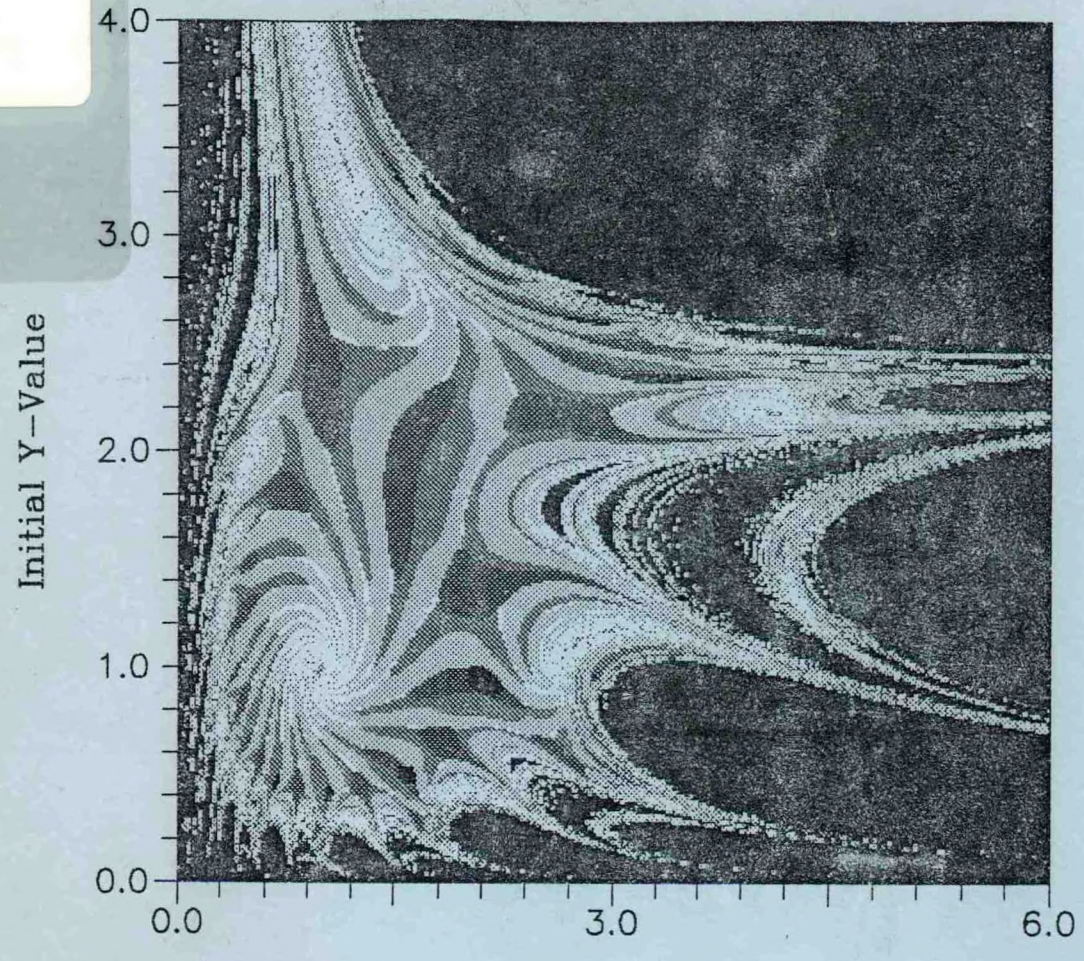
AOML ANNUAL REPORT
FISCAL YEAR 1987



Level set diagram for a discretized version of the non-linear equations:

$dX/dt=A_1+B_1X+C_1Y+D_1X^2+E_1XY+F_1Y^2$ and $dY/dt=A_2+B_2X+C_2Y+D_2X^2+E_2XY+F_2Y^2$

Where $B_1=1.000$, $B_2=-1.000$, $E_1=-1.000$, $E_2=1.000$ and other constants = 0.000

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office of Oceanic and Atmospheric Research
Environmental Research Laboratories
Atlantic Oceanographic and Meteorological Laboratory

AOML ANNUAL REPORT

Fiscal Year 1987

December 1987

Atlantic Oceanographic and Meteorological Laboratory
4301 Rickenbacker Causeway

Miami, Florida 33149

UNITED STATES
DEPARTMENT OF COMMERCE
C. WILLIAM VERITY, SECRETARY

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION
J. CURTIS MACK, II, ACT. DIRECTOR

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Atlantic Oceanographic and Meteorological Laboratory

FY 1987 Annual Report

PREFACE

This document presents the major accomplishments and plans of NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML) for fiscal years 1987 and 1988. This is the fifth annual report AOML has published in this format since the FY 1983 Annual Report was presented. It is the first such report, however, that has been completely computerized and printed inhouse using the AOML system. No annual reports were published during the period of 1980–1982 due to federal restrictions on such documents, but the AOML accomplishments were, as always, widely published in the open literature. The AOML Collected Reprint Series which were published annually between fiscal years 1970 and 1979 provide information on the plans and accomplishments for those years. The reader is invited to contact the AOML Director's Office for additional information which may be available.

AOML is located in Miami, Florida, and is one of nine Environmental Research Laboratories (ERL) which are housed within NOAA's Office of Oceanic and Atmospheric Research (OAR). The collected plans and accomplishments of all nine Environmental Research Laboratories are jointly published in two separate volumes: the *ERL Plans and Programs Document* and the *ERL Publication Abstracts*. This AOML document supplements the two ERL publications by providing a more detailed view of the AOML program during FY 1987 and 1988.

The document is organized into four major sections: (1) the Overview section is concerned primarily with management information such as the AOML mission statement, organizational chart, program structure, and information on resources; (2) the Accomplishments/Plans section discusses major FY 1987 accomplishments and FY 1988 plans within the context of the ERL program structure; (3) the Publications section includes a complete list of AOML's FY 1987 publications, with abstracts, and a list of some publications which were published in prior years but not reported in the annual reports; and (4) the AOML staff section lists the employees assigned to the laboratory as of October 31, 1987.

Inquiries and/or comments are welcomed and should be addressed to:

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OVERVIEW

FY 1987 ANNUAL REPORT

ATLANTIC OCEANOGRAPHIC AND METEOROLOGICAL LABORATORY

MISSION

The mission of NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML) is to conduct a basic and applied research program in oceanography and tropical meteorology. The program seeks to understand the physical characteristics and processes of the ocean and the atmosphere, both separately and as a coupled system. Oceanographic investigations center on the fluxes of energy, momentum, and materials through the air–sea interface; the transport and composition (thermal and chemical) of water in the ocean volume; and hydrothermal processes of mineralization at seafloor spreading centers. Meteorological research is carried out to improve the description, understanding, and prediction of hurricanes. The principal focus of these investigations is to provide knowledge that will ultimately lead to: improved prediction and forecasting of severe storms; better utilization and management of marine resources; better understanding of the factors affecting both climate and environmental quality; and improved ocean and weather services for the nation.

Organizational Structure

The AOML organizational structure (Figure 1) features four research divisions, organized according to scientific discipline as follows: (1) Hurricane Research Division (HRD); (2) Physical Oceanography Division (PhOD); (3) Ocean Chemistry Division (OCD); and (4) Ocean Acoustics Division (OAD). Hurricane research and physical oceanography are the major disciplines represented at AOML, with HRD and PhOD each comprising about a third of the total scientific effort (38% and 35%, respectively). The remaining 27% is split between OCD and OAD, with chemistry accounting for 20% and acoustics approximately 7% of the total research effort.

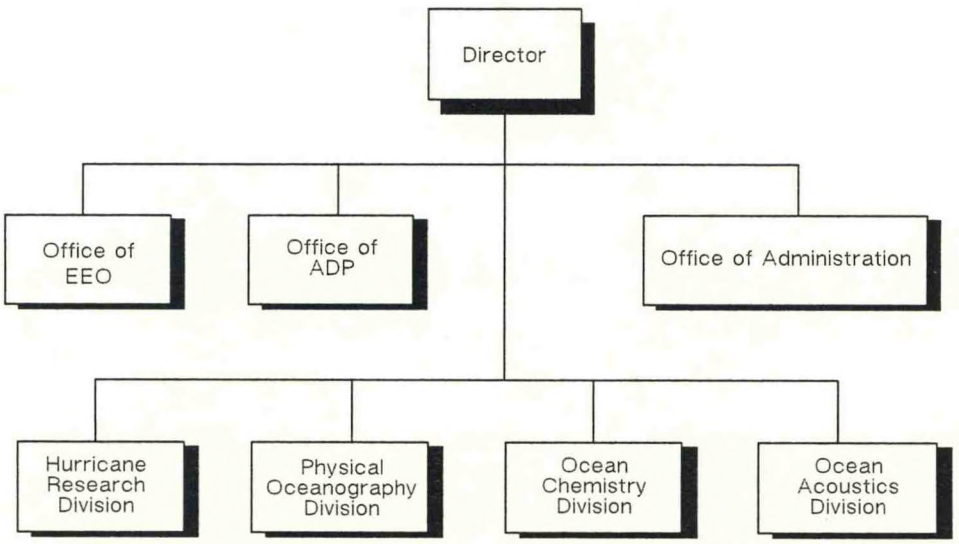

Figure 1. AOML Organizational Chart.

AO-080

PALMER, D.R., P.A. RONA, and M.J. Mottl. Acoustic imaging of high-temperature hydrothermal plumes at seafloor spreading centers. *Journal of the Acoustical Society of America* 80(3):888-898 (1986).

We explore the possibility of using active sonar techniques to acoustically image high-temperature "black smoker" hydrothermal plumes. We examine recent sonar images of a hydrothermal vent field at 11°N on the East Pacific Rise obtained from *DSRV Alvin* which may show the presence of plumes. For vent fields on the East Pacific Rise estimates are obtained of the minimum detectable concentration of precipitates as a function of the range between the sonar and the plume boundary. These estimates are compared with measured concentrations. Some of the anticipated advantages of acoustic imaging are discussed. We conclude that acoustic imaging techniques have the potential of providing a coherent framework for point sampling of physical and chemical properties of hydrothermal plumes and for determining the dynamics of their injection into the surrounding water mass.

AO-081

Peterson, D.H., D.R. Cayan, and J.F. FESTA. Interannual variability in biogeochemistry of partially mixed estuaries: Dissolved silicate cycles in northern San Francisco Bay. *Estuarine Variability* 1986:123-138 (1986).

Much of the interannual variability in partially-mixed estuaries in dissolved inorganic nutrient and dissolved oxygen patterns results from an enhancement or reduction of their annual cycle (generally via climatic forcing). In northern San Francisco Bay estuary the annual cycle of dissolved silicate supply peaks in spring and the effect of phytoplankton removal peaks in fall. Because riverine silicate sources are enhanced in wet years and reduced in dry years, the annual silicate cycle is modified accordingly. Effects of phytoplankton removal are reduced and delayed in wet years and enhanced and advanced (seen earlier) in dry years. Similar reasoning can apply to interpreting and understanding other mechanisms and rates.

AO-082

PIOTROWICZ, S.R., D.A. BORAN, and C.J. FISCHER. Ozone in the boundary layer of the equatorial Pacific Ocean. *Journal of Geophysical Research* 91:13,113-13,119 (1986).

Shipboard (~ 7 m) ozone measurements made in the equatorial Pacific Ocean between 20°N and 17°S and 140°-160°W confirm the existence of a distinct ozone minimum in the vicinity of the equator in the late spring, its decline in the summer, and its absence in autumn. This minimum could not be correlated with high biological activity in surface waters. Coincident aircraft measurements of ozone from near sea surface (50-100 m) to 2 km in altitude were made along 150°W at stations at 10°N, 0°, 5° and 12°S in May-June 1984. Aircraft data identified the existence of a distinct ozone maximum between the lifting condensation level (LCL) or cloud base ($Z\beta$) and the trade wind inversion, with ozone mixing ratios amounting to 2-2.5 times the ozone levels in the well-mixed subcloud layer. A gradient of decreasing ozone with decreasing altitude extended from the LCL (or $Z\beta$) to the near-surface superadiabatic region but did not include it.

AO-083

RONA, P.A. Black smokers on the Atlantic seafloor: Preliminary dive report. *Deep-Sea Newsletter* 12:10-11 (1986).

No abstract.

AO-084

RONA, P.A. Direct observations of black smokers on the Mid-Atlantic Ridge. *EOS* 67:1327 (1986).

No abstract.

AO-085

RONA, P.A., and D.A. Clague. Geologic setting of hydrothermal activity at the northern Gorda Ridge. *EOS* 67:1028 (1986).

The northern Gorda Ridge is a relatively sediment-starved, intermediate-spreading oceanic ridge that is morphologically similar to the Mid-Atlantic Ridge. An intensive investigation comprising bathymetry, sidescan sonar, seafloor imagery, and dredging focused on a 10 x 10 km area encompassing a zone where prior NOAA and Oregon State University cruises detected chemical and physical indicators of ongoing hydrothermal venting in the water column. The study area extends northward from the Narrowgate section where the rift valley narrows and shoals at 42°44'N, 126°45'W. The floor of the rift valley at 3,100 m is predominantly covered by fresh pillow flows with a restricted area (1 x 1 km) of sheet flows and is locally fissured. Talus in fissures in the area of sheet flows is coated white with albite by hydrothermal solutions. The walls of the rift valley rise up to 1.5 km in discrete terraces separated by fault scarps predominantly aligned subparallel to the rift valley axis (027°). A subsidiary set of fault scarps trends transverse to the rift valley axis and segments that axis at spacings of several kilometers. Sediment cover progressively increases from less than 10 percent on the floor to greater than 50 percent at mid-depth (2,500 m) on the walls of the rift valley. An anomalous row of hills about 2 km long parallel to the rift valley axis rises up to 50 m above the 2,700 m isobath on the east wall centered at 42°45.5'N, 126°42.2'W beneath the zone of hydrothermal anomalies detected in the water column. The hills are formed by fractured pillow flows. Relatively dark sediment inferred to be metalliferous and dense biomass around the hills suggests that bounding faults may be hydrothermal venting zones. Our investigation reveals that this northern section of the Gorda Ridge is a tectonically and volcanically active setting for ongoing hydrothermal activity.

AO-086

RONA, P.A., G. Klinkhammer, T.A. NELSEN, J.H. Trefry, and H. Elderfield. Black smokers, massive sulfides and vent biota at the Mid-Atlantic Ridge. *Nature* 321:33-37 (1986).

No abstract.

AO-087

RONA, P.A., R.A. Pockalny, and G. Thompson. Geologic setting and heat transfer of black smokers at TAG Hydrothermal Field, Mid-Atlantic Ridge, 26°N. *EOS* 67:1021 (1986).

The first black smokers discovered on a slow-spreading oceanic ridge occur at the center of a mound about 200 m in diameter and 60 m high situated at depths between 3,610 and 3,670 m at the juncture between the floor and east wall of the rift valley in the TAG Hydrothermal Field at 26°08'N, 44°49'W. Geologic features of the mound and the adjacent area are reconstructed from 12 deep sea camera transects, Sea Beam coverage of a 35 x 35 km area centered on the mound, and observations made on 1986 submersible dives. The mound is constructed primarily of massive sulfides and is surrounded by a zone about 150 m wide of basalt flows. A range of hydrothermal phenomena is encountered from the edge to the center of the mound increasing in temperature from schlieren effects over broad areas of the seafloor, to white and blue-white smokers discharging from bulbous chimneys up to 5 m high, to black smokers venting from spire-like chimneys up to 20 m high. A relict mound of similar size and composition is located about 2 km northeast of the active mound. Preliminary estimates of convective heat transfer from the active mound based on multiple methods indicate values of the order of 10^7 W within an order of magnitude of the vent field at 21°N at the East Pacific Rise. The zone of high-temperature hydrothermal phenomena on the lower portion of the east wall is laterally contiguous with a previously delineated zone of low-temperature phenomena at mid-depth (2,400-3,100 m) on the east wall. The low-temperature zone is characterized by weak venting of warm springs and the presence of manganese and iron oxide, hydroxide and silicate deposits. It is inferred that the high- and low-temperature zones are related by physical and chemical gradients as lateral facies of a hydrothermal system.

The total AOML program during FY 1987 was supported by 125.2 staff years of effort, with a research funding support of about 8.4 million. AOML's research funding level has remained relatively stable during the past five years (Figure 2).

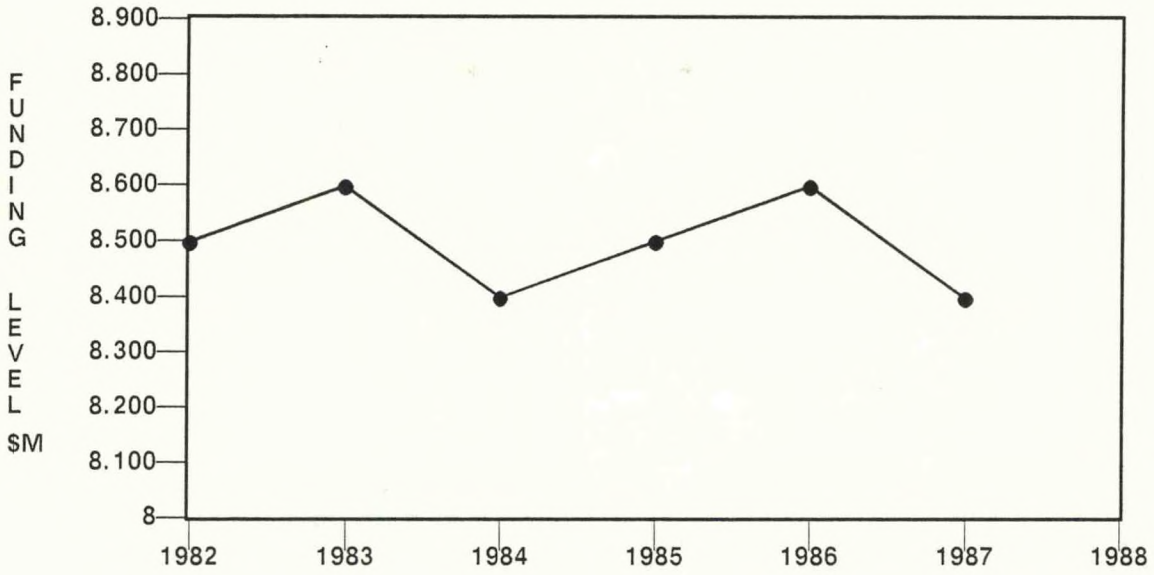

Figure 2. Research Funding Levels for FY 1983–1987.

A review of the laboratory's sources of FY 1987 program funds (Figure 3) indicates that about 95% of the total research done at AOML was funded by NOAA either by ERL directly (89%) or by NOAA Program Offices (6%). Only about 5% of the AOML effort was funded by reimbursable projects with agencies outside of NOAA. These percentages have been fairly stable over the past five years.

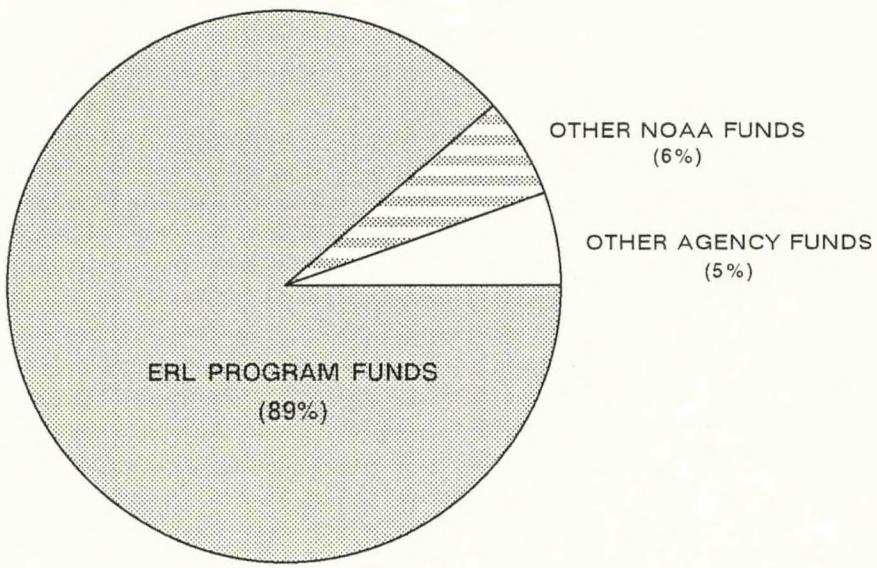

Figure 3. Funding Source Distribution (total FY 1987 funding $8.4 million).

Figure 4 portrays how AOML's funds were disbursed during FY 1987. Climate and Air Quality programs accounted for a little over $3.7 million; Weather Research was a bit more than $2.7 million; and Marine Resources work expended slightly over $1.9 million. The merging of Climate and Air Quality programs reflects the recent development of DOC and NOAA's objectives for the two programs. The distribution of funds between programs at AOML has been quite stable during the past five years.

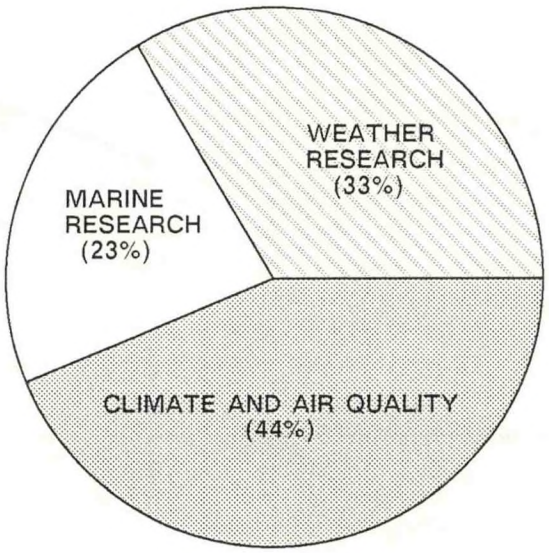

Figure 4. Program Funding Distribution (total FY 1987 $8.4 million).

The past year's high level of scientific productivity, in terms of quality and quantity, continues the long trend of proud accomplishments that AOML has maintained through the years. The uncertainties of FY 1988 pose a challenge that we look forward to meeting and overcoming with similar success.

A review of AOML's FY 1987 accomplishments is outlined in the following section, along with an outline of major plans for FY 1988.

FY 1987 ACCOMPLISHMENTS/FY 1988 PLANS

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

CLIMATE AND AIR QUALITY

Climate research at AOML focuses on aspects of ocean heat transport and storage in relation to interannual and longer term variations of weather and climate. The scope of the problems addressed requires extensive cooperation and coordination between groups. Tradition and convenient access to sea–going research facilities result in a research program with an emphasis on collection and analysis of oceanographic data. The ultimate goal of the work is to improve forecasting of oceanic and atmospheric variations. Improvement of skill in use of coupled ocean–atmosphere models is critical to achieving this goal. The primary mission of AOML's climate program is to obtain data and descriptions of the oceanic environment and processes by means of which modeling skill can be evaluated and improved, and to develop methods for assimilation of data into models as a means of providing the best possible description of the environment with whatever observations are available.

Activities are currently concentrated on problems associated with two different time scales of climate variations. The shorter of these is the interannual time scale; the El Nino/Southern Oscillation phenomenon, which is most clearly manifested in the tropical Pacific Ocean, but has global implication, is the best recognized pattern. Accordingly, AOML is a major participant in the EPOCS and TOGA programs in the tropical Pacific. AOML activities in these programs are closely integrated with those of PMEL and GFDL within ERL, and extensive cooperation exists with NWS, NMFS, NOS, and scientists in universities and in several foreign countries. There is also a modest level of investigation of the Indian Ocean in the context of TOGA.

On longer time scales, the effects of ocean circulation in carrying heat from low latitudes, where it is received in excess quantity from the Sun, to high latitudes, where it is received in deficiency, is believed to be one of the critical processes governing the climate of the Earth and its variations. Most evidence indicates that the Atlantic Ocean is particularly important in this process. Therefore, AOML is leading a program named Subtropical Atlantic Climate Studies (STACS) to learn more about the process. Although STACS is a much smaller program than TOGA, or even EPOCS, it also involves close interaction with other organizations, most notably PMEL, NOS, and the University of Miami through CIMAS.

Air quality research at AOML is a multidisciplinary research program addressing the four major categories of processes that dominate geochemical cycles in the marine troposphere as well as in the global atmosphere. These categories are related to sources, transport and distribution, transformation, and removal. The program involves inorganic and organic chemistry, lower trophic level (primarily marine) biology, meteorology, and physical oceanography, and has as its goals the generation of descriptive data on the distribution of important atmospheric trace species and the evolution of a quantitative understanding of geosphere/biosphere interactions.

AOML uses both ship and aircraft expeditions to delineate the global distributions, temporal variabilities, and air/sea fluxes of radiatively important trace species (RITS) and other substances that

directly affect their cycles. The RITS species being studied are ozone (O_3) and aerosols; among the related substances being studied are methane (CH_4), carbon monoxide (CO) and the low-molecular-weight non-methane hydrocarbons (NMHCs). A quantitative understanding of geosphere/biosphere interactions is being achieved through laboratory and field studies of the production of volatile, tropospherically important species by oceanic phytoplankton, microzooplankton, and bacteria, and the environmental factors that control this production. The laboratory program involves growing pure cultures of organisms under controlled conditions to identify volatile species being produced and to quantify their production rates as functions of parameters controlling growth. The field program involves characterization of biological activity in specific marine environments and its relationship(s) to the chemical composition of the marine boundary layer.

Accomplishments FY 1987

TOGA/EPOCS Program

- AOML has for several years been collecting sea surface current and temperature data from the tropical Pacific by means of satellite-tracked drifting buoys. Development of strategies to reduce the cost of data collection, and an increased commitment to the western Pacific on the part of the TOGA Program have led to a significant improvement in data coverage. In 1987, data were being collected at moderate density across the entire tropical Pacific Ocean.
- A series of oceanographic cruises was conducted to explore oceanographic conditions and their seasonal and interannual variations westward from Peru. Part of this work led to a historic water-sampling section; a section completely across the Pacific basin at about 15°S, in collaboration with PMEL.
- Close cooperation with NMFS was initiated to conduct water sampling from two NOAA research vessels that are scheduled to conduct an extensive census of marine mammals in the eastern tropical Pacific during each of the next several years. These data will contribute to the goals of NMFS as well as TOGA/EPOCS.
- A project was initiated to collect and apply the information necessary for evaluation of the possibility of using satellite altimeter data for determination of ocean surface currents with spatial resolution on the order of 1 kilometer.
- Substantial progress was made toward development of methodology for four-dimensional assimilation of data into numerical models of the ocean circulation. Data assimilation was possible in principle by using methods developed for engineering problems involving just a few variables, but for application to ocean circulation this required unrealizable computer capability. The new approach appears to have made it practical.

Acoustical Dynamic Height Measurements (EPOCS)

AOML/Ocean Acoustics Division (OAD) has had an on-going study of acoustical inverted echo-sounder/pressure gauge (IES/PG) systems used for the measurement and study of oceanic dynamic height variations. In FY 1987 three IES/PG systems were deployed in the Pacific Ocean at selected locations for use in comparison with satellite derived dynamic heights; IES/PG data gathered near and east of the island of Abaco in the Bahamas have been processed and partially analyzed.

Subtropical Atlantic Climate Studies

- During FY 1987 three research cruises were conducted in the region of the Florida Current and the Antilles Current.
- An array of sea level stations and measurements of induced electrical potential (by PMEL) were maintained in operation for monitoring the surface current and total flow of the Florida Current.

- A method for using sea-level data for nowcasting of surface currents off Florida was provided to NWS for its suite of service products.
- A pilot measurement program using radar to measure near-coastal current patterns on an operational basis was initiated in cooperation with NWS and NOS.

RITS

Two major field programs were conducted.

- A research cruise in the equatorial Pacific Ocean continued efforts to determine what processes control the distribution of RITS in the equatorial regions and, specifically, to understand the cycle and causes of the ozone minimum observed at certain times of the year in the equatorial Pacific.
- An aircraft experiment in the western equatorial Pacific and eastern equatorial Indian Oceans investigated the role of dynamic processes in determining the distribution of ozone in the marine boundary layer, the transfer rate of ozone from the free troposphere to the marine boundary layer, the fluxes of ozone within the boundary layer, and the spatial scales over which ozone distributions are homogeneous.

AOML published the results of its first two years of research on ozone. These data, together with other published data and the FY 1987 RITS research cruise data, further defined the temporal limits of the equatorial ozone minimum. It appears to be a totally Northern Hemisphere spring phenomenon. A FY 1989 field program is planned to investigate these processes further in February and March. Data from the FY 1986 program indicate that the transport of ozone, ozone precursors, and other species off the west coast of central Africa during the dry season may have a much more significant role in global, tropospheric chemical processes in equatorial regions than originally thought. Preliminary results from the aircraft experiment indicate that ozone is distributed homogeneously in the clean, marine boundary layer over mesoscale regions. Above the boundary layer, however, heterogeneity in horizontal distributions of ozone on kilometer scales, probably associated with advective processes, was observed. The frequency of such episodic events and their effect on ozone budgets in the free troposphere remain to be quantified.

Plans FY 1988

TOGA/EPOCS Programs

Participation in TOGA and EPOCS will continue as the major focus of AOML's research on the interannual variation of climate.

- The ongoing program of drifting buoy releases in the tropical Pacific Ocean will be coordinated with buoys to be released by scientists associated with Scripps Institution of Oceanography, Woods Hole Oceanographic Institution, Australia, and France. This joint activity, named the TOGA Drifter Pan Pacific Project, will yield a sixfold increase in the density of sea-surface current and temperature data from drifting buoys in the tropical Pacific. A drifter data center will be established at AOML.
- Research vessel cruises, drifting buoys, and satellite altimetry will be used to study the spatial and temporal variations of the North Equatorial Countercurrent (NECC), the possible relationship between the NECC and instability waves, the role of the NECC in advecting heat into the eastern Pacific, and the generation of thermal anomalies associated with El Nino.
- The established level of interaction and cooperation with oceanographic institutions in countries on the Pacific coast of Latin America will be expanded to include more countries and to include cooperation with these countries for collection of coastal sea level and meteorological observations of critical importance to the TOGA Program.
- The data assimilation scheme that has been developed and evaluated in use with simple models will be developed for use with the ocean general circulation model constructed at GFDL and now in use at NWS.

Acoustical Dynamic Height Measurements (EPOCS)

In FY 1988, further reduction and analysis of the acoustical dynamic height data from the vicinity of Abaco will continue. The IES/PG in the Pacific will continue recording data, and earlier portions of the data records will be processed and analyzed. An in-depth study of the basic performance characteristics of the IES/PG systems will be carried out with an emphasis on interpretation of the acoustical echo returns.

Subtropical Atlantic Climate Studies

The emphasis of the Subtropical Atlantic Climate Studies will shift to more distant problems associated with the North Atlantic subtropical circulation, especially those in the southwestern section of the gyre. This program will evolve into a major part of the NOAA contribution to addressing problems of global change. Close coordination with other agencies is planned, to take maximum advantage of the existence of the World Ocean Circulation Experiment of the World Climate Research Program.

- Research vessel cruises will be conducted to investigate the pattern, variability, and climate effects of the boundary currents in the region from the Bahama Islands to Brazil.
- Investigation of the use of sea-level measurements to infer the pattern and variations of ocean currents will continue. A new dimension in sea-level data coverage will be provided by the altimeter data from the GEOSAT satellite.
- Increased cooperation with oceanographic agencies in nations of the Caribbean region is planned for the purpose of increasing their interest and capability in operating sea-level stations to obtain data for global climate studies as well as regional applications.

RITS

Shipboard and aircraft work will be conducted in the North Atlantic Ocean. Included with the suite of existing work, new studies in FY 1988 will investigate the distribution and chemistry of nitric oxide (NO) and nitrogen dioxide (NO_2) in the ocean environment.

WEATHER RESEARCH

The focus of AOML's weather research is on tropical meteorology and hurricanes. Research teams in the Hurricane Research Division (HRD) concentrate on field programs, numerical hurricane modeling, and theoretical studies of hurricanes. The Laboratory's hurricane field program makes use of NOAA research aircraft to acquire unique data sets. AOML interacts with the National Hurricane Center (NHC) and the National Meteorological Center (NMC) in problems of hurricane prediction, the National Center for Atmospheric Research (NCAR) on scientific investigations of the inner cores of hurricanes, and the Geophysical Fluid Dynamics Laboratory (GFDL) on hurricane modeling.

Accomplishments FY-1987

Synoptic-Scale Flow Around Mature Hurricanes

This work is concerned with obtaining accurate and sufficiently dense meteorological information for use in identifying steering currents and their effects on mature hurricanes, their movement, and their potential for change. Data are being obtained from Omega dropwindsondes (ODWs) deployed from NOAA research aircraft while they are investigating in and around hurricanes. The data (the most recent of which is from Hurricane Emily, 1987) are part of a growing, unique set, which, after supplied in

real-time to assist operation forecasters at the National Hurricane Center, are being used in cooperative research with the National Meteorological Center to test dynamical hurricane track prediction models. These tests include models under development as well as those that are used in aiding operational forecasting. A movable fine-mesh (MFM) hurricane track prediction model used at NMC is now undergoing tests to determine the impact of the ODW data on the model's performance.

Mesoscale Precipitation in Mature Hurricanes

This research seeks to identify the mesoscale and convective-scale features in mature hurricanes and to describe their basic organization and structure. Recent work has concentrated on the wind field derived from Doppler radar for Hurricane Norbert (1984), the first hurricane for which a complete set of such data exists. Partitioning these wind data into various components has shown complex interactions between the components in determining the storm motion and in forcing mesoscale divergence-convergence patterns. The forcing components appeared to be a major influence in producing a significant asymmetry in vertical velocity such that ascent was on the west side of the storm and descent on the east side.

Convective Rainbands in Hurricanes

This research attempts to understand the role of convective rainbands in modifying hurricane structure and intensity. A study of one rainband in Hurricane Irene of 1981 has shown how the airflow toward the storm center is modified by the band and how the band structure and intensity are modified as a result of band position and motion relative to the storm center. Large differences in static stability were found between the interior and exterior edges of the rainband. The position and motion of the rainband appear to be critical to its maintenance or intensification. Rainband data from Hurricanes Raymond (1983) and Paine (1986) are also under study.

Microphysical Studies in Hurricanes

This research is to determine the microphysical characteristics of hurricane clouds as a function of the measured vertical velocity of the air at important structural locations within the storm, and to understand how the latent heat released on the cloud scale is transmitted to the mesoscale circulation of the storm. Analyses of the stratiform precipitation regions of several hurricanes were completed. Some of the data sets include air velocity profiles through the melting layer that were derived from Doppler radar. Analysis of data obtained in a two-aircraft microphysics experiment carried out in Hurricane Newton (1986) has started. These analyses should result in excellent microphysical and radar data descriptions of the hurricane's melting layer.

Convective and Mesoscale Structure of Landfalling Hurricanes

This research examines changes in hurricane structure that are revealed by data from National Weather Service (NWS) radars, recorded during the approach and landfall of hurricanes. Color, time-lapse movies of such data, collected during the landfall of Hurricanes Diana of 1984 and Elena of 1985 were completed. A color video tape was made that includes data from Hurricanes David, Frederic, Alicia, Diana, and Elena. The soundtrack of the videotape describes the significant events represented. The movies conceptualize storm development and movement by showing a color sequence of storm radar reflectivities for a selected period in plan view and in reference to geographic outline of the landfall area. Storm movement and center position are identified with a track line representation and a storm symbol.

Time variations of area-averaged rainfall in the inner core regions of Hurricanes Alicia, David, and Elena were estimated through calculations from these radar data, for times before storm landfall (when the inner core regions of the hurricanes were over the ocean). Rainfalls were calculated for the area

within 75 km of the center of the hurricanes. Large, short-term (3–5 h) rainfall variations were detected and found to be caused by short-lived, small mesoscale convection occurring within the storms.

Tropical Cyclone Supercells

This work concerns the formation, structure, and evolution of large supercells within tropical cyclone circulations. Large convective bursts lasting 12 to 24 hours sometime occur near tropical cyclone eyewall regions and disrupt any trends in storm deepening for a day or two. Such supercell events observed in Hurricanes Norbert (1984) and Gladys (1975) were compared. High cloud motions indicate that an easterly jet impinged on both storms at the time of supercell occurrence. It appears that interaction of the easterly jet with the storm circulation produced a vertical motion couplet (down on the east side of the storm and up on the west side) that generated anomalously warm, dry air at low levels, which then advected from the east to the west side of the storm. The result was the development of a condition similar to a Midwest severe weather type sounding in the presence of forced ascent. Intense supercell convection followed.

Observational Studies of Hurricane Air–Sea Interaction

The goals of this research are to develop a surface-wind analysis scheme for tropical cyclones and to study the structure and dynamics of the atmospheric and oceanic boundary layers associated with tropical cyclones. A full-scale boundary layer experiment was conducted in Hurricane Earl of 1986. The two NOAA WP-3D aircraft flew simultaneous sounding patterns on either side of an intense rainband associated with the storm, and also made cross-band profiles 50 km apart. AXBTs and ODWs were dropped from 1500 m by both aircraft. Preliminary results show the initiation of a major thermodynamic perturbation in the atmospheric boundary layer, which took the form of low equivalent potential temperature air spreading out downwind from a large, intense convective cell. This event will be studied further to assess its role in the modification of convective processes farther downstream.

During this experiment, surface winds, derived from stepped frequency microwave radiometer (SFMR) data, were calculated in real time and continuously updated by means of a microcomputer with direct input from the SFMR. This work will soon lead to real-time transmission of surface wind estimates to NHC during NOAA WP-3D storm flights, for use in intensity forecasting.

Quasi-Spectral Hurricane Model

To achieve substantial improvement over the existing operational hurricane prediction models, and to facilitate studies of hurricane dynamics, a general-purpose hurricane model on nested grids is under development. This model uses an accurate and flexible numerical method known as QSTING (Quasi-Spectral Time Integration on Nested Grids) in which the spectral representation of field variables is by cubic beta-splines. This method combines the numerical accuracy of spectral methods with the freedom of specifying boundary/interface conditions for nested finite domains. A major achievement in 1987 was the addition of a mesh-moving capability to the basic model. The method of movable nesting used here is noise-free as expected from the theory of spline-spectral representation and requires no device to control numerical noise. The method is two orders of magnitude more accurate than the finite-difference methods used elsewhere in comparable applications. The basic model is now ready for HRD use.

Vortex Motion and Dynamics

This research seeks to improve understanding of hurricane motion, evolution, and internal structure through detailed analysis of data from research aircraft and through formulation of relatively simple theoretical models. The work also includes an effort to improve hurricane forecasts through real-time analysis and interpretation of aircraft data.

Calculations with a quasi-analytical linear model for the motion of a hurricane-like vortex showed that if the total relative angular momentum of the mean vortex is zero, the motion of the vortex through its surroundings is also zero in contrast to earlier studies that predicted a westward drift.

Software for real-time analysis of hurricane tracks and structure based on real-time transmissions of data from aircraft flying in the hurricane circulation was developed and implemented. The software had been tested operationally during Hurricane Charley of 1986 and now runs on a microcomputer that HRD has installed for use at NHC.

Objective Analysis of the Tropics

The goal of this research is to develop objective analysis schemes for the large-scale tropics and for the hurricane environment. The analysis schemes will incorporate ODW and other available data such as rawinsondes, NOAA WP-3D data, USAF reconnaissance data, and satellite-derived products. Particular uses of the scheme apply to ODW data from the hurricane environment and to routine daily analysis over the tropics.

Three-dimensional wind, temperature, and relative humidity analyses for the environment of Hurricane Debby were completed. The analysis has high resolution in the vertical (19 levels from 100 mb to the surface), and the winds are on a nested grid. Several diagnostics were computed from the thermodynamic fields including estimated precipitation rates. Comparisons with estimated precipitation from the WP-3D radars show that the results are reasonable.

Tropical Wave Dynamics

The goal of this research is to improve understanding of the structure and dynamics of the easterly atmospheric wave disturbances over the tropical Atlantic Ocean. The work complements observational studies of these systems through use of a theoretical model of interactions between the waves and their environment. A linear primitive equation model was used to study the vertical structure of Caribbean easterly waves as determined by the interaction between convective heating and the environmental wind. Very good agreement was found between the model-derived vertical structure of the waves and the observed vertical structure.

Tropical Climatology

The goal of this research is to establish a climatology for quasi-steady and propagating atmospheric disturbances over the tropical Atlantic. This will include studies of the relationship of the long-term variability of the winds to climatic fluctuations and hurricane cycles.

Monthly mean winds were derived from the ATOLL (Analysis of the Tropical Oceanic Lower Layer) and 200 mb analyses over the southern North Atlantic, Caribbean, Gulf of Mexico, and eastern Pacific during the hurricane seasons of 1975-1985. After the seasonal cycle was removed, the winds were expressed in terms of empirical orthogonal functions. The dominant mode of variability for the combined 200 mb/ATOLL circulation strongly resembled part of a Walker cell confined near the Equator. This mode is strongly correlated with an objective El Nino index, and is associated with the El Nino/Southern Oscillation. A positive (El Nino-like) index tends to be associated with more anticyclonic vorticity at the ATOLL analysis level, and with increases in the vertical shear between 10°N and 30°N, both of which are unfavorable for tropical storm formation.

Correlations were derived between the monthly mean winds and monthly tropical storm frequency in the Atlantic basin. Contemporaneous correlations in August, September, and October, the three most active months, as well as correlations between winds and tropical storm formation 1 and 2 months later,

were computed. Predictability of monthly tropical storm frequency at the 2-month lead is statistically significant, true skill being approximately 45% of the variance. A favorable environment for storm formation is apparently established at least 2 months before the actual formation.

Equatorial Mesoscale Experiment (EMEX)

EMEX was held in conjunction with NASA's Stratospheric Experiment (STEP) and the Australian Monsoon Experiment (AMEX). The primary scientific objective of EMEX was to define the vertical profile of atmospheric heating produced by cloud clusters in the oceanic area around northern Australia. The accurate determination of this profile is critically important for numerical weather prediction and for climate studies. It is expected that the diabatic heating profile, averaged over a cloud cluster, will reflect a maximum at a much higher level in the troposphere when stratiform clouds are present than when only deep cumulus clouds are present. A second objective is the definition of the details of the mesoscale circulation within the stratiform region of the cloud cluster. The field phase of EMEX was based in Darwin, Australia, from 10 January to 3 February 1987 and was a complete success in terms of gathering the data required to achieve the core objective. HRD has processed all (about 60) of the EMEX ODWs and prepared a data book that was distributed to EMEX scientists.

PRE-STORM and GALE

HRD participated in the PRE-STORM and GALE field programs in 1985 and 1986, respectively, by obtaining data from NWS radars. The data are being used to study mesoscale convective systems (MCSs) observed in the Midwest and off the Carolina coast.

Climatology of the Atmosphere's Thermodynamic Structure

The Arakawa-Schubert cumulus parameterization is being applied to various atmospheric regimes to quantify the buoyant energy (the cloud work function) available to cumulus clouds and to predict the cumulus precipitation over areas comparable in size with a grid box of a global model. Calculations made with south Florida summer data show that the means and standard deviations of the work function are generally similar to those in other regions and are quite similar to those found during the Venezuela International Meteorological and Hydrological Experiment (VIMHEX) (1969; 1972) experiment.

Plans FY 1988

Synoptic-Scale Flow Around Mature Hurricanes

Cooperative studies with NMC and NHC to examine the effect of ODW data on the operational analyses and hurricane track prediction models will continue. ODW data collected during the 1987 hurricane field program will be processed and distributed to other institutions.

Mesoscale Precipitation Features in Mature Hurricanes

Studies describing the kinematic and microphysical structure of the eyewall of Hurricane Norbert will be completed. Work on the eyewall water budget calculation for Norbert will continue. Work on a climatology of vertical incidence data and vertical velocity data from mature storms that have been sampled since 1983 will begin.

Convective Rainbands in Hurricanes

Wind fields derived from Doppler radar for Hurricane Raymond of 1983 will be studied to determine the outflow, inflow, and convergence characteristics of the rainband convection as a function of time.

This will lead to improved understanding of the rainband–hurricane interaction process. Work will continue on the rainband data from Tropical Storm Isabel of 1985 and Hurricane Paine of 1986.

Microphysical Studies in Hurricanes

Microphysical data collected in the Hurricane Norbert (1984) supercell will be analyzed and compared with the results for earlier cases. The microphysical data from Norbert will also be used to continue research on the origins of ice in hurricane clouds. Work will continue on a comprehensive study of the shapes of ice distributions in hurricane clouds. Research will attempt to assess how much of the ice mass in hurricane stratiform precipitation areas is added *in-situ* by particle growth due to mesoscale ascent, and how much is due to the transport of ice into these regions from more convective features.

Convective and Mesoscale Structure of Landfalling Hurricanes

A study of estimates (based on radar data) of the temporal and spatial variations of rainfall near the centers of Hurricanes Alicia, David, and Elena will be completed. Analysis of data gathered from NWS radars at Miami and Key West during Hurricane Floyd will start.

Tropical Cyclone Supercells

Analyses of the supercell events in Hurricanes Norbert, Diana, and Gladys will continue. Work will begin on a qualitative model of the thermodynamic, kinematic, and microphysical structures of supercells.

Observational Studies of Hurricane Air–Sea Interaction

Work will begin on developing a method to synthesize various types of surface data to provide an objective surface analysis for tropical cyclones. The SFMR data will be the primary input to the synthesis. It is planned to provide the analysis to NHC in real time. Studies will be made of near-surface winds derived from airborne Doppler. These will be compared with the SFMR data and low-level aircraft *in-situ* measured winds.

Quasi-Spectral Hurricane Model

Theoretical work on the design of three-dimensional models of the moist atmosphere will continue. A relatively simple three-dimensional model of a hurricane consisting of four layers in the vertical, and with multiple nested domains in the horizontal, will be developed and used to compare the vertical coupling and interaction in the hurricane that results from parameterized and explicitly calculated moist convection.

Studies that make use of the quasi-spectral moving nested-grid technology will include experiments in hurricane track prediction with a barotropic model and real data, and studies with hypothetical initial data for the purpose of studying the properties of a barotropic quasi-spectral nested-grid model on various map projections with variable map-scale factors. A set of idealized numerical experiments is planned to investigate the influence of divergence and advective nonlinearities on hurricane motion and on asymmetries due to the beta effect.

Objective Analyses of the Tropics

Real-time analysis of the tropics at the 850 mb and 200 mb levels will be undertaken and the results will be compared with NMC and NHC products. Research will be directed at the incorporation of winds

derived from the airborne Doppler radars aboard the NOAA WP-3D aircraft. This is of particular importance in the presence of a hurricane since the Doppler winds provide necessary information on the structure of the vortex core.

Tropical Climatology

Studies of the long-term variability of the tropical atmosphere will be extended to concentrate on several time scales. These will include the quasi-biennial and 40-50 day oscillations. The studies will establish the tropical wind variability and hurricane cycles associated with these oscillations, as well as the predictability of the cycles. Research to relate the cycles to objective indices of the quasi-biennial and 40-50 day oscillations will be carried out.

Equatorial Mesoscale Experiment (EMEX)

An EMEX analysis plan will be developed. A workshop for EMEX scientists is planned for January 1988 in the United States. An international EMEX meeting will be held in Brisbane, Australia, in July 1988.

PRE-STORM and GALE

A climatology of Gulf Stream-associated rainbands observed during GALE will be completed. Work will continue on a climatology of Oklahoma MCSs.

Climatology of the Atmospheric Thermodynamic Structure

The study of the south Florida data will be completed. The methodology will be extended to middle-latitude data sets, and analysis of thermodynamic variables over the United States for four summer months in the years 1973-1976 will be started.

MARINE RESEARCH

AOML studies in Marine Research are directed toward determining the chemical and thermal effects on the ocean of hydrothermal venting at the ocean floor from representative sections of the slow-spreading Gorda-Juan de Fuca Ridge and Mid-Atlantic Ridge. These efforts are central to the objectives of the NOAA VENTS program.

AOML studies in Marine Research are also concentrated in the following: (1) Improving the definition and measurement of the ocean bottom depth for charting, navigation, and bathymetric purposes; (2) Potential operational system evaluation and demonstrations. This research is aimed at improving the observational equipment and techniques that are used to collect data on the marine environment; particular emphasis is placed on the use of new, advanced, high-technology systems; (3) Improving measurements of naturally occurring water column particle distributions and the distribution of particulate matter produced through human activities (*e.g.*, dumping materials in the ocean).

The Fisheries-Oceanography Cooperative Investigations (FOCI) at AOML seek to understand the several processes that, either in combination or separately, serve to regulate year class strengths of commercial fisheries. AOML researchers, in cooperation with PMEL, NMFS's Northwest and Alaska Fishery Center, and the University of Miami, are attempting to combine emerging technologies in physical and biological oceanography with those in fisheries science and meteorology. By successfully linking all the parameters involved with these various scientific regimes, researchers hope to better predict fisheries stocks.

Accomplishments FY 1987

VENTS

Prior to the first discovery of black smokers at the slow-spreading Mid-Atlantic Ridge by the VENTS program in 1985, the scientific consensus was that high-temperature venting (350°C) was limited to faster-spreading oceanic ridges where geothermal heat would be supplied at a rate adequate to sustain such venting. The discovery of the black smokers has prompted a new evaluation of the role of hydrothermal activity at slow-spreading oceanic ridges which extend more than half the 55,000 km global length of the oceanic ridge system. This new evaluation pertains to the influence of venting from these slow-spreading oceanic ridges on the ocean environment through effects on ocean chemistry, ocean thermal structure, seafloor mineralization, and biological adaptation. Significant progress was made with reference to this new evaluation in FY 1987 along several lines of research, as follows.

Mid-Atlantic Ridge

The initial investigation of high-temperature hydrothermal fluids venting from any slow-spreading oceanic ridge was made by the NOAA-WHOI-MIT scientific team (supported by NOAA and NSF) diving with *Alvin* at the discovery site of black smokers at the Mid-Atlantic Ridge. This investigation revealed chemical and physical characteristics.

- Solution chemistry: Solution chemistry was similar, with reference to major elements (iron, manganese and silica), to solutions sampled from faster-spreading oceanic ridges, but differed with reference to minor elements (rare-earth elements and boron isotopes). The measurements indicate both similarities and significant variations in the evolution of hydrothermal fluids between slow- and faster-spreading oceanic ridges.
- Heat transfer: A preliminary estimate of the convective component of heat transferred by the venting solutions at the Mid-Atlantic Ridge site is the same order of magnitude as that measured at a hydrothermal field at a fast-spreading portion of the East Pacific Rise (10^8 W). This measurement suggests that, although the overall rate of heat supply may differ between slow- and faster-spreading oceanic ridges, the convective component of heat transfer at individual hydrothermal sites may be similar.

The variation of hydrothermal activity at the Mid-Atlantic Ridge black smoker site through the past 10,000 years has been deciphered from a sediment core about 1 m long. AOML and Florida Institute of Technology scientists have analyzed the particulate metals (iron, copper, aluminum, zinc, lead, cadmium, nickel, chromium) present along the length of the core as an index of hydrothermal input within a radiometrically determined time frame (carbon 14). Their findings indicate significant fluctuations in temperature and intensity of venting during the time interval analyzed, demonstrating that venting is not a steady-state phenomenon.

Gorda-Juan de Fuca Ridge System

The findings reported at the black smoker site at the Mid-Atlantic Ridge feed back directly to the area of VENTS program focus at the Gorda-Juan de Fuca Ridge.

- The Gorda Ridge is the only ridge in the Pacific Ocean with slow-spreading characteristics and, as such, is an analog of the Mid-Atlantic Ridge. Discoveries at the Mid-Atlantic Ridge are being used to guide investigation of the Gorda Ridge and to predict the nature of hydrothermal activity at the Gorda Ridge, and will be used to generalize results of studies of venting at the Gorda Ridge with reference to chemical effects on the ocean.
- Cooperative work by NOAA and Oregon State University investigators has revealed the presence of active hydrothermal sites at the northern Gorda Ridge.

- Analysis at AOML of sediment cores and suspended particulate matter recovered from the hydrothermal sites at the northern Gorda Ridge revealed the presence of high-temperature assemblages of metal compounds (iron sulfide, copper silicate, and calcium sulfate), indicating that the venting is from high-temperature black smokers. Analysis of sediment recovered from the GR-14 site indicated enrichment of at least copper (1000 ppm), supporting the inference of high-temperature hydrothermal activity at this site.

- Work in collaboration with U.S. Geological Survey investigators has revealed that the location of the high-temperature venting sites at the northern Gorda Ridge is localized at the intersection of anomalous seafloor lineaments that create permeability, which channelizes and focuses hydrothermal venting from the seafloor. One of the two principal venting zones (GR-14) was located to within hundreds of meters; the second venting zone (GR-15) was located to within kilometers. A NOAA cruise used deep-towed, high-resolution side scan sonar (SeaMARC 1A system) to delineate the intersections of these anomalous seafloor lineaments along the northern segment of the Gorda Ridge. This finding is being applied as a key to pinpoint the locations of the principal venting zones at the northern Gorda Ridge, which then will be characterized to determine the chemical effects of the venting from these zones on the northeast Pacific.

- Collaborative AOML-PMEL field work to obtain heat transfer measurements and sediment cores at selected locations at the intermediate-spreading-rate Juan de Fuca Ridge (including Axial Seamount) is providing a basis to tie together the VENTS program work on venting across the range of spreading rates present in the northeast Pacific.

Plume Studies

As part of an ongoing program for the study of waste material plumes in the coastal ocean environment, AOML and EPA plume models were installed in the AOML/VAX computer for use in conjunction with a series of wastewater plume field exercises to commence in October 1987. AOML plume models were used to analyze plume particulate materials released in an oceanic oil drilling field exercise. A theoretical framework was developed to relate acoustic backscattering intensity levels to particle concentration levels and to the concentration of substances associated with particles.

Echo Formation Models

AOML has an ongoing cooperative program with NOS to improve echo-formation models and hence improve the quality of bottom-depth charts. In FY 1987, data from an echo-formation experiment in Chesapeake Bay, which presented a variety of bottom types, were processed and analyzed. These data were then used to evaluate theoretical bottom echo-formation models.

The predictions of the theoretical models were generally confirmed by the field data when proper allowance was made for ship motion and other instrumental effects. The best method for timing the echo and hence locating the bottom was found to be a threshold energy criteria in which the threshold energy is determined by an average obtained from a large number of pulses. This method can be implemented with a microprocessor embedded within the depth-sounder. Further work is in progress on the possibility of using microprocessor "speech-recognition" hardware to extract information about the bottom type from the echo waveforms.

Fisheries-Oceanography Cooperative Investigations (FOCI)

The AOML FOCI program has conducted three Spring cruises during FY 1987. The initial cruise had as its primary objectives the delineation of the two-dimensional structure of plankton patchiness by photographic and acoustic methods in conjunction with detailed physical mapping using acoustic Doppler current profiling systems. Sampling occurred within the San Pedro Basin off Los Angeles aboard *R/V New*

Horizons of the Scripps Institution of Oceanography. This study was a collaborative effort with investigators from the University of Southern California and Tracor, Inc. The site was selected because of its relative stability within the complex advective system of the California Current, and the choice proved to be judicious. A degree of spatial resolution heretofore unattainable was achieved. A new electronics system proved to be far more reliable than previous systems, and more than 95% of the deployments were entirely successful.

The second and third cruises were both FOX (Fisheries Oceanography Experiment) cruises aboard *F/V Miller Freeman*. This program sought to apply, to a specific fishery (pollock) within a specific ecosystem (the Gulf of Alaska), the tools and insights generated by recent basic research programs. The first cruise was scheduled right after the presumed pollock spawning period. For the first time, detailed vertical profiles of the distribution of pollock eggs were obtained. Although this information is critical to the NMFS/PMEL model seeking to explain larval abundance, it was not, for primarily technical reasons, previously available. In addition, considerable data were obtained on the scattering strengths of pollock eggs of different ages and of representative food organisms and planktonic competitors of larval pollock. These data are prerequisite to finalizing designs for the acoustic sensor that will be an integral part of the system being developed for the FY 1988 mixing experiment cruise.

The last cruise repeated the FY 1986 larval abundance cruise. Once again a spawning center was located, and both its vertical and horizontal extent were accurately delimited. It proved, as expected, to be considerably more dispersed than the egg patch preceding it. The data from the two larvae cruises represent the first truly quantitative assessment of pollock larvae distribution within the Shelikof Straits.

For this field season fully microprocessor-controlled zooplankton sampling gear, the hardware and software for which were largely of AOML's design and construction, was employed for the first time. Results exceeded all expectations, and the prototypes used on the cruises are now being converted into PC configurations for enhanced ruggedness and reliability. The design called for later incorporation of a real-time acoustic sensor, the "searchlight sonar," which is currently under construction. The goal has been to have real-time display of both physical (temperature and salinity) and biological (acoustic backscatter and fluorescence) data, and photographic confirmation of organism identity.

Film sequences were obtained on a series of *in-situ* camera profiles in 1985. The plankton have been enumerated to yield high-resolution vertical profiles of distribution.

The results of AOML's basic research program highlight the degree to which vertical structure within the organisms of the upper water column can radically change over intervals of a few hours and the potential utility of integrating acoustic Doppler current profiler (ADCP) data with biological sampling. These results have already substantially influenced the planning efforts for the FOX program in FY 1988 and the zooplankton research to be conducted within the national GOFS (Global Ocean Flux Study) as proposed to the National Science Foundation.

Plans FY 1988

VENTS

- Identify and begin to characterize the venting zones at the northern Gorda Ridge at sites GR-14 and GR-15.
- Resolve tectonic trends that are controlling the venting at these two sites, using the Sea MARC 1A deep-towed side scan sonar.

- Establish a common basis for comparison and extrapolation of measurements from the Mid-Atlantic Ridge to the Gorda-Juan de Fuca Ridge by carrying out a parallel set of observations of hydrothermal plume characteristics at the TAG segment of the Mid-Atlantic Ridge where the VENTS program found the first black smokers in the Atlantic Ocean. Also, develop another ridge segment that will extend the limited known composition and pressure field of hydrothermal solutions in this setting. Use this work as the basis of surface ship and submersible investigations of hydrothermal processes at the Mid-Atlantic Ridge as part of the U.S.-France Bilateral Agreement.

Plume Studies

- Process and analyze the data from the October 1987 wastewater plume field exercises, and use that data to evaluate the AOML plume model.
- Compare acoustical backscattering levels with dye tracing; conduct biotoxicity tests.

Echo Formation Models

- Describe the future directions for research in and applications of the new echo-formation model.

Fisheries-Oceanography Cooperative Investigations (FOCI)

- Work-up of the previous year's samples, analyze last year's data, participate in a cruise to Shelikof Straits, and complete research and development efforts directed toward improved sampling techniques for eggs, larvae, and zooplankton.

FY PUBLICATIONS

(Publications which were published in 1986 but which were not mentioned in the 1986 Annual Report are listed in the addendum to this section.)

FY-1987 PUBLICATIONS

ATLANTIC OCEANOGRAPHIC AND METEOROLOGICAL LABORATORY

AO-001

ATWOOD, D.K., H.H. CUMMINGS, W.J. NODAL, and R. CABALLERO-CULBERTSON. The CARIPOL Petroleum Pollution Monitoring Project and the CARIPOL petroleum pollution database. *Caribbean Journal of Science* 23(1):1-3 (1987).

In 1976 an IOC/FAO/UNEP workshop on Marine Pollution Monitoring in the Caribbean and Adjacent Regions established petroleum to be the priority pollutant of concern to the region. In 1979 IOCARIBE established the CARIPOL Marine Pollution Research and Monitoring Program and defined, as its first project, the monitoring of petroleum pollution in terms of three parameters, *i.e.*, tar on beaches, floating tar, and dissolved/dispersed petroleum hydrocarbons. In 1980 IOCARIBE conducted workshops in English and Spanish to train participants from regional governments in the methodology necessary to measure these parameters and published a manual for use by these participants in both languages. Since that time, participants from various governments in the region have made close to 8,000 observations and have reported them to a central data center. This data is stored in a computer and can be accessed by a data management system. It is available to regional scientists for use in assessing the state of petroleum pollution in the region. This symposium is designed to report progress on this effort, both on an individual government and regional basis.

AO-002

ATWOOD, D.K., S. Dinkel-McKay, G.C. ROMERO, and E. Van Vleet. Floating tar and dissolved/dispersed petroleum hydrocarbons in the northern Gulf of Mexico and the Straits of Florida. *Caribbean Journal of Science* 23(1):73-76 (1987).

As part of the IOCARIBE/CARIPOL Petroleum Pollution Monitoring Project, the USA has made 393 measurements of floating tar and 114 measurements of dissolved/dispersed petroleum hydrocarbons (DDPH) using CARIPOL described procedures. The majority of these were made in the northern and eastern Gulf of Mexico and the Straits of Florida. Results indicate that DDPH and floating tar covary in the study area and that the highest levels of contamination exist in the southern Straits of Florida between Cuba and the Florida Keys. The lowest levels were found on the western Florida Shelf and in the northern Straits of Florida between southeast Florida and the Bahamas. These results are consistent with beach tar studies along the coast of Florida which show that western and northeastern Florida beaches are quite pristine whereas beaches on the windward (southeast) side of the Florida Keys are heavily oiled. Intermediate levels of contamination were found in the northern Gulf of Mexico and the Gulf Loop Intrusion waters which would indicate that beaches along the northern Gulf coast should have average tar contamination levels of roughly 1 to 20 grams per square meter as compared to 20 to 80 grams per square meter in the Florida Keys.

AO-003

Baker, E.T., G.J. Massoth, R.W. Collier, J.H. Trefry, D. Kadko, T.A. NELSEN, P.A. RONA, and J.E. Lupton. Evidence for high-temperature hydrothermal venting on the Gorda Ridge, northeast Pacific Ocean. *Deep-Sea Research* 34(8):1461-1476 (1987).

The first water-column survey of the axial valley of the Gorda Ridge, a slow- to medium-rate spreading center within 300 km of the coast of Oregon and California, found strong evidence for ongoing hydrothermal venting. At the northern end of the ridge, anomalously high concentrations of helium-3, dissolved manganese, particulate iron, and methane confirmed the hydrothermal origin of the above-bottom plumes identifiable as maxima in light-attenuation profiles. The presence of excess

radon-222 and the highly soluble hydrothermal precipitate anhydrite in the plumes require a local vent source; the precipitation of anhydrite requires fluid temperatures of at least 130°C. Indications of hydrothermal activity elsewhere in the axial valley were inconclusive.

AO-004

Barnes, G.M., G.J. Stossmeister, M.A. LeMone, and J.F. GAMACHE. A rainband on the trailing side of a fast-moving hurricane. Extended Abstracts, 17th Conference on Hurricanes and Tropical Meteorology, April 7-10, 1987, Miami, Florida. American Meteorological Society, Boston, 377-380 (1987).

No abstract.

AO-005

BLACK, M.L., and R.W. BURPEE. Temporal and spatial variations of precipitation near the center of tropical cyclones. Extended Abstracts, 17th Conference on Hurricanes and Tropical Meteorology, April 7-10, 1987, Miami, Florida. American Meteorological Society, Boston, 170-173 (1987).

No abstract.

AO-006

BLACK, P.G. New measurements within, around, and under tropical cyclones using airborne microwave remote sensors and expendable probes. Program Booklet, Second Airborne Science Workshop, Miami, Florida, February 3-6, 1987. NASA, Washington, D.C., 29-30 (1987).

No abstract.

AO-007

BLACK, P.G., and F.D. MARKS, JR. Environmental interactions associated with hurricane supercells. Extended Abstracts, 17th Conference on Hurricanes and Tropical Meteorology, April 7-10, 1987, Miami, Florida. American Meteorological Society, Boston, 416-419 (1987).

No abstract.

AO-008

BURPEE, R.W., J. Ward, and D.G. Marks. A preliminary evaluation of Omega dropwindsonde data in track forecasts of hurricanes. Extended Abstracts, 17th Conference on Hurricanes and Tropical Meteorology, April 7-10, 1987, Miami, Florida. American Meteorological Society, Boston, 98-100 (1987).

No abstract.

AO-009

Charlou, J.L., P.A. RONA, and H. Bougault. Methane anomalies over TAG Hydrothermal Field on the Mid-Atlantic Ridge. *Journal of Marine Research* 45:461-472 (1987).

Black-smoker-type hydrothermal venting was discovered in July 1985 at the TAG Hydrothermal Field in the rift valley of the Mid-Atlantic Ridge near 26°N. We present here the first methane profiles in the seawater column over this black smoker along with methane profiles away from the black smokers for comparison. The CH_4 plume, spreading over 400 m above the seafloor, shows a maximum concentration of 105 nl/l at 3,450 m (238 m above the bottom), correlated with a positive temperature anomaly (0.02°C). CH_4 concentrations up to 2,422 nl/l, correlated with a huge positive increase of *in-situ*

temperature (0.349°C), have been measured in samples taken 5 m above the seafloor, showing an important CH_4 input in this slow-spreading site similar to fast-spreading sites like the East Pacific Rise.

AO-010

CHEW, F., and M.H. BUSHNELL. Changing transport and curvature bias: A new type of meandering in the Florida Straits. *Journal of Geophysical Research* 92(C9):9503-9513 (1987).

Meanders in strong, inertial flows are generally asymmetric. Florida Current meanders with periods of 7-10 days and flows that tend to meander offshore when strong and onshore when weak, which we call type A, have been widely documented. We find a countertrend in the Florida Current data collected under the aegis of Subtropical Atlantic Climate Studies: a type B meandering where flows tend to meander offshore when weak and onshore when strong. On time scales of several months and depending on the strength of the flow, the tendency displays a largely one-sided preference for either the onshore or the offshore component of the meander. In particular, the data reveal a negative curvature bias during lower transports in fall and winter when most speed cores were offshore. The data show that any use of cross-channel sea level slope to estimate the transport would generally overestimate the weaker, but underestimate the stronger flows. Type B meander is interpreted as one of three types embodied in a meandering equation in which curvature changes are controlled primarily by the Coriolis effect of downstream acceleration and hence by that of changing transport. In this light the bimodal paths of the Kuroshio south of Japan is a type B meander.

AO-011

Ciesielski, P.E., L.J. SHAPIRO, and D.E. Stevens. A comparison of the observed and model-derived structures of tropical easterly waves. Extended Abstracts, 17th Conference on Hurricanes and Tropical Meteorology, April 7-10, 1987, Miami, Florida. American Meteorological Society, Boston, 249-252 (1987).

No abstract.

AO-012

CLARKE, T.L., and J.R. PRONI. A pattern recognition approach to remote acoustic bottom characterization. In *Progress in Underwater Acoustics,* H.M. Merklinger (ed.), Plenum Press, New York, 225-229 (1987).

The possibility of extracting useful bottom information from reflected pulse waveforms at customary echo-sounding frequencies has been demonstrated experimentally. The one-dimensional nature of the sediment property continuum should also enable the use of remotely measured acoustical sedimentary properties to predict navigationally important mechanical characteristics. A convenient mathematical model has been developed to assess the effects of bottom roughness and material properties on bottom echo shape. The physical basis of the model is explained and model output is presented. The ability of this model to easily generate sample echoes from a wide range of bottom types permits a pattern recognition approach to be taken to the problem of extracting information from the echo signals. An adaptive algorithm can be "trained" using model-generated echoes in the same way speech recognition systems are "trained." The linear discriminant algorithm can be trained to distinguish mud from gravel, but has difficulty with mud versus fine sand. A commercially available voice recognition system conversely has difficulty distinguishing sand from gravel. More sophisticated algorithms will be needed for general bottom discrimination.

AO-013

DODGE, P.P., M.L. BLACK, R.W. BURPEE, and F.D. MARKS, JR. Time-lapse radar imagery from landfalling hurricanes. Extended Abstracts, 17th Conference on Hurricanes and Tropical Meteorology, April 7-10, 1987, Miami, Florida. American Meteorological Society, Boston, 166-169 (1987).

No abstract.

AO-014

Donoso, M.C.I., B. Le Mahaute, and R.B. LONG. Data base of maximum sea states during hurricanes. *Journal of Waterway, Port, Coastal and Ocean Engineering* 113(4):311-326 (1987).

No abstract.

AO-015

Esbensen, S.K., L.J. SHAPIRO, and E.I. Tollerud. The consistent parameterization of the effects of cumulus clouds on the large-scale momentum and vorticity fields. Extended Abstracts, 17th Conference on Hurricanes and Tropical Meteorology, April 7-10, 1987, Miami, Florida. American Meteorological Society, Boston, 48-51 (1987).

No abstract.

AO-016

Esbensen, S.K., L.J. SHAPIRO, and E.I. Tollerud. The consistent parameterization of the effects of cumulus clouds on the large-scale momentum and vorticity fields. *Monthly Weather Review* 115(13):664-669 (1987).

A physical and mathematical framework for the mutually consistent parameterization of the effects of cumulus convection on the large-scale momentum and vorticity fields is proposed. The key to achieving consistency is the understanding that the vorticity dynamics of the clouds below the spatial resolution of the large-scale dynamical model may be neglected in the vorticity budget when the statistics of the clouds are considered to be locally homogeneous. This simplified approach is used to obtain a consistent pair of large-scale momentum and vorticity equations based on Ooyama's (1971) theory of cumulus parameterization. The results focus attention on the need to obtain a better understanding of the detrainment process and the pressure interactions of the clouds and their local environment.

AO-017

Fine, R.A., and R.L. MOLINARI. Observations of the deep western boundary current in the subtropical North Atlantic Ocean. *EOS* 36(16):338 (1987).

No abstract.

AO-018

FRANKLIN, J.L. Reduction of errors in Omega dropwindsonde data through postprocessing. NOAA TM ERL AOML-65 (PB87-173308), 22 pp. (1987).

The postprocessing of Omega dropwindsonde (ODW) data at the NOAA Hurricane Research Division (HRD) is described. The errors common to ODW data are illustrated with examples, and the improvements to ODW accuracy through postprocessing are estimated.

AO-019

FRANKLIN, J.L., K.V. OOYAMA, and S.J. LORD. Two improvements in Omega windfinding techniques. *Journal of Atmospheric and Oceanic Technology* 4(1):214-219 (1987).

A one-dimensional local spline smoothing technique is applied to Omega navigational signals for the purpose of windfinding. Wind profiles so produced depend largely on two parameters of the smoothingprocedure: the nodal spacing, which determines the smallest resolvable scale, and a filtering wavelength, which produces the necessary smoothing of the phase data, and prevents representational distortion of any power from the unresolved scales. Phase "noise" from stationary test sondes is superimposed on synthetic Omega signals to compare wind profiles obtained with this new procedure with profiles computed using other techniques. It is shown that the effect of aircraft maneuvers on Omega

wind accuracy is not completely removed by the normal practice of evaluating all phase derivatives at a common time. Additional improvements in accuracy of 2–3 m s^{-1} can be obtained by a "rate-aiding" technique using aircraft navigational data.

AO-020

GAMACHE, J.F. The bulk water budget of Hurricane Norbert (1984). Extended Abstracts, 17th Conference on Hurricanes and Tropical Meteorology, April 7–10, 1987, Miami, Florida. American Meteorological Society, Boston, 351–354 (1987).

No abstract.

AO-021

GOLDENBERG, S.B., S.D. ABERSON, and R.E. KOHLER. An updated, fine-grid version of the operational barotropic hurricane-track prediction model. Extended Abstracts, 17th Conference on Hurricanes and Tropical Meteorology, April 7–10, 1987, Miami, Florida. American Meteorological Society, Boston, 86–89 (1987).

No abstract.

AO-022

HANSON, K., G.A. MAUL, and W. MCLEISH. Precipitation and the lunar synodic cycle: Phase progression across the United States. *Journal of Climate Applied Meteorology* 26(10):1336–1340 (1987).

The question of whether there is significant variation in precipitation in the United States at the lunar synodic period (29.531 days) has been examined, based on daily precipitation data for the period 1900–80. Our results confirm previous studies and indicate by a new method that there is statistically significant variation in precipitation at this lunar frequency. We also show for the first time there is spatial progression over the United States in the phase of the lunar-precipitation relationship. During spring, a precipitation maximum occurs first when the moon is gibbous in the northwestern United States, progressively later during the lunar cycle in the midwest, and, finally, about the time of the new moon in the east. The recognition of spatial progression in phase raises questions about the reality of previously proposed global, lunar-precipitation mechanisms. We suggest, instead, the actual cause-effect relationship may involve the long wave circulation of the atmosphere.

AO-023

HARVEY, G.R. A personal overview of oil in the marine environment. *Caribbean Journal of Science* 23(1):5–9 (1987).

Any personal perspective of oil in the sea is certain to be controversial. Environmental scientists and other citizens concerned with the health of the oceans usually disagree with those working in the multifaceted international petroleum industry. However, one fact does seem clear to both sides of the oil-in-the-sea controversy: the single most important event that led to less operational petroleum being discharged into the sea was not any environmental concern. It was the 1974 oil embargo of the OPEC countries which catapulted the price of a barrel of crude oil up to a level at which it was too valuable to lose. There is probably less oil entering the sea from production and transportation in 1985 than there was fifteen years ago. Even the global carbon dioxide monitoring network recorded the effects of the1974 embargo. There was actually less carbon dioxide entering the atmosphere for a while because of reduced fuel burning. Major accidents have occurred and we have learned a great deal from studying the physical, chemical and biological effects of precipitously injecting massive quantities of oil into the sea. We have learned much more about the nature and frequency of occurrence of natural seeps. Although nothing can be done to prevent such occurrences, we now understand what the natural exposure level of

marine organisms would be, and, what the natural burden of tar on beaches would probably be without human intervention. Though oil pollution of the sea is presently less than that of a decade ago, there is an urgent need to continue to monitor its presence because social, economic or political reversals in any part of the world could change the situation in less than one year.

AO-024

JOHNS, E., R.L. MOLINARI, K.D. Leaman, and J. Harris. Observations of current variability northeast of the Bahamas. *EOS* 68(16):338 (1987).

No abstract.

AO-025

Kumar, M., and G.A. MAUL. Symposium Directors, Proceedings, International Symposium on Marine Positioning, INSMAP 86, Reston, VA, October 14-17, 1986. D. Reidel Publishing Company, Dordrecht, Holland, 463 pp. (1987).

The International Symposium on Marine Positioning (INSMAP) was conceived by the Marine Geodesy Committee at OCEANS 84, Washington, D.C. It became clear at that time, that timing was appropriate to focus attention on individual specific problem areas under the broad umbrella of marine geodesy. After scheduling INSMAP 86 by the Marine Technology Society, we were fortunate to generate strong support from our co-sponsors. All their assistance and support are gratefully acknowledged. Our special thanks are expressed to the U.S. Geological Survey (Charting and Geodetic Services, NOS/NOAA), Office of Naval Research, and Naval Ocean Research No. N00014-86-G-0107, NOS/NOAA No. 40AANC601637, and USGS No. 14-08-0001-G1207 as partial funding to the INSMAP 86. We are also grateful to the U.S. Geological Survey for providing the auditorium and other logistic support in making the symposium a success. A total of 165 persons attended INSMAP 86, of which 20 percent were from outside the United States. Nine technical sessions and five special workshops were held within a four-day format. Invited speakers included Dr. Alan Berman, Dean, Rosenstiel School of Marine and Atmospheric Sciences; RADM J. R. Seesholtz, Oceanographer of the U.S. Navy; RADM John D. Bossler, Director of Charting and Geodetic Services, NOS/NOAA; Mr. Chris von Alt, Woods Hole Oceanographic Institute; and RADM L. H. van Opstal, Hydrographer of the Royal Dutch Navy. These proceedings contain the written versions of the talks, presentations, and the reports as submitted by the authors of workshop chairpersons. A few papers have also been included (with appropriate footnotes) which were submitted but could not be presented at the INSMAP 86 due to last minute exigencies. We acknowledge with gratitude the support of all of the committee members, advisors, authors, chairpersons, and participants of INSMAP 86, and are very grateful to the National Geodetic Survey's editor, Mrs. Eleanor Andree, for her effort in organizing these proceedings.

AO-026

Leaman, K.D., R.L. MOLINARI, and E. JOHNS. Velocity and transport variability at 26.5°N east of Abaco Island, The Bahamas. *EOS* 68(16):338 (1987).

No abstract.

AO-027

Leaman, K.D., R.L. MOLINARI, and P.S. Vertes. Structure and variability of the Florida Current at 27°N: April 1982-July 1984. *Journal of Physical Oceanography* 17:565-583 (1987).

Results of a two-year field experiment as part of the Subtropical Atlantic Climate Studies (STACS) program in the Straits of Florida are presented. Temperature and absolute ocean current observations were obtained by PEGASUS acoustic current profilers over 16 cruises during which repeated cross sections of the Florida Current were made at 27°N. Results are shown for the mean velocity and

temperature fields, the perturbation horizontal kinetic energy and potential energy fields and for those energy conversion terms that could be computed directly from the data. The barotropic and baroclinic energy conversion terms, although small, indicate that the flow is stable for both types of perturbations. A large part of the variability is contributed by short time scales (one week or less). The average and standard deviation of northward volume transport by the Florida Current during these cruises was (31.7 $\pm$ 3.0) x 10^6 m^3 s^{-1} Barotropic and baroclinic contributions to the total heat flux across the North Atlantic Ocean at 27°N are computed for each cruise and for the two-year average of all cruises. With the use of previous estimates of the midbasin baroclinic and Ekman heat fluxes, the total average northward heat flux from the observations is (1.29 $\pm$ 0.21) x 10^{15} W. To compare STACS data with results from a recent numerical model by Anderson and Corry, Florida Current transports are resolved in a simple manner into barotropic and baroclinic modes. Although the barotropic mode is considerably more variable than the baroclinic, the basic annual signal obtained from the model also appears in the STACS observations. In particular, a rapid transport decrease in the fall with a secondary decrease in the spring are found in both model and observations.

AO-028

LORD, S.J., and J.L. FRANKLIN. Wind analyses for the environment of Hurricane Debby (1982): Some diagnostic calculations and forecast experiments. Extended Abstracts, 17th Conference on Hurricanes and Tropical Meteorology, April 7-10, 1987, Miami, Florida. American Meteorological Society, Boston, 94-97 (1987).

No abstract.

AO-029

MARKS, F.D., JR., and R.A. Houze, Jr. Inner core structure of Hurricane Alicia from airborne Doppler radar observations. *Journal of the Atmospheric Sciences* 44(9):1296-1317 (1987).

Airborne Doppler radar measurements are used to determine the horizontal winds, vertical air motions, radar reflectivity and hydrometeor fallspeeds over much of the inner-core region (within 40 km of the eye) of Hurricane Alicia (1983). The reconstructed flow field is more complete and detailed than any obtained previously. The data show both the primary (azimuthal) and secondary (radial-height) circulations. The primary circulation was characterized by an outward sloping maximum of tangential wind. The secondary circulation was characterized by a deep layer of radial inflow in the lower troposphere and a layer of intense outflow above the 10 km altitude. The rising branch of the secondary circulation was located in the eyewall and sloped radially outward. Discrete convective-scale bubbles of more intense upward motion were superimposed in this mean rising current, and convective-scale downdrafts were located throughout and below the core of maximum precipitation in the eyewall. Precipitation particles in the eyewall rainshaft circulated 18-20 km downwind as they fell, consistent with the typical upwind slope with increasing altitude of eyewall precipitation cores. Outside the eyewall, the precipitation was predominantly stratiform. A radar bright band was evident at the melting level. Above the melting level, ice particles were advected into the stratiform region from the upper levels of the eyewall and drifted downward through a mesoscale region of ascent. Hypothetical precipitation particle trajectories showed that as these particles fell slowly through the mesoscale updraft toward the melting level, they were carried azimuthally as many as 1 1/2 times around the storm. During this spiraling descent, the particles evidently grew vigorously. The amount of water condensed by the ambientmesoscale ascent exceeded that transported into the stratiform region by the eyewall outflow by a factor of 3. As the particles fell into the lower troposphere, they entered a mesoscale region of subsidence, the top of which coincided with the radar bright band.

AO-030

MARKS, F.D., JR., and R.A. Houze, Jr. Three-dimensional structure of the eyewall of Hurricane Norbert as determined from an airborne Doppler radar. Extended Abstracts, 17th Conference on Hurricanes and Tropical Meteorology, April 7-10, 1987, Miami, Florida. American Meteorological Society, Boston, 347-350 (1987).

No abstract.

AO-031

MAUL, G.A., M. BUSHNELL, W. KRUG, and S.R. Baig. Nowcasting cross-stream averaged surface speed in the Florida Current between Florida and the Bahamas. *Oceanographic Monthly Summary* 7(2):12-13 (1987).

No abstract.

AO-032

MAUL, G.A., D.A. MAYER, and M. BUSHNELL. Relationships between local sea level and weather with Florida-Bahamas cable and PEGASUS measurements of the Florida Current: 1982-1986. *EOS* 68(16):336-337 (1987).

No abstract.

AO-033

MAYER, D.A., and J.C. Larsen. Tidal transport in the Florida Current and its relationship to tidal heights and cable voltages. *Journal of Physical Oceanography* 16(12):2199-2202 (1987).

A linear relationship between tidal height (sea level of tidal frequencies) and tidal transport near 27°N in the Straits of Florida is confirmed. Transport estimates from this relationship for the 0_1 and M_2 constituents are compared with those computed from cable voltages across the Florida Current. These estimates are independent in that the weighted tidal height model (tidal-height transport relationship) was developed using collective sets of current meter and velocity profiler data obtained at different times of the year and in different locations. The cable voltages, however, were calibrated using a quasi-synoptic sectional integration of depth-averaged profiler data. Further, a means is suggested by which changes in the cable calibration can be detected.

AO-034

MOLINARI, R.L. Air mass modification over the eastern Gulf of Mexico as a function of surface wind fields and Loop Current position. *Monthly Weather Review* 115(3):645-652 (1987).

The effects of surface wind patterns and Loop Current position on surface distributions of latent and sensible heat fluxes in the eastern Gulf of Mexico are demonstrated. Mean monthly fields of these fluxes computed from data collected during February 1975 and February 1976 are decomposed into two different modes, a north-wind mode associated with winter outbreaks of dry cold continental air masses and a trade-wind mode associated with advection from the south of warm moist maritime air. The distributions of sensible and latent heat fluxes are different for each mode, with both heat fluxes considerably larger over the northern Gulf, in particular, during times of the northerlies. However, during these two months, trade-wind days are more numerous and the mean monthly flux patterns reflect thispreponderance. A simple model of the effect of extreme Loop Current configurations and the associated sea surface temperature distributions on air parcels traversing the Gulf below the inversion layer is presented. Total changes in air parcel temperature and specific humidity are shown to depend on the configuration of the Loop Current parcels which traverse the Gulf and cross the U.S. coastline between Louisiana and Florida during the time of a deep northern Loop intrusion and have 1.3°C higher temperatures and 1.0 g kg^{-1} greater specific humidities than parcels which cross the Gulf during a shallow Loop intrusion.

AO-035

MOLINARI, R.L. A review of STACS results on Florida Current variability. *EOS* 68(16):337 (1987).

No abstract.

AO-036

MOLINARI, R.L. Ocean-atmosphere relations. In *McGraw-Hill Yearbook of Science and Technology*. McGraw-Hill, New York, 323-325 (1987).

No abstract.

AO-037

MOLINARI, R.L., and D.V. HANSEN. Observational studies of near-surface thermal budgets in the tropics: Review, evaluation and recommendations. In *Further Progress in Equatorial Oceanography*, E.J. Katz and J.M. Witte (eds.). Nova University Press, Fort Lauderdale, 421-438 (1987).

No abstract.

AO-038

MOLINARI, R.L., E. JOHNS, G.A. MAUL, D. MAYER, J.C. Larsen, R. Fine, K.D. Leaman, T.N. Lee, W.E. Johns, and F.A. Schott. Subtropical Atlantic Climate Studies (STACS). Proceedings, IUGG XIX General Assembly 3:1013 (1987).

No abstract.

AO-039

OOYAMA, K.V. Numerical experiments of steady and transient jets with a simple model of the hurricane outflow layer. Extended Abstracts, 17th Conference on Hurricanes and Tropical Meteorology, April 7-10, 1987, Miami, Florida. American Meteorological Society, Boston, 318-320 (1987).

No abstract.

AO-040

PALMER, D.R., and P.A. RONA. The acoustics of "black smoker" hydrothermal plumes. 113th Meeting of the Acoustical Society of America, Indianapolis, Indiana, May 11-15, 1987. *Journal of the Acoustical Society of America* 81:S50 (1987).

High-temperature "black-smoker" hydrothermal plumes occur when seawater that has penetrated into the oceanic crust and assimilated heat from magma is discharged from vents located at the axis of a mid-ocean ridge. The acidic, metal-rich discharge mixes with alkaline, oxidizing seawater, and a fine suspension of sulfide particles is precipitated and convected by the flow. Vent fields have now been foundat both fast and slow seafloor spreading centers and may be an ubiquitous feature of mid-ocean ridges. A review of the progress made in using underwater acoustics to study black smoker plumes is presented. Both active and passive techniques are being investigated. Active techniques involve a high-frequency monostatic sonar mounted on a submersible. Analysis of the amplitude and phase of the signal backscattered from the plume provides information about the three-dimensional shape of the plume as well as estimates of the flow-velocity field of the discharging fluid. Passive techniques use bottom-mounted hydrophones to listen to the very low-frequency, hydrodynamic noise generated by a plume. These noise signatures have potential use in locating, characterizing, and monitoring plume sites and in determining the contribution plume noise makes to the overall ambient noise field in the ocean.

AO-041

POWELL, M.D. Boundary-layer structure in convective hurricane rainbands. Extended Abstracts, 17th Conference on Hurricanes and Tropical Meteorology, April 7-10, 1987, Miami, Florida. American Meteorological Society, Boston, 373-376 (1987).

No abstract.

AO-042

POWELL, M.D. Changes in the low-level kinematic and thermodynamic structure of Hurricane Alicia (1983) at landfall. *Monthly Weather Review* 115(1):75-99 (1987).

Aircraft, land station, and buoy data were composited with respect to the center of Hurricane Alicia (1983) for three 8 h periods corresponding to prelandfall in the open Gulf of Mexico, landfall in the Galveston area, and postlandfall in the vicinity of Houston. Comparison of the wind analyses before, during, and after landfall emphasizes the land-sea frictional asymmetry at landfall. In addition, other asymmetries in the surface wind field and differences between the flight-level and the surface wind fields are revealed. The asymmetric structure of the surface wind field may be interpreted as having resulted from the combined effects of land-sea roughness differences, background environmental flow, and storm translation. The land-sea frictional difference acted to oppose the mean vortex flow over land and reinforce it over water. The southwest background environmental flow acted nearly parallel to the coastline, producing surface inflow on the left side and outflow on the right side, while the effect of the storm translation increased winds on the right and decreased winds on the left. At landfall, the analysis revealed a broad region of high wind speeds and a mesoscale divergence-convergence couplet along the outer rainband axis just offshore on the northeast (right) side of the storm. The outer rainband axis acted as an obstruction to the surface flow, separating the warmer central core of the storm from the environment through which the storm moved. In contrast to recent numerical model studies, surface convergence was also noted on the left side of the storm just offshore, despite outflow at flight level. Analyses of temperature, dew point, and equivalent potential temperature indicate that loss of the oceanic heat and moisture source, combined with advection of drier air on the landward side of the storm, was responsible for cooling and drying of the inflowing boundary layer air. Upon introduction of this air into the core convection and vertical ascent, a decrease in the release of latent heat could then lead to cooling in the middle levels of the storm and a subsequent increase in the central sea-level pressure.

AO-043

RATNASWAMY, M.J., and G.A. BERBERIAN. Nutrient, oxygen, and salinity distributions along the western boundary of the subtropical North Atlantic Ocean. *EOS* 68(16):338 (1987).

No abstract.

AO-044

ROMERO, G.C., G.R. HARVEY, and D.K. ATWOOD. Stranded tar on Florida beaches: September 1979-October 1980. *Caribbean Journal of Science* 23(1):65-72 (1987).

Amounts of tar stranded on Florida beaches were determined periodically over one year (September 1979-October 1980). Results show that tar fouling of southeast Florida beaches is an order of magnitude greater than the rest of the state. This may result from the extensive ship traffic in the Straits of Florida. There is no evidence that any Florida beaches received increased amounts of tar as a result of the 1979 IXTOC-1 blowout in the southern Bay of Campeche. There is also no evidence that the amounts of tar on southeast Florida beaches have increased over amounts measured in API studies conducted in 1958 and 1971.

AO-045

RONA, P.A. Hydrothermal mineralization at slow-spreading centers: The Atlantic model. *Marine Mining* 6:1-7 (1987).

The recent discovery of the first black smoker-type hydrothermal venting and massive sulfide mineral deposits at a site in the rift valley of the slow-spreading Mid-Atlantic Ridge near latitude 26°N, longitude 45°W (Rona *et al.*, 1986) demonstrates that a complete series of hydrothermal mineral deposit types exists at slow-spreading oceanic ridges (half-rate $\leq$ 2 cm/yr), similar to the series previously known at faster-spreading oceanic ridges (half-rate > 2 cm/yr). The largest hydrothermal mineral deposit known at a seafloor spreading center is a stratiform massive sulfide body with bulk dry weight of about 100×10^6 metric tons in the Atlantis II Deep at the slow-spreading axis of the Red Sea. This observation invalidates the concept that size of a hydrothermal deposit is directly proportional to rate of seafloor spreading. Instead, the occurrence, grade, and size of a hydrothermal deposit formed at a seafloor spreading center is controlled by anomalous chemical and physical conditions that may occur at extremely localized sites at the full range of spreading rates. The basic hydrothermal process involving subseafloor hydrothermal convection driven by magmatic heat sources appears to be similar at slow- and faster-spreading centers. However, differences exist in the periodicity of magmatic cycles that energize hydrothermal circulation (10^4 years at slow-spreading centers; 10^3 years at faster-spreading centers); in the distribution of hydrothermal sites along a spreading axis (estimated 100 km along slow-spreading centers; 10 km along faster-spreading centers); and in residence time of a parcel of oceanic crust near an axial magmatic heat source (up to 10 times longer at a slow-spreading center than at a faster-spreading one). These findings have favorable implications for the occurrence of sizable hydrothermal mineral deposits at discrete sites on the slow-spreading oceanic ridge system that extends through the North Atlantic Ocean, South Atlantic Ocean, western Indian Ocean, and the Gorda Ridge within the proclaimed U.S. exclusive economic zone off northern California and Oregon.

AO-046

RONA, P.A. Ocean ridge crest processes. U.S. National Report to International Union of Geodesy and Geophysics, 1983-1986. *Reviews of Geophysics* 25(5):1089-1114 (1987).

Oceanic ridge crest processes constitute a vigorous frontier of multi-disciplinary research with global ramifications in the earth, atmospheric and biologic opening in response to investigations which are elucidating the role of these processes in the lithosphere, hydrosphere, atmosphere and biosphere, and the application of advanced instrumental and interpretive techniques which are increasing the quality and quantity of data. These techniques include crustal drilling with borehole logging (Deep Sea Drilling Project reports), high-resolution bathymetry (Sea Beam, etc.), side-scan sonar (SeaMARC I and II, GLORIA, etc.), imagery with video and photography, multichannel seismics, determination of water column properties (CTD with rosette sampler, etc.), and submersible applications. Commentary and bibliography reporting this research are divided into consideration of magmatic, tectonic, hydrothermal, sedimentary and biologic processes. In the extensive bibliography of publications from 1982 through 1986, papers treating each of these processes are subdivided into specific oceanic ridges and ophiolites;the papers are further subdivided into physics, chemistry and history according to their emphasis. The bibliography was compiled from three databases, supplemented by a general search of the literature. The databases comprised GEOREF which was most comprehensive for earth sciences but lacked abstracts; OCEANIC ABSTRACTS which included abstracts; and BIOSIS which provided biological references.

AO-047

RONA, P.A. Recent hydrothermal mineralization at seafloor spreading centers: Tectonic, petrologic, and geochemical constraints. Symposium Program and Abstracts, Montreal, Canada, February 5-6, 1987. Mineral Exploration Research Institute, McGill University (1987).

No abstract.

AO-048

RONA, P.A. The Indian Ocean: Exploitable mineral and petroleum resources. *Economic Geology* 82:1396-1397 (1987).

No abstract.

AO-049

RONA, P.A., L. Widenfalk, and K. Bostrom. Serpentinized ultramafics and hydrothermal activity at the Mid-Atlantic Ridge crest near 15°N. *Journal of Geophysical Research* 92(B2):1417-1427 (1987).

The initial occurrence of serpentinized ultramafic rocks at the nontransform intersection of a wall of a rift valley with the wall of a fracture zone is described from a site at the Fifteen Twenty Fracture Zone. The ultramafics crop out in block-faulted terrain on the upper portion of the eastern intersection between the rift valley and fracture zone walls in water depths between 2,910 and 3,300 m. They comprise cumulate harzburgites, pyroxenites, lherolites, and wehrlites, as well as gabbronorites, olivine gabbronorites, gabbropegmatites, and alteration products including serpentinites, bastite serpentinites, and asbestos. The Ti-Zr-Y relations and relatively constant Zr/Ti ratio in basalts recovered with the ultramafic rocks indicate a cogenetic relation from a common magmatic source that has undergone a late stage differentiation in the lower crust. Ongoing hydrothermal activity is indicated by chemical anomalies (δ^3He, Mn) in the near-bottom water at the ultramafic outcrop. The upwelling hydrothermal circulation apparently follows crust-penetrating faults that may have controlled the diapiric ascent of the serpentinites and that continue to tap degassing magma and/or mantle. The observations presented indicate that ultramafic cumulates form beneath the rift valley adjacent to long-offset (> 100 km) ridge-ridge transform faults, where they are serpentinized by hydrothermal processes within the initial 1 x 10^6 years of generation of lithosphere at a slow-spreading axis. The corners formed by the intersections of the walls of a rift valley with both the transform (RT corner) and the nontransform (RN corner) portions of these fracture zones are principal loci of diapiric emplacement of serpentinized ultramafics.

AO-050

Ross, D., L.M. LAWSON, and W. MCLEISH. Comparisons of Hurricane Fico winds and waves from numerical models with observations from SEASAT-A. In *Wave Dynamics and Radio Probing of the Ocean Surface*, O.M. Phillips and K. Hasselmann (eds.). Plenum Press, New York, 595-613 (1987).

Several types of satellite data collected during SEASAT-A overpasses of Hurricane Fico are used to adjust input parameters in a hurricane wind prediction model. Derived winds are then used in a complex discrete spectral wave prediction model to calculate wave heights and directional spectrum distributions. Three different areas of the storm with winds ranging from 12 m/s to 23 m/s and hindcast wave heights varying from 4 m to 8 m were used to compare model-normalized directional wave spectra with those from SEASAT synthetic aperture radar (SAR) imagery. The two-dimensional normalized spectral energyresults from the SAR and wave model showed an average difference in peak directions of 0.9° with a standard deviation of 6.8°. Wind and wave model results are also compared with altimeter data along a subsatellite track. This study shows the value of satellite observations in model, validation, and, conversely, the value of the model results in verification of the efficacy of the satellite data sets. Especially noteworthy is the snapshot view of the characteristics of the storm, a demonstration of the potential power of satellite remote sensing.

AO-051

SHAPIRO, L.J. Month-to-month variability of the Atlantic tropical circulation and its relationship to tropical storm formation. Extended Abstracts, 17th Conference on Hurricanes and Tropical Meteorology, April 7-10, 1987, Miami, Florida. American Meteorological Society, Boston, 231-233 (1987).

No abstract.

AO-052

Shay, L.K., R.L. Elsberry, and P.G. BLACK. Mesoscale ocean temperature and current patterns induced by hurricanes. Extended Abstracts, 17th Conference on Hurricanes and Tropical Meteorology, April 7-10, 1987, Miami, Florida. American Meteorological Society, Boston, 388-392 (1987).

No abstract.

AO-053

Simpson, R.H., J. Simpson, and S.L. ROSENTHAL. Hurricane. In *Encyclopedia of Science and Technology*, 6th Edition, Vol. 8, McGraw-Hill, New York, 554-557 (1987).

No abstract.

AO-054

Skubis, S., and J. Molinari. Angular momentum variation in a translating cyclone. Research supported by NOAA Grant 50-WCNR-6-06096. *Quarterly Journal of the Royal Meteorological Society* 113(477):1041-1048 (1987).

An expression for the time rate of change of relative angular momentum in a moving cyclone is derived which allows a kinematic interpretation of the effects of motion. One term arises from the convergence of flux of momentum by the storm motion vector as the storm moves through an environmental gradient of momentum and has a counterpart in the equation for the time change of any scalar in a moving volume. A second term, which appears because angular momentum depends upon distance from the axis of rotation, arises purely due to the motion of the axis. This latter term is shown to be proportional to the deviation of the storm motion vector from the basic current and to make a positive contribution when the storm moves to the left of the mean flow. The Lagrangian terms were calculated for an observed rapidly moving hurricane about to make landfall in a baroclinic environment. Their overall contribution was negative and equal in magnitude to the largest terms in the Eulerian momentum budget, indicating that the rapid observed decay of the storm was influenced not only by its landfall, but also by unfavorable environmental interactions as the storm moved into a region of reduced cyclonic momentum. The results suggest that the effects of translation cannot be neglected for a vortex which is rapidly moving or embedded in a nonuniform environment.

AO-055

Tanner, A., C.T. Swift, and P.G. BLACK. Operational airborne remote sensing of wind speeds in hurricanes. Extended Abstracts, 17th Conference on Hurricanes and Tropical Meteorology, April 7-10, 1987, Miami, Florida. American Meteorological Society, Boston, 385-387 (1987).

No abstract.

AO-056

Velden, C.S., and S.B. GOLDENBERG. The inclusion of high-density satellite wind information in a barotropic hurricane forecast model. Extended Abstracts, 17th Conference on Hurricanes and Tropical Meteorology, April 7-10, 1987, Miami, Florida. American Meteorological Society, Boston, 90-93 (1987).

No abstract.

AO-057

WILLIS, P.T., and F.D. MARKS, JR. Convective-scale transports in a mature hurricane. Extended Abstracts, 17th Conference on Hurricanes and Tropical Meteorology, April 7-10, 1987, Miami, Florida. American Meteorological Society, Boston, 343-346 (1987).

No abstract.

AO-058

WILLOUGHBY, H.E. Tropical cyclone track prediction: Some theoretical aspects. Extended Abstracts, 17th Conference on Hurricanes and Tropical Meteorology, April 7-10, 1987, Miami, Florida. American Meteorological Society, Boston, 262-265 (1987).

No abstract.

AO-059

WILLOUGHBY, H.E. Use of aircraft in hurricane research. Program Booklet, Second Airborne Science Workshop, Miami, Florida, February 3-6, 1987. NASA, Washington, D.C., 83 (1987).

No abstract.

AO-060

WILLOUGHBY, H.E., and W.P. BARRY. Real-time data acquisition and analysis in Hurricane Charley of 1986. Extended Abstracts, 17th Conference on Hurricanes and Tropical Meteorology, April 7-10, 1987, Miami, Florida. American Meteorological Society, Boston, 341-342 (1987).

No abstract.

Addendum

AO-061

BEHRINGER, D.W. Oceanographic observations in the southeastern tropical Pacific (SETP). *EOS* 67(44):1025-1036 (1986).

No abstract.

AO-062

BURPEE, R.W. Mesoscale structure of hurricanes. In *Mesoscale Meteorology and Forecasting*, P.S. Ray (ed.). American Meteorological Society, Boston, 311-330 (1986).

No abstract.

AO-063

CLARKE, T.L., S. Alper, J.R. PRONI, and L. Huff. A definition of "ocean bottom" and "ocean bottom depth." *Proceedings, Oceans 85* 2:1212-1215 (1986).

The question of the definition of "ocean bottom" for charting and other purposes has been discussed for many years. Intimately associated with the question of the definition of "ocean bottom depth," acoustical echo-sounding has been the dominant approach in making bottom depth estimates. NOAA has undertaken an applied research program to determine the maximum information content available in an acoustical echo from an ocean bottom which may be used to characterize that bottom in terms of texture, particulate type and engineering properties such as the shear modulus of elasticity; the resulting information to be analyzed and synthesized resulting in a scientific/engineering based definition of "bottom" or "bottom-depth." Results shall be presented from a computer model of acoustic information from different bottom types, *e.g.*, of varying surface roughness, porosity and so on. Initial model data indicate that with appropriate choices of acoustic frequency, bottom-roughness scattering can be less than bottom volumetric scattering, thereby allowing inferences of bottom characterization and engineering parameters.

AO-064

Govoni, J.J., P.B. ORTNER, F. ALYAMANI, and L.C. HILL. Selective feeding of spot (*Leiostomus xanthurus*) and Atlantic croaker (*Micropogonias undulatus*) larvae in the northern Gulf of Mexico. *Marine Ecology Progress Series* 28:175-183 (1986).

No abstract.

AO-065

HANSEN, D.V. History and status of the NOAA EPOCS program. Proceedings, Workshop on the Dynamics of the Equatorial Oceans, Honolulu, Hawaii, August 11–15, 1986. U.S. TOGA Program (1986).

No abstract.

AO-066

HARVEY, G.R., and R. Lang. Dimethylsulfoxide and dimethylsulfone in the marine environment. *Geophysical Research Letters* 13(1):49–51 (1986).

New isolation and detection methods were developed to measure dimethylsulfoxide (DMSO) and dimethylsulfone ($DMSO_2$) in marine rain and marine air masses. Central equatorial Pacific rain contained 1 to 10 μg/l of each of these compounds. Uncontaminated air sampled off Miami contained 2 to 6 ng/m^3 of each component. These concentrations suggest that DMSO and $DMSO_2$ may be as significant as dimethylsulfide (DMS) in marine sulfur transport. In fact, DMSO was observed to undergo disproportionation in illuminated seawater or distilled water to DMS and $DMSO_2$. This latter observation implies a partially reversible loop in the sulfur transport cycle and complicates the calculation of the flux of sulfur into the marine boundary layer.

AO-067

Lalou, C., G. Thompson, P.A. RONA, E. Brichet, and C. Jehanno. Chronology of selected hydrothermal Mn oxide deposits from the Trans-Atlantic Geotraverse "TAG" area, Mid-Atlantic Ridge, 26°N. *Geochimica Cosmochimica Acta* 50:1737–1743 (1986).

Radiometric ages on discrete layers in some hydrothermally deposited Mn-oxide (birnessite) samples from the TAG Hydrothermal Field on the Mid-Atlantic Ridge range from 16,000 to 4,000 years, with marked increased activity noted about 15,000 and 7,000 years ago. These observations, along with previously published data and inferences on different kinds of hydrothermal activity in the TAG field, suggest episodic, multistage hydrothermal events ranging from high-temperature black smokers precipitating sulfides to low-temperature events precipitating Fe and Mn oxides over this entire time range. Black smokers are presently active. The location of the various deposits on the eastern wall of the median valley at this latitude suggests that the high temperature events occur at greater depths.

AO-068

LONG, R.B. Inverse modeling in ocean wave studies. In *Wave Dynamics and Radio Probing of the Ocean Surface*, O.M. Phillips and K. Hasselmann (eds.). Plenum Press, New York, 694 pp. (1986).

No abstract.

AO-069

MAUL, G.A. Linear correlations between Florida Current volume transport and surface speed with Miami sea level and weather during 1964–1970. *Geophysical Journal of the Royal Astronomical Society* 87(1):55–66 (1986).

The 1964–70 Florida Current data of Niiler and Richardson are examined for linear correlation with observed sea-level and weather, because their data provide an independent test of similar correlations reported in Maul *et al.* Seventy-five values of directly measured volume transport and 67 values of surface speed from Niiler and Richardson's unevenly spaced data are correlated with available daily mean values of Miami Beach sea-level, Bimini sea-level, Bimini-Miami Beach sea-level difference, and Miami weather (barometric pressure, air temperature, and north and east components of wind speed). Statistical frequency distribution of transport and of surface speed suggest variability that is not dominated by annual and/or semiannual cycles. Volume transport is most highly correlated with Bimini minus Miami Beach

sea-level difference, and surface speed is most highly correlated with inverted Miami Beach sea-level. Including certain weather variables, results in statistically significant improvements in linear multivariate modeling of transport and surface speed from sea-level, the standard errors are ± 2.6 Sverdrup and ± 10 cm s^{-1} respectively. Linear correlation coefficients and multivariate regression parameters from Niiler and Richardson's data are in agreement with those from Maul *et al.*, except that the standard error of estimating volume transport from sea-level is smaller in Maul *et al.*, apparently because of smaller errors in the direct measurements.

AO-070

MAUL, G.A. Water masses and circulation of the Caribbean Sea. IOCARIBE Workshop on Physical Oceanography and Climate. Annex III, IOC Workshop Report No. 45, UNESCO, Paris, 1-2 (1986).

No abstract.

AO-071

MAUL, G.A., and N.J. BRAVO. Satellite-tracked buoys and drift cards: Description of buoy trajectories and drift card returns. Chapter 5.1 in final report, Physical Oceanography Study of Florida's Atlantic Coast Region. Florida Atlantic Coast Transport Study (FACTS), OCS Study MMS 86-0079. Florida Institute of Oceanography 2:253-308 (1986).

No abstract.

AO-072

McBride, J.L., and H.E. WILLOUGHBY. Comment--An interpretation of Kurihara and Kawase's two-dimensional tropical-cyclone development model. *Journal of the Atmospheric Sciences* 43:3279-3283 (1986).

This comment presents a detailed examination of the published model results of Kurihara and Kawase (1985) in an attempt to clarify the role of wave-CISK in the development of tropical cyclones. Kurihara and Kawase's model simulates the development of a tropical depression, although the vertical structure differs significantly from observations. The physical roles of vertical shear and nonlinear dynamics in the development in this model are unclear. The authors propose that the nonlinear terms in the equations promote rapid growth by increasing the "inertial stiffness." A major concern, however, is that the enhanced development may occur because the nonlinear terms excite modes with high horizontal wavenumbers. These modes grow rapidly through wave-CISK. From considerations of the climatological importance of horizontal shear to tropical-cyclone development in nature, this model may be less relevant to tropical cyclogenesis than one that allows horizontal shears of the environmental flow. The authors discuss the model's response to changes in the vertical shear of the basic state, which appears to have the opposite effect in the model from what it has in nature.

AO-073

MOLINARI, R.L., J.F. FESTA, and J. Swallow. Climatic atlas of mixed layer and thermocline depth climatologies in the western Indian Ocean. NOAA Technical Memorandum ERL AOML-64 (PB87-154613), 40 pp. (1986).

Mean monthly distributions of the mixed layer depth (defined as the first depth at which the temperature is 0.5°C less than the sea-surface temperature) and thermocline depth (defined as the depth of the 20°C isotherm) are derived from data collected between 1948 and 1981. Approximately 50,000 data points are available to generate the climatologies. Amplitude and phase distributions for the annual and semi-annual signals are computed from the monthly time series. The mixed layer depth distributions are compared to the thermocline depth distributions to identify possible regions where thermocline displacements influence mixed layer displacements.

AO-074

MOLINARI, R.L., J.F. FESTA, and J. Swallow. Evolution of the near-surface thermal structure in the western Indian Ocean during FGGE, 1979. *Journal of Marine Research* 44:739-762 (1986).

The evolution of mixed layer temperature (taken as sea-surface temperature, SST) in the western Indian Ocean north of 20°S and west of 80°E during the First GARP Global Experiment (FGGE), 1979, is described and modeled. The FGGE-year development in time and space of SST is compared to the appropriate climatology. FGGE events occurred in phase with climatology, but some amplitude anomalies were observed. Heat budget computations for the surface mixed layer indicate that over 25% of the region-studied energy fluxes through the sea surface can account for 80% of the observed SST variance. South of the equator, 80% of the variance is accounted for in 36% of the area and north, only 11%. Exceptions are noted along the western boundary, in the central and eastern Arabian Sea, and in a band south of the equator between 6°S and 12°S, east of 60°E. The addition of entrainment through the base of the mixed layer improves the heat budget estimates over most of the region, in particular, along the Arabian coast. Near the northern part of the coast of east Africa, however, inclusion of the effect of horizontal advection gives more improvement. The breakdown of the heat budget computations in the central and eastern Arabian Sea and in the band south of the equator is attributed to a small signal in SST variance and few data in the regions.

AO-075

Morrison, J.M., and R.L. MOLINARI. Circulation in the eastern Gulf of Mexico: 1974-1976. *EOS* 67(44):1049 (1986).

No abstract.

AO-076

NELSEN, T.A., G.P. Klinkhammer, J.H. Trefry, and R.P. Trocine. Real-time observation and tracking of dispersed hydrothermal plumes using nephelometry: Examples from the Mid-Atlantic Ridge. *Earth and Planetary Science Letters* 81:245-252 (1986).

As part of the 1984-1985 NOAA VENTS program on the Mid-Atlantic Ridge, nephelometry was used to provide real-time detection and tracking of dispersed hydrothermal plumes. At all nine 1984 study sites, hydrothermal activity was detected by *in-situ*, real-time nephelometer measurements and later confirmed by dissolved Mn and particulate Fe measurements. These same techniques were employed in a site-specific survey of the Trans-Atlantic Geotraverse (TAG) area in 1985 where large water-column anomalies in turbidity and in dissolved Mn helped lead to the discovery of high-temperature black smokers. The optical response of the nephelometer was to hydrothermally-derived particulate matter. Thus, strong correlations existed between the nephelometer readings and total suspended matter ($r = 0.98$, $n = 34$), and particulate Fe ($r = 0.88$, $n = 32$). In addition, digital nephelometer data correlated well with dissolved Mn ($r = 0.88$, $n = 78$) throughout a large concentration range (0.2-31.0 nmol/kg). These data provide good evidence for the utility of *in-situ* nephelometer measurements for locating and surveying plumes from hydrothermal vents. It also appears possible, within limits, to predict concentrations of *in-situ* total suspended matter, of particulate Fe and of dissolved Mn.

AO-077

NELSEN, T.A., S. Metz, J.H. Trefry, and A. Pimmel. Sedimentology and composition of sediment near a black smoker field on the Mid-Atlantic Ridge. *EOS* 67:1022 (1986).

A 1.25 m core was recovered in 1985 from the Mid-Atlantic Ridge (26°N) approximately 2 km north-northeast of the newly discovered black smokers in the TAG Hydrothermal Field. Structural evidence within the core suggests that it was recovered from the edge of a small infilling basin. Sediment transport mechanisms for the hydrothermal materials appear to be both by mass movement and grain-by-grain sedimentation. Sediment deposited by the latter mechanism has accumulated at rates

varying from 2–30 cm/1,000 years. Relative to mass movement transport, X-radiography reveals a debris-flow deposit capped by an associated fine-grained turbidite. Upcore, two course-grained turbidite deposits of hydrothermal material were identified. These mass flow deposits account for approximately 44% of the recovered sediment. The balance of the recovered sediment was deposited in a grain-by-grain fashion with hydrothermal material dominating these intervals. Hydrothermal input was pulsed, with events ranging from the sub-millimeter scale to layers as thick as 25 cm. Within the top 12 cm, representing approximately the last 4,000 years, interlayering of normal pelagic sediments and hydrothermal material indicates either sporadic deposition of, or intermittent venting of, hydrothermal material. Superimposed on the above, chemical and mineralogical data show considerable variability with time as well as providing sustaining evidence for the interpretations stated above.

AO-078

NELSEN, T.A., and J.H. Trefry. Pollutant-particle relationships in the marine environment: A study of particles and their fate in a major river-delta-shelf system. *Rapports et Proces-Verbaux des Reunions* 186:115–127 (1986).

The Pollutant-Particle Relationships in the Marine Environment (P-PRIME) program was designed to look at the association between particles (lithogenic and biogenic) and selected heavy-metal pollutants for their source-pathway-dispersal patterns and behavior from a major United States river (Mississippi River) to the adjacent continental shelf. Data from four cruises indicate the following: (a) the river's SPM concentration varied on an hourly to seasonal scale; (b) suspended particulate matter in the study area was composed of three distinct suites: a dominant lithogenic suite and two subordinates, but distinct and seasonally variable biogenic (phytoplankton) suites; (c) in order of abundance, the offshore concentration of particulate matter is in the bottom nepheloid layer, the surface turbid layer, and the midwater region; (d) in the near-shore and midshelf zone, rapid removal of river-derived (lithogenic) particles from the water column to the underlying sediments may be "driven" by biopackaging; (e) 210 Pb sediment accumulation-rate support the rapid removal and accumulation of river-derived sediments very near the river mouth; (f) data for sediment pollutant Pb support the concept of rapid sediment burial in the near-shore zone and also indicate no losses of Pb from these particles. These findings indicate that modeling and sediment transport of river/shelf systems such as the one described above must consider variability on the hourly to seasonal scale to provide an accurate reflection of the natural system. Because of close coupling of pollutants such as Pb with particles, even after burial, future studies of the pathways and sinks of many pollutants can be, to a first approximation, that of the river-derived particles.

AO-079

ORTNER, P.B. Application of simple photographic techniques to zooplankton sampling and sample processing in the Arabian Sea. Proceedings, International Conference of Marine Science in the Arabian Sea, March 29–April 2, 1986. Van Nostrand Reinhold (1986).

Over the past few years we have been experimenting with the use of photographic techniques to process zooplankton samples collected with traditional sampling devices and to sample the plankton in lieu of such collection systems. The basic approach is particularly suitable in situations where rapid feedback is desirable and where functional group characterization of the fauna is sufficient for the ecological objectives of a particular study. The rapidity, ease, and low cost of silhouette photography make it potentially useful to field workers with limited facilities. It will produce a permanent record of a live sample which is unobtainable at present by any other means. Most important, the technique is non-destructive and, if desired, the sample itself can be preserved for subsequent detailed taxonomic examination. In time it will be possible to process such photographic records entirely automatically and even at the present time microcomputer techniques can facilitate data analysis. The applicability of this methodology to studying the plankton of the Arabian Sea is discussed in some detail. A ship-of-opportunity program employing it and other tractable techniques is suggested which could greatly enhance our understanding of the Arabian Sea.

AO-088

SHAPIRO, L.J. The three-dimensional structure of synoptic-scale disturbances over the tropical Atlantic. *Monthly Weather Review* 114:1876-1891 (1986).

Twice-daily analyses of low-level and 200 mb winds over the tropical Atlantic region, archived by the National Hurricane Center, are used to diagnose the structure of synoptic-scale disturbances in the 3-5 day period band. The large-scale disturbances, extracted by a complex Empirical Orthogonal Function technique, are found to have a preferred westward shift of the 200 mb relative to the low-level troughs of somewhat less than one-quarter cycle. The presentation concentrates on July 1985, during which a repeated series of strong disturbances propagated through the region. The relationship between these disturbances and systems in the eastern Pacific is discussed. An analysis of the vorticity propagation characteristics for the disturbances during the month indicates a very different balance from level to level. At the lower level, advection by the mean wind plays a major role; at 200 mb, the meridional advection of mean vorticity is more important. Rawinsonde data from several island stations are used to resolve the vertical structure of the disturbances. After adjustment for lower intensity aloft, the kinematic energy at the lower and upper levels is found to be almost equal. The systems propagate westward faster than the mean zonal wind at any level, with a zonal phase speed that is relatively constant with height. It is inferred that the disturbances most likely propagate as a coherent system due to vertical coupling by convection. Evidence is found that the influence of low-level waves on the evolution of 200 mb systems may be stronger than has previously been described.

AO-089

SHAPIRO, L.J., and D.B. Chelton. Comments on "Strategies for assessing skill and significance of screening regression models with emphasis in Monte Carlo screening." *Journal of Climate and Applied Meteorology* 25:1295-1298 (1986).

In a recent paper, Lanzante reviewed methods for estimating the skill and significance of screening regression models through the use of Monte Carlo simulations. The strategies reviewed have several limitations that were not specified by the author. Due to the influence of true model skill, the Monte Carlo method provides an upper bound on the expected artificial skill itself as assumed. Lanzante emphasizes the advantages of the use of independent (uncorrelated) predictors. However, the disadvantages of their use and the advantages of dependent predictors in a screening regression were not considered. The review of the effects of serial correlation on estimates of skill is misleading. The assertion that the formulations developed by Davis and Chelton are erroneous is incorrect. Moreover, contrary to the implication of the review, the use of effective sample size in tests of model significance has practical utility in applications including the Monte Carlo method.

AO-090

Trefry, J.H., T.A. NELSEN, R.P. Trocine, S. Metz, and T.W. Vetter. Trace metal fluxes through the Mississippi River delta system. *Rapports et Proces-Verbaux des Reunions* 186:277-288 (1986).

River deltas serve as an important sink for many continentally-derived contaminants, thereby restricting their flux through the coastal zone. We have investigated the geochemical cycling of several trace metals, especially Cd, Mn, and Pb, in the Mississippi River delta-Gulf of Mexico system to establish the efficiency of this deltaic sink. Greater than 90% of the Mississippi River trace metal load is associated with detrital particles. As a result, dissolved metal concentrations are very low and appear to be controlled in several instances by a predictable partitioning between dissolved and particulate phases. To model this partitioning, distribution coefficients (Kd) were calculated for several metals using field and laboratory data. Much of the river-borne sediment is deposited within 30-50 km of the river mouth. This is especially evident in the sediment record for Pb which shows a sharp decrease in the depth to which pollutant Pb is found with increasing distance offshore. Sediment Pb profiles and river particulate Pb concentrations also support a 40% decrease in the 1982-1983 Mississippi River burden of pollutant Pb relative to the mid-1970's. Delta sediments are not always the ultimate sink for trace metals.

Remobilization of Mn and Cd to the overlying water column leads to a 10–50% net loss of these metals from the sediment. In contrast, the Pb cycle shows rapid, permanent removal to the sediments. The Mississippi delta is thus a near-perfect filter of Pb, and traps much, but not all, of the incoming fluxes of Cd and Mn. The availability and potential reactivity of sediment trace metals were elevated by leaching sediments with a series of buffers at pH 2.2–6. Results show that Cu, Fe, and Pb have a much lower tendency towards removal than Cd and Mn.

AO-091

Williams, A.B., and P.A. RONA. The new caridean shrimps (Bresiliidae) from a hydrothermal field on the Mid-Atlantic Ridge. *Journal of Crustacean Biology* 6(3):446–462 (1986).

Rimicaris, a new genus, and two new species of caridean shrimps, *R. exoculata* and *R. chacei,* are recorded in swarms from a thermally-influenced site in the rift valley of the Mid-Atlantic Ridge at 26°08.3'N, 44°49.6'W, 3,620–3,650 m depth. The shrimps appear to be the predominant macroinvertebrates in heated waters (at least 1.0°C above ambient, 2.37°C away from vents) on black sediments and layered rocks with the appearance of polymetallic sulfides precipitated from black smoker-type vents. Characters of these species indicate placement in the family Bresiliidae which is distributed in surface to mid-ocean depths. A key to the seven bresiliid genera is given.

AO-092

WILSON, D., C. ROFFER, and D. BITTERMAN. The shipboard acoustic Doppler current profiling program at AOML. *EOS* 67(44):1061 (1986).

No abstract.

AO-093

Woodward, W.E., G.A. MAUL, W. MCLEISH, S.R. Baig, R.D. Crissman, D.E. Barrick, G.D. Garrett, and K. Nancarrow. CODAR operations in the Straits of Florida. Florida from a dual-site CODAR installation. *Proceedings, Oceans 86, 1986 IEEE,* 421–425 (1986).

No abstract.

AO-094

YOUNG, R.A., and R. Mann. Erosion velocities of skeletal carbonate sands, St. Thomas Virgin Islands. *Marine Geology* 69:171–185 (1985).

Erosional shear velocities, μ^*, for irregular skeletal carbonate sands were determined from sea-going flume experiments on the insular shelf of St. Thomas to be in the range 0.4–1.0 cm s^{-1}. Erosional velocities are only weakly correlated with grain size and do not correlate well with various shape factors. Non-dimensional Shields and Yalin plots of the skeletal sand data overlap but fall mainly below the accepted curves for spherical grains, and corrections for grain shape only slightly improve the fit to the curves. This result is consistent with other experiments which show that threshold curves for regular (flaky) non-spherical grains form separate trends from the established curves for spherical grains. This suggests that only approximate agreement with accepted non-dimensional threshold curves may be expected for irregular grains until a better method is found to characterize and correct grain size and shape.

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BLACK, Peter G.	Meteorologist
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ROFFER, Carol	Oceanographer
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STRUCK, John H.	Electronics Technician
SWEENEY, Dennis P.	Physical Science Technician
TANNER, James P.	Biological Technician
THACKER, William C.	Physicist
THOMAS, Gregg G.	Oceanographer
TIRADO, Pedro W.	Student Trainee (physical science)
TORRES, Randolph	Student Trainee
TROUT, James W.	Supervisory Meteorologist
TSAI, John J.	Physicist
VICTORIA, Celia L.	Computer Programmer
WESTON, Dorothy L.	Secretary
WIGGERT, Victor	Meteorologist
WILBURN, Anne Marie	Oceanographer
WILLIAMS, Helen	Computer Operator
WILLIS, Paul T.	Meteorologist
WILLOUGHBY, Hugh E.	Meteorologist
WILSON, William D.	Oceanographer
WOOLDRIDGE, Anita L.	Oceanographer
WRIGHT, Robert E., Jr.	Meteorological Technician
YOUNG, Margie S.	Oceanographer