities are under development to support the International Magnetospheric Study program by receiving data at Boulder from 25 magnetometer stations, located mostly in remote polar regions. Data will be relayed from the remote sites via the NOAA/GOES satellite to the NOAA ground-reception point near Washington, D.C. and thence by wire to Boulder, Colorado, where the data will be processed, formated, recorded on magnetic tape and microfilm, and distributed in near real-time to scientists participating in the International Magnetospheric Study. These data will be delivered on a monthly basis to the NOAA World Data Center A for archiving. RTDS is arranging for the necessary hardware and software. It is anticipated that the data system will be operational in 1977.

Facilities for acquiring data from the SOLRAD HI satellite (launch in the spring of 1976) are being completed and the data values will be put in the real-time data base.

Plans are being made to accommodate the TIROS-N data when they become available in 1978.

SPACE ENVIRONMENT SERVICES CENTER

The Space Environment Services Center (SESC) is the national and international center for space environment information. It provides data, analyses, and forecasts to national and international users in the fields of (ground-based and satellite) communications; in scientific support for national and international programs; in natural resource and energy development; in power distribution; in conservation; and in radiation protection for civil aviation and space missions.

Accomplishments FY 1975

The real-time continuous data from the GOES satellite, consisting of solar X-ray, solar proton, and magnetic field, were fully integrated into the SESC operation. These data provide an improved technical base for issuing warnings and forecasts to operational systems and to special scientific programs. The operational real-time data system permits a duty forecaster to call up, on demand, displays of current activity for routine forecasts and to meet specific requests of users.

SESC provided radiation support to the Apollo/Soyuz joint mission, and, in cooperation with the Hydrometeorological Service of the Institute of Applied Geophysics of the USSR, an exchange of real-time solar geophysical data was commenced in July and will continue indefinitely.

A joint agreement between NOAA and the Air Weather Service was signed to provide for joint operation of the SESC and for cooperation in developing improved forecasting techniques.

SPACE ENVIRONMENT SERVICES CENTER

Plans FY 1976

Planning is under way to provide support services that will be required in the future by the International Magnetospheric Study, Solar Maximum Mission, and the SHUTTLE satellite activities. The reception and use of data from the SOLRAD HI satellite will begin during the year.

The personnel of SESC, in cooperation with the Joint Committee for Space Environment Forecasting, are reviewing the needs for a national program for real-time space environment services for the next decade. National programs that will require such support include:

1) Scientific research programs such as the International Magnetospheric Study, the Solar Maximum Mission, and Space Shuttle missions in solar, atmospheric, magnetospheric, and environmental sciences.

2) Military electromagnetic systems (communication, surveillance and navigation).

3) Civil aviation radiation protection.

4) Long-line power and communication lines.

5) Air-to-ground and satellite-to-ground communications systems.

6) Geophysical exploration.

Planning the capabilities and resources necessary to meet these service requirements will be one of the primary activities in the next year.

The SESC is now making plans for streamlining the operation of the forecast center in order to meet the workloads under conditions of increasing solar activity. The number of geophysical alerts made by SESC varies in proportion to the level of solar activity and is now near minimum. By 1979 to 1980 the alert rate is expected to be twenty times present levels.

Provision for improved environmental monitoring will also be made. Solar X-ray, ultraviolet, particle, and solar wind data from the SOLRAD HI satellite will be sent to Boulder, Colorado, in real-time for display, event recognitiion, and forecast use in the SESC.

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