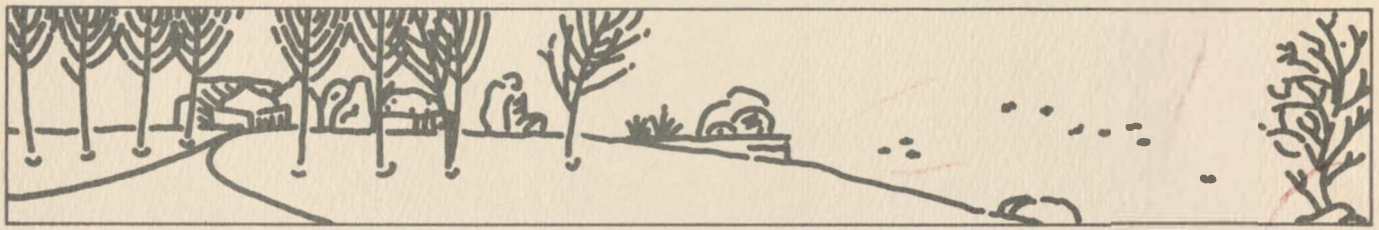
PACIFIC MARINE ENVIRONMENTAL LABORATORY



ANNUAL REPORT FY 83

PACIFIC MARINE ENVIRONMENTAL LABORATORY
Seattle, Washington

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U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
John V. Byrne, Administrator

OFFICE OF OCEANIC AND ATMOSPHERIC RESEARCH
Joseph O. Fletcher, Assistant Administrator

ENVIRONMENTAL RESEARCH LABORATORIES
Vernon E. Derr, Director

CONTENTS

INTRODUCTION

The Pacific Marine Environmental Laboratory (PMEL) is a mission-oriented government laboratory located in Seattle, Washington, conducting research in oceanography, marine meteorology, and related subjects. Its research goal is to improve our understanding of environmental processes in both coastal and open-ocean systems in support of NOAA's mission to ensure the wise development and rational conservation of ocean resources and to monitor and predict weather and environmental conditions. The PMEL program focuses on the Pacific Ocean and adjacent coastal regions. Studies are conducted to understand better the complex physical and geochemical processes that determine the extent of human impact on the marine environment; to define the forcing functions and to determine the time and space scales of the processes driving ocean circulation and the global climate system; and to improve environmental forecasting capabilities and other supporting services for marine commerce and fisheries. Products of PMEL's research are environmental information and predictive models. These are disseminated by means of scientific papers, technical reports, presentations to other researchers, NOAA operational elements, and interested local and Federal agencies.

This research requires professional scientists with a broad range of disciplinary backgrounds, a strong technical support staff, and a research approach that integrates field, laboratory, and analytical efforts. The staff is organized into four research divisions sharing a programmatic or technical focus (Figure 1). PMEL research projects are elements of larger national or international programs, and laboratory scientists are consequently active in the broader oceanographic research community, serving on scientific steering committees and collaborating in multi-institutional field efforts. Cooperative research institutes established between NOAA and the Universities of Washington and Hawaii provide close research collaboration as well as opportunities for PMEL scientists to teach and supervise graduate student research through affiliate faculty appointments.

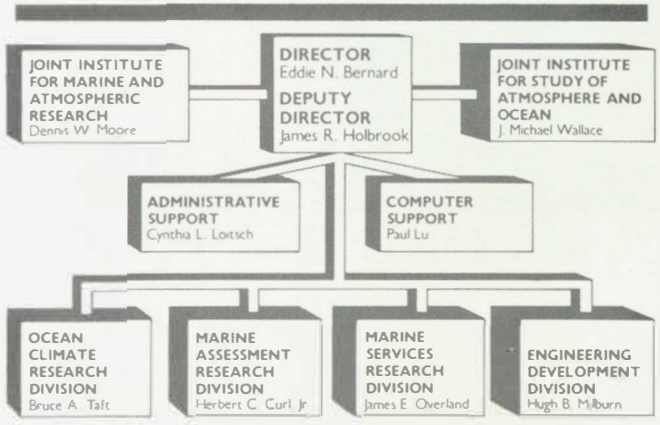


Figure 1
PMEL organizational chart

The assemblage of NOAA personnel and activities in Seattle is the second largest in the United States and includes elements of the National Weather Service (NWS), National Marine Fisheries Service (NMFS), the National Ocean Service (NOS) and the National Environmental Satellite, Data, and Information Service (NESDIS). PMEL's collocation with these groups provides a unique opportunity for cooperative work and exchange of information, direct transfer of research results from PMEL to the operational components of NOAA, and ready access to major NOAA facilities such as the NOS Pacific Fleet, the National Analytical Facility, the Northwest Calibration Center, and the Northwest Ocean Services Center.

E. N. Bernard, Director

OVERVIEW OF THE PMEL PROGRAM

FY 1983 was a year characterized for NOAA by organizational change and refocusing of scientific programs. These changes were reflected at PMEL through the selection of a new permanent Director and Deputy Director and internal reorganization. In July, PMEL consolidated its three separate facilities (a remodeled motel, a former airport tower, and a WWII vintage aircraft hangar) in a new building specifically designed to support modern oceanographic research at NOAA's Western Regional Center in Seattle, Washington. This physical move further enhanced the integration of our programs. As a result, PMEL has emerged as a stronger, better-focused laboratory.

During fiscal year 1983, PMEL's scientific program was concentrated in four major areas that correspond to NOAA's areas of interest in oceanography: Ocean Climate Dynamics, Marine Environmental Quality, Marine Observation and Prediction, and Marine Resources. The mission of the Pacific Marine Environmental Laboratory is to conduct scientific investigations in oceanography, marine meteorology, and related disciplines. Research focuses on NOAA's mandate in climate, ocean services, marine environmental assessment, and marine resources to improve understanding of environmental processes in coastal and open-ocean systems.

PROGRAM AREAS

Within PMEL's four program areas are ten elements (Figure 2), highlighted in the following sections of the Annual Report. The individual elements are integrated and redirected as necessary as the Laboratory's research plan is implemented.

Ocean Climate Dynamics

During recent years there has been an increasing awareness of the impact of short-and long-term climatic changes on human systems, particularly food and energy, and conversely, a concern about the impact of technology and population growth on world climate. When the National Climate Program Act was passed in 1978, NOAA became the lead agency for U.S. research in climate dynamics. PMEL scientists have been heavily involved in the formulation and implementation of the NOAA Ocean Climate Program.

To predict climatic change, it is necessary to understand the processes of heat, moisture, and momentum exchange between the ocean and atmosphere, as well as the large-scale movement of heat by the atmosphere and ocean. The PMEL ocean climate dynamics program investigates the problem in studies of both local (small-scale) and basic-wide (large-scale) ocean dynamics and the coupled ocean-atmosphere circulation. Laboratory participation in multi-institutional field experiments — the Mixed Layer Experiment (MILE) in the North Pacific, the Joint Air-Sea Interaction Experiment (JASIN) off the coast of Scotland, the Coastal Upwelling Ecosystems Analysis (CUEA) Program in the southeast Pacific, the North Pacific Experiment (NORPAX) in the central tropical Pacific, and the PMEL equatorial program (EQUA) in the equatorial Pacific — has established the groundwork for present efforts in the NOAA Equatorial Pacific Ocean Climate Studies (EPOCS). These studies are testing the hypothesis that ocean surface temperature anomalies in equatorial regions have a pronounced effect on atmospheric circulation in both temperate and equatorial latitudes. A major research goal is to determine the relative importance of the physical mechanisms that generate anomalies in sea surface temperature distributions in the equatorial ocean. This research falls within the broader ENSO research area. ENSO is the name given to the combined areas of El Niño (identified by warm waters in the eastern and central Pacific) and Southern Oscillation (identified by a shift in atmospheric pressure systems) studies. These two phenomena, both known to scientists for over a half a century, now appear to be closely connected with an impact on both U.S. weather and fisheries.

Heat transport by major western boundary currents, the Gulf Stream and Kuroshio in the Northern Hemisphere, are also postulated to have an important impact on world climate. Studies during 1983 focused on the Florida Current as part of the Subtropical Atlantic

OCEAN CLIMATE DYNAMICS	**ENSO**	**page 6**
	Western Boundary Current	**10**
	Marine Carbon Dioxide	**19**
MARINE OBSERVATIONS AND PREDICTION	**Sea Ice Processes**	**23**
	Coastal Winds and Waves	**24**
	Fisheries Oceanography	**26**
	Tsunami	**26**
MARINE ENVIRONMENTAL ASSESSMENT	**Long-Range Effects**	**13**
	Acid Rain	**19**
MARINE RESOURCES	**Sea-floor Spreading Processes**	**21**

Figure 2
PMEL program areas.

Climate Study (STACS) and the Kuroshio in the vicinity of the Emperor Seamounts. These two studies will provide insight into the fluctuations of two of the world's major currents.

PMEL is also conducting two unique marine-chemistry research activities for NOAA under the National Climate Program. These activities relate to the ocean's behavior as a sink for atmospheric carbon dioxide, which has been steadily increasing over the past century. One project measures the flux of human-made fluorocarbons into the ocean in order to trace gaseous diffusion across the ocean-atmospheric boundary. The other project is examining the role of biologically produced, particulate calcium carbonate as an absorber of carbon dioxide at high latitudes. Together these studies will help determine the potential of the oceans for absorbing carbon dioxide.

Marine Environmental Quality

Marine Environmental Quality, the most diverse area of PMEL research, emphasizes understanding the complex physical and geochemical processes that ultimately determine the health of the marine system and its ability to assimilate potential pollutants. Included in this area are studies of suspended-sediment transport and geochemistry, distributions of hydrocarbons and synthetic organics, coastal and estuarine circulation, theoretical modelling of pollutant transport processes, and a program in marine sources of acid rain.

The results of marine environmental quality research support NOAA's mission to provide timely information on the state of the marine environment to assist public decision makers in balancing economic development and environmental conservation. This service is critical in coastal and estuarine areas where an increasing assortment of both natural and synthetic materials enters the marine environment. Under the Marine Protection, Research and Sanctuaries Act of 1972 and the National Ocean Pollution Research and Development and Monitoring and Planning Act of 1978, NOAA has responsibility for monitoring and conducting research on ocean waste disposal, long-range effects of man's activities on marine areas and for coordinating Federal research programs in ocean pollution. Within this context, the PMEL program addresses environmental concerns associated with offshore oil development, transport and marine disposal of municipal waste water, and the reaction of marine systems to continuous influx of pollutants. PMEL research has been used to assess both the fate of potential oil spills in the Strait of Juan de Fuca arising from the Northern Tier proposal and the fate of potential spills associated with outer continental shelf oil and gas leasing. Under the NOAA Long-Range Effects Research Program, PMEL is examining the role of suspended particulates in transporting pollutants or in removing them from the marine system. Researchers are also studying the mechanisms by which heavy metals and organic pollutants adhere to particulates. As these processes become better understood, we will be able to assess the long-term effect of chronic, low-level input of pollutants into the marine system. PMEL is also participating in the Acid Rain Research Program focusing on identifying and quantifying marine sources of organic sulfur compounds.

Ocean Services Research and Development

The goal of the PMEL program in ocean services is to improve NOAA's capabilities for providing information, forecasts, and warnings of possible environmental hazards to people in the offshore and coastal areas of the United States and its territories. PMEL scientists, in conjunction with personnel from NOAA operational elements, have identified priority areas where directed research can provide substantial improvement in marine forecasting and prediction. Research under way in 1983 was aimed at predicting the movement of the Bering Sea ice edge, predicting coastal wave conditions at harbor entrances, and improving tsunami forecasts and warnings in the Pacific Basin. The U.S. Army Corps of Engineers, the U.S. Coast Guard, the U.S. Navy, the Northwest Ocean Services Center, the Seattle Office of the National Weather Service, and the Pacific Tsunami Warning System will be among the direct users of this information.

PMEL has also begun planning and coordinat-

ing with the National Marine Fisheries Service for a joint research effort to better understand environmental factors that affect fish and shellfish production and mortality. This year saw the beginnings of a comprehensive fisheries oceanography data management system which ties together data bases in both fisheries and oceanography so scientists at both institutions will have access to interdisciplinary information.

Marine Resources

PMEL participates in research activities that provide information for resource management decisions by NOAA and other agencies. Building on past experience with ocean minerals in the Deep Ocean Mining Environmental Study (DOMES), PMEL has begun a study of geochemical plumes associated with sea-floor spreading centers. Understanding these processes will enhance our knowledge of the chemistry of the oceans as well as provide information on the formation of metalliferous deposits.

MAJOR RESEARCH ACCOMPLISHMENTS

OCEAN CLIMATE DYNAMICS

ENSO

- PMEL has lead many of the studies of the 1982-83 El Niño. (El Niño is the phenomenon of unusually warm water which occurs occasionally in the equatorial eastern Pacific Ocean. This surface warming is also associated with changes in the winter climate over parts of North America).
- Research documented, for the first time, the disappearance of the Equatorial Undercurrent (EUC). This occurred during the 1982-83 El Niño.
- Data on sea level and currents were successfully recorded throughout the 1982-83 El Niño. These measurements are the most comprehensive ever obtained during an El Niño.
- Analysis of ship-of-opportunity XBT data in the region between the equator and Hawaii showed that the transport in the North Equatorial Countercurrent was unusually high during the onset of the 1982-83 El Niño, then swung to unusually low values. Transport of the North Equatorial Current was not anomalous during this period.
- Historical data sets of use to ENSO research were studied leading to a better understanding of the statistical reliability of the data. This work helps demonstrate the validity of inferences drawn from the data.
- A new instrument was installed aboard the NOAA ship *DISCOVERER* which allows, for the first time, underway profiles of ocean currents within 200 m of the surface. This instrument is particularly valuable in transport studies in the tropics which are related to ocean climate research.

Western Boundary Current

- Cross-stream voltage differences were used to measure transport of the Florida current. For the first time this method proved itself capable of providing results within 2% of more expensive traditional methods.
- Remote effects in the ocean of the 1982-83 El Niño were documented in the northern latitudes off the coast of North America. These changes are thought to be associated with the unusual fisheries conditions of that period.

Marine Carbon Dioxide

- The greatest accumulations of freon-11 and fossil-derived CO_2 in the North Pacific Ocean occur beneath the subtropical gyre. The deep penetration of both gases beneath the subtropical gyre is due to winter cooling in the vicinity of the subarctic front in the western Pacific followed by isopycnal mixing and geostrophic transport.
- Measurements in the western North Pacific indicate that the colder surface waters of the subarctic gyre are only slightly supersaturated with respect to aragonite. Our calculations indicate that continued atmospheric buildup of CO_2 will result in aragonite undersaturation in the surface waters of the North Pacific as early as the second half of the next century, at which time the ocean's ability to absorb additional amounts of CO_2 will begin to diminish.

MARINE ENVIRONMENTAL ASSESSMENT

Long Range Effects

- The framework for a pollutant source model was developed. Ancillary variables, such as population, number of autos, and gasoline consumption, were enumerated on the basis of water shed areas rather than by the usual pattern of political boundaries.
- A mass transport model for estuarine systems was formulated. The model enables the user to quantify the transport in surface and bottom layers at various locations in the estuary based on observations of salt and mass fluxes at a few locations. Transport calculations then allow predictions of the basin-wide distribution of dissolved, conservative substances based on the strength and location of the input.
- The erosion rate model developed from recently collected field data indicates that erosion of fine-grained material is proportional to the fourth power of the bed stress, and thus is acutely sensitive to changes in current speed. Knowledge of this relationship makes prediction of sediment transport near the bed more certain.
- A synthesis of past direct measurements of currents has been published. These studies are in general agreement with mass balance models of circulation and flushing in Puget Sound.
- Personnel at PMEL and contract geochemists have determined the lead (^{210}Pb) and thorium (^{234}Th) geochronologies of Puget Sound sediment samples and have inventoried trace metal and organic pollutants in those sediments. These results have led to the development of a profile of the deposition of pollutants during this century.
- Geochemical cycles have been developed for several pollutants in Puget Sound. From the cycle for lead, an actual budget has been computed.

Acid Rain

- The search for oceanic precursors to acid rain was extended along the west coast of the U.S. and the eastern equatorial Pacific. Calculations of the flux of a major precursor (dimethylsulfide) showed a total load of 0.15 Tg/yr, about equal to the sulfur emission from the Mt. St. Helens eruptions of 1981 and four times the annual emission of the Tacoma copper smelter, the major anthropogenic point source in the Pacific Northwest.

MARINE OBSERVATION AND PREDICTION

Sea Ice Processes

- A forecasting model for sea ice extent was transferred to the National Meteorological Center of the National Weather Service.
- Investigators from PMEL, University of Washington, U.S.G.S., Scott Polar Research Institute, England, SAI, NASA, and other parts of ERL cooperated in a study of the Bering Sea Marginal Ice Zone called MIZEX West. All field objectives were fully met.

Coastal Winds and Waves

- A hindcasting experiment to determine the errors associated with Columbia River Bar wave forecast methods was completed. These data form a benchmark against which new methods can be evaluated.
- Experimental data from the Columbia River were analyzed to produce an improved forecast methodology. Consisting of programs requiring inputs of current strength on the bar and the offshore wave period and direction, the model accounted for 70% the observed variance in significant waveheight during the most critical period, peak ebb. This represents a 25% improvement over previous methods.

Fisheries Oceanography

- A relational distributed data base management system, FOCUS, was developed to make both fisheries, oceanographic, and meteorological data available to scientists working on the problems of fisheries oceanography. This was accomplished by personnel at PMEL and NWAFC with financial assistance from the NOAA Administrator.
- A synthesis report of northeast Pacific meteorological and oceanographic data relevant to fisheries studies was developed and has become the basis for increased communication and cooperation with fishery scientists through IRIS (International Recruitment Investigations in the Subarctic), the NWAFC Ecosystem Working Group and several Fisheries Oceanography workshops.

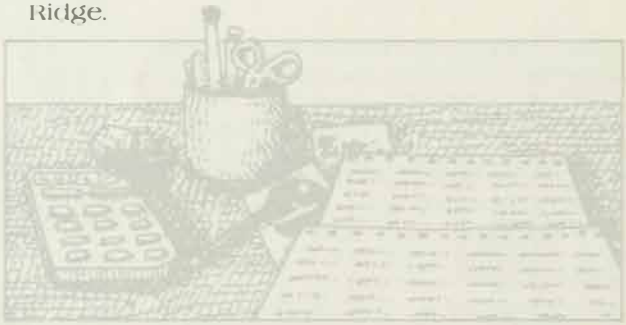
Tsunami

- A pressure gauge deployed in the equatorial Pacific measured three passing tsunami thus demonstrating that a tsunami can be measured in the deep oceanic environment.

MARINE RESOURCES

Sea-floor Spreading Processes

- Measurements of iron and manganese enriched waters near hydrothermal vents were taken at several sites on the Juan de Fuca Ridge.



FUNDING

PMEL operations are supported by a combination of NOAA operations, research, and facilities funding (both one-time and permanent), and reimbursable funding from other agencies. During FY 1983, recurring NOAA-based funding accounted for 46% of the Laboratory support, one-time NOAA funding constituted 41% and reimbursable funding 13% (Figure 3). Support to universities, and in particular the cooperative institutes, was 13% of the PMEL budget.

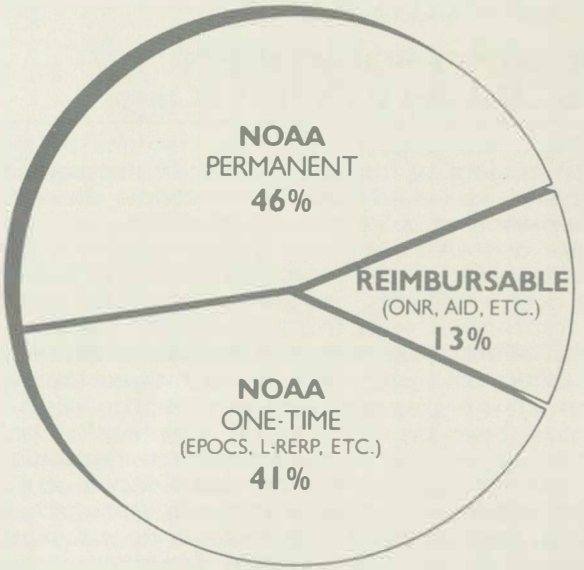


Figure 3
PMEL Funding Sources.

OCRD

Bruce A. Taft, Division Leader

The Ocean Climate Research Division conducts research on the oceanographic processes that determine ocean climate change. Because the ocean and atmosphere are intimately coupled, these studies involve considerations of the effects of atmospheric forcing on the ocean as well as the response of the atmosphere to the oceanic changes. These problems are approached through a combination of extensive collections of atmospheric and oceanographic data in the tropics and subtropics and the ongoing interpretation of these data by means of dynamical models.

EL NIÑO-SOUTHERN OSCILLATION (ENSO)

There are large interannual changes in the heat content of the upper layer of the tropical Pacific. Associated with these oceanic changes (anomalies of 2 to 5°C in sea-surface temperature are observed) are perturbations in the atmospheric circulation which appear to initiate the ocean changes and are also to be the result of interaction with the ocean after the near-surface heat content distribution has been modified. The phenomenon of mutual interaction of the tropical ocean with the global atmosphere on interannual time scales has been termed the El Niño-Southern Oscillation (ENSO) problem, and is the main focus of the NOAA sponsored EPOCS Program. Research at PMEL on the ENSO problem is coordinated through the EPOCS Program. During the past year our field program has included taking measurements of wind, current and temperature from deep-sea moorings at the equator in the eastern Pacific, making north-south transequatorial sections to measure velocity, temperature, salinity and dissolved oxygen across the major components of the current system in the eastern Pacific, recording sea level at the Galápagos Islands, and analyzing ship-of-opportunity subsurface and surface temperature data. A selection of results from the studies is included below.

Equatorial Undercurrent

Perhaps the most interesting current in the equatorial region of the Pacific is the Equatorial Undercurrent (EUC). The Undercurrent is a subsurface, eastward-flowing current about 200 m thick and 400 km wide. Usually the maximum speed (1 m s^{-1}) is centered in the thermocline at depths of 50-150 m and occurs within 50 km of the equator. Continuous measurement of the Undercurrent in the eastern Pacific near 110°W has continued since March 1980 using vector-averaging current meters to sample current and temperature data beneath tautly moored surface buoys (Figure 4).

These measurements have shown that the EUC goes through an annual cycle in which the undercurrent rises each year in March-April coincident with the period of maximum transport and sinks in October-November coincident with minimum transport. During normal years the undercurrent neither disappears nor reverses.

The most striking feature of the EUC response to the 1982-1983 El Niño was its complete disappearance and reversal at 110°W during January-February, 1983 (Figure 4). It was replaced for a couple of months by a westward subsurface current, then by an intense eastward surface jet at all measured depths. In late February, 1983 the Undercurrent abruptly reappeared with a strong westward South Equatorial Current at the surface. Continuing analysis of these data is aimed at developing an understanding of the dynamics of these dramatic changes of heat distribution.

D.Halpern

Role of Kelvin Waves

An interesting feature of the dynamics of the near equatorial region is the existence of a class of free waves, trapped at the equator, which is capable of rapidly propagating fluctuations from west to east. These waves, called equatorially trapped Kelvin waves, play an important role in our theoretical understanding of the response of tropical oceans to wind changes. In particular, in the Pacific Ocean, this wave response is a striking characteristic of models which explain El Niño. However, it was not until recently that observational evidence, centered around the work done at PMEL, documented their existence. It was shown that the north-south structure of low frequency sea-level fluctuations at the Galápagos Islands was consistent with Kelvin wave theory. A pulse was first found in

eastward transport in the upper 200 m which propagated non-dispersively along the equator from 153°W to 110°W at the Kelvin wave phase speed. This study has now been extended in space and time. Coherent sea level fluctuations were found propagating 10,000 km across the Pacific from the Gilbert Is. to the Galápagos Is. at the Kelvin wave phase speed. These independent studies of sea-level and currents implied a relationship between the two parameters which was firmly established in the recently completed study of moored current

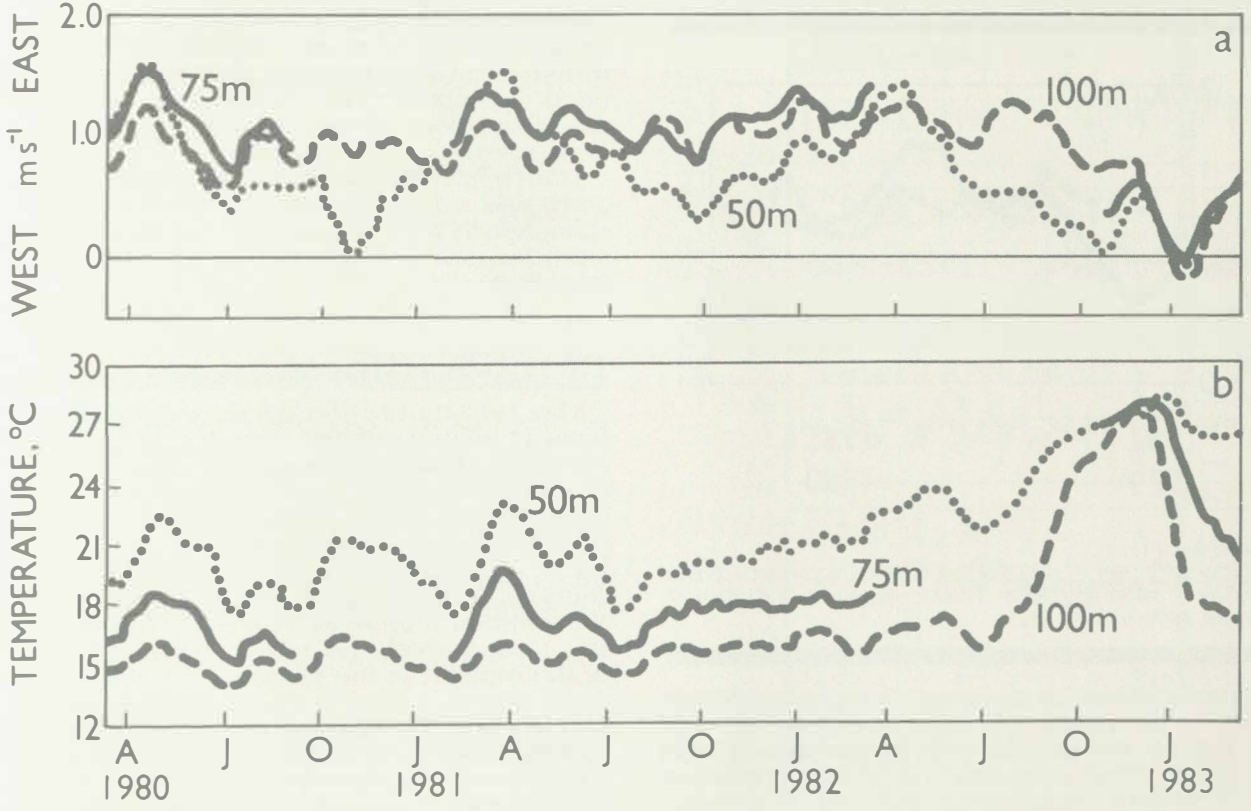


Figure 4
Low pass filtered zonal current a) and temperature b) variations at 50, 75, and 100 m within the Equatorial Undercurrentr (EUC) near 110°W show normal seasonal fluctuations during April 1980 to March 1982 and strong current andr temperature anomalies during the El Niño event (September 1982 to March 1983).r

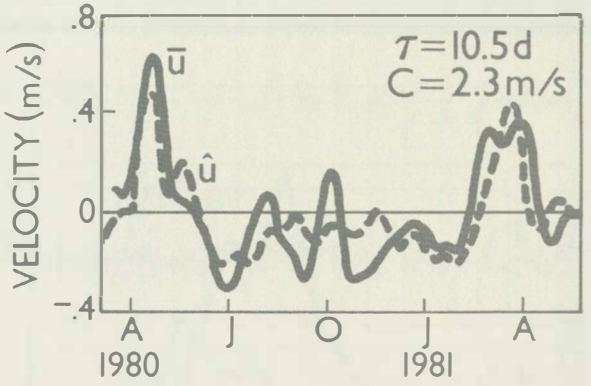


Figure 5
Time series of measured average zonal velocity between the surface and 200 m depth at 0°, 110°W (ū) and the average velocity estimated from sea level measurements at the Galápagos Is. using a Kelvin wave model (û). The model assumes a Kelvin wave phase velocity of 2.3 ms^{-1}, which corresponds to a 10.5 day travel time between 110°W and the Galápagos Is.

measurements at 0°, 110°W and sea level at the Galápagos. The two time series are highly correlated (Figure 5) at a lag of 10.5 d (corresponding to a Kelvin wave phase speed of 2.3 m s^{-1}) and their relative amplitudes are also specified by the Kelvin wave relationships. A single Kelvin wave mode explains 70% of the Galápagos sea level in terms of the zonal transport per unit width at 0°, 110°W. This model does not account for the large, near-surface currents which appear to be locally forced.

S. P. Hayes and D. Halpern

Transport of NECC in 1982-83 El Niño

Although maximum El Niño surface temperature anomalies occur at the equator and much of the observational effort has been concentrated in the band of latitude where equatorial wave motions are trapped, the effects on surface temperature distribution extend off the equator. The one hypothesis that has been proposed to explain the broader scale effects is that there are off-equatorial adjustments in the north-south slope of the thermocline and a resulting change in the strength of the zonal currents. Because of the large-scale temperature gradients, these anomalous currents will produce an anomalous heat transport. The ship-of-opportunity program to measure the temperature field in the Pacific has yielded a data set which can be used to compute the transports of the zonal currents. The pressure gradients and resulting geostrophic flow can be computed from temperature profiles when combined with historical data on the temperature-salinity relationship. Data supplied by other institutions has been used to compute the time series of surface transport through most of the 1982-83 El Niño event. In the central Pacific, the results may be compared with the data collected during the 1979-80 NORPAX FGGE Shuttle. This earlier time period may be considered to be representative of a "normal" period in the tropical Pacific. The maximum transport of the eastward North Equatorial Countercurrent (NECC) in the central Pacific was 50 percent higher in 1982-83 than in 1979-80 and the maximum appeared in September rather than at the end of the year (Figure 6). Quarterly maps of the sea-surface temperature anomaly (published by the NOAA Climate Analysis Center) show the warming in the central Pacific to have commenced by June-August 1982 and to be very strong by September-November 1982. By April 1983, the NECC transport had reached a minimum and temperatures in the central Pacific at the latitude of the NECC (5°-10°W) had become anomalously cool. The data suggest that there were large changes in the eastward volume transport and that the high transports were associated with warming in the central Pacific. Further calculations of volume transport in the western and eastern Pacific need to be carried out before the role of anomalous transports off the equator, in changing the heat content, can be evaluated.

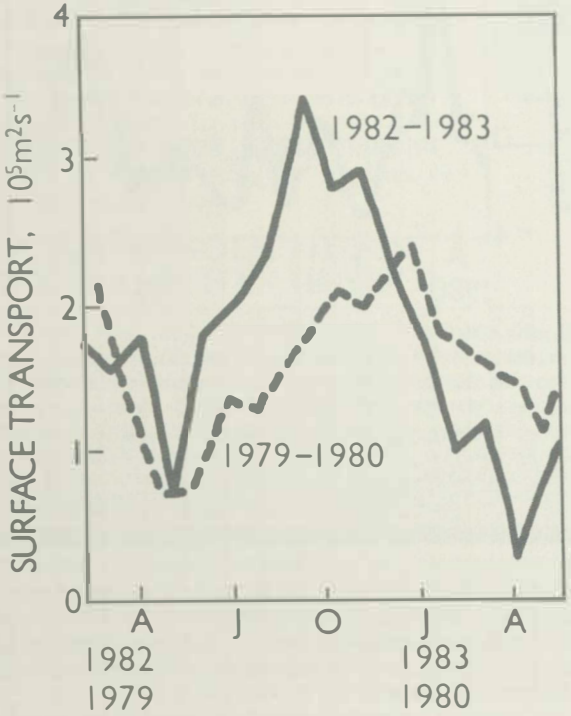


Figure 6
Surface transport of the North Equatorial Countercurrent (NECC) of January 1982 to May 1983 compared with that of January 1979 to May 1980.

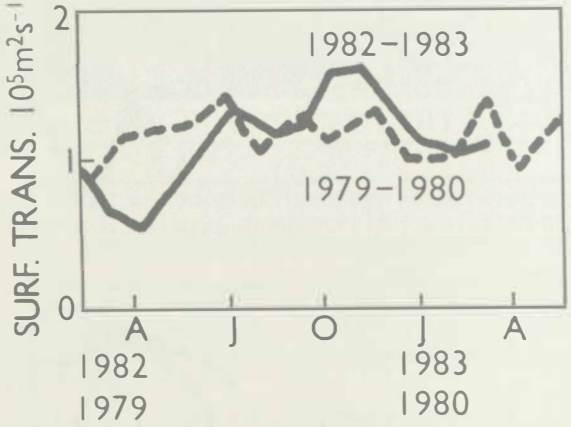


Figure 7
Surface transport of the North Equatorial Current (NEC) of January 1982 to March 1983 compared with that of January 1979 to May 1980.

Transport of the North Equatorial Current (10°-20°N) was not anomalous during the 1982-83 El Niño, which may account for the lack of a clear signal in surface temperature north of 10°N (Figure 7).

B. Taft

Remote Effects

The 1982-83 El Niño event had significant effects at high northern latitudes in the Pacific. This was clearly evidenced by a significant rise in sea level and increase in temperature off the coasts of the Pacific Northwest and Alaska. The monthly anomaly of sea level increased by more than 7 cm from December, 1982 to January, 1983 in Sitka, Alaska and Neah Bay, Washington (Figure 8). A few months earlier, a rise in sea level and major warming occurred at the equator in the eastern Pacific, which suggests a 2 to 3 month transit time between the equator and the high latitudes. Daily rather than monthly values of sea level will be analyzed to determine whether the coastal sea level increases do indeed exhibit patterns characteristic of a coastally trapped propagating wave.

The 1982-83 sea level anomalies from California to Alaska were compared to signatures from earlier events (Figure 9). The greatest

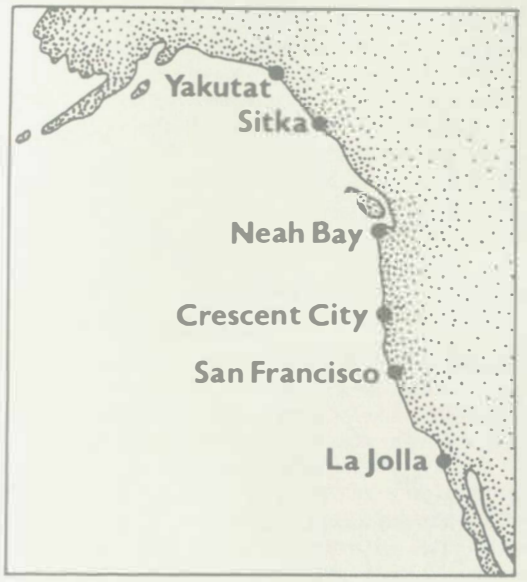


Figure 8
Locations of sea level stations shown in Figure 9.

similarity was with the 1957-58 El Niño. In addition, a significant signal as far north as Alaska was also evident following the 1941 event. For other El Niño events, sea level anomalies were not evident further north than La Jolla, California. A possible explanation is that local effects dominated the coastal water structure and that the remote effects were masked.

R. K. Reed and P. Pullen

Historical Data

In order to study long-period climate fluctuations, the 100-year Fletcher data set must be used. PMEL is engaged in an evaluation of the quality of this data set. The study is preparatory to using this data set for a study of low frequency air-sea interaction processes.

During the past few years, historical data sets of sea-surface temperature, air temperature, sea-

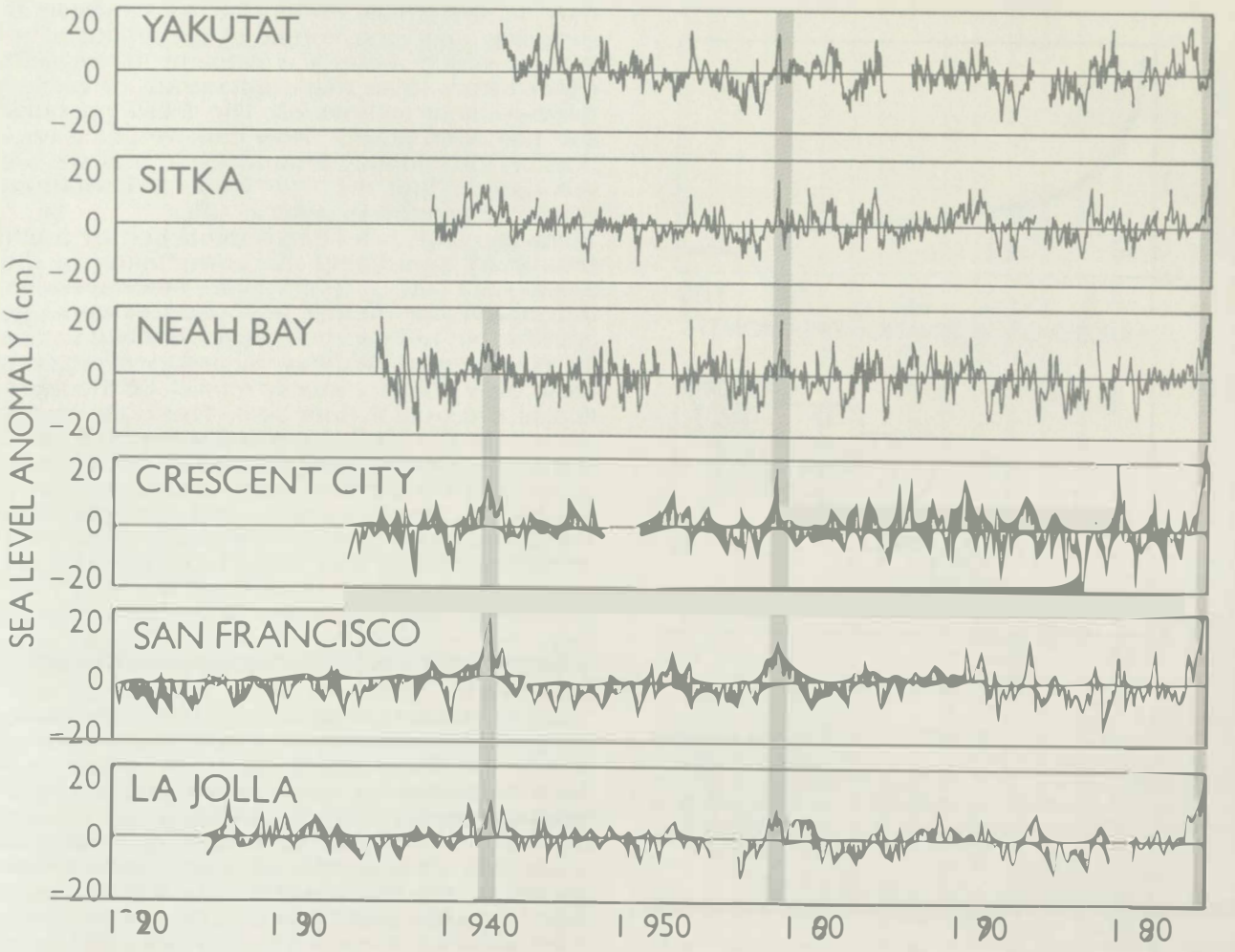


Figure 9
Time series of monthly sea-level anomalies (mean removed) at six stations along eastern boundary of the North Pacific. Vertical lines indicate rise in sea level associated with past El Niño events.

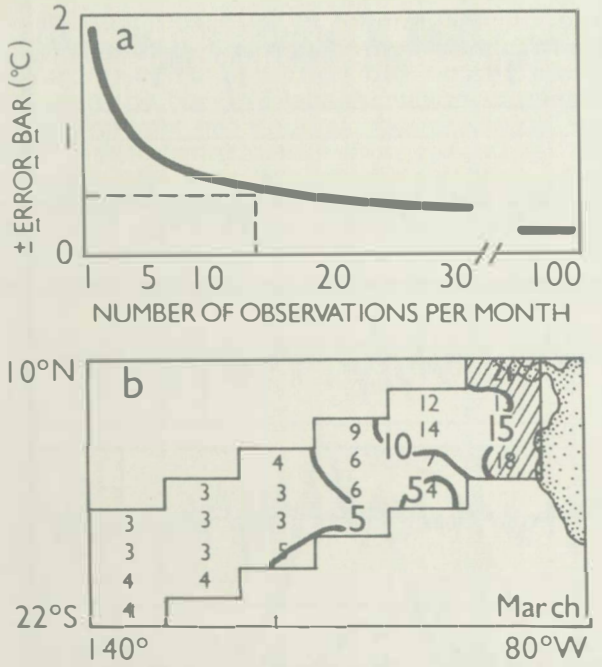


Figure 10
a) Error bars associated with the number of observations per month for March SST anomalies near the Galápagos Islands. b) Geographic distribution of the number of observations required to achieve an error of ±0.5°C or less in monthly SST anomalies.

level pressure, winds and cloudiness have been compiled. These data sets have been examined for evidence of large-scale, long-term climate changes during the last century. They have also been used to study the evolution of temperature and wind fields during El Niño events.

There are questions about the reliability of these data sets, especially for the period before the 1950's and for regions of sparse data. In particular, there are errors due to the small samples taken of rapidly varying fields. There may be systematic errors due, for example, to sampling only one corner of geographical region in which there is a gradient in the field. Other errors arise from inaccurate or biased measurement techniques. The following question has been posed: "How can we place error bars on the monthly anomalies so that we are 90% certain that the true value is contained within the specified range?"

This question has been approached by mathematically simulating the compilation of the actual data sets. A multivariate, autoregressive, moving-average model was used to generate artificial, but realistic, time series of daily values for each region. Monthly means derived from these daily values correctly reproduce the statistics of the actual data sets. The daily series were then sampled in various ways and, using Monte Carlo techniques, probability distributions of the sampling errors were constructed as a function of month, location and sampling rate. These distributions allow estimation of the error to be associated with each monthly anomaly obtained from the actual data set. It is then possible to state when and where the historical data are of sufficient reliability to allow statements to be made with a given degree of confidence.

Figure 10 shows example results of the study for SST anomalies for the calendar month of March. It is shown that for a certain region near the Galápagos Is., 14 observations taken at random times during the month lead, with 90% confidence, to an error of ±0.5°C in the monthly anomaly. Note that if only a few observations are made, the error bar is comparable in magnitude to a typical El Niño anomaly, which is of order 2°C. Also shown is the spatial variation in the number of observations required to achieve ±0.5°C accuracy in a relatively well-sampled region. Near the coast of South America, many more observations are required in order to achieve the desired accuracy (shaded region). This is a reflection of the inherently noisier SST signal in the extreme eastern equatorial Pacific.

R. Preisendorfer and C. Mobley

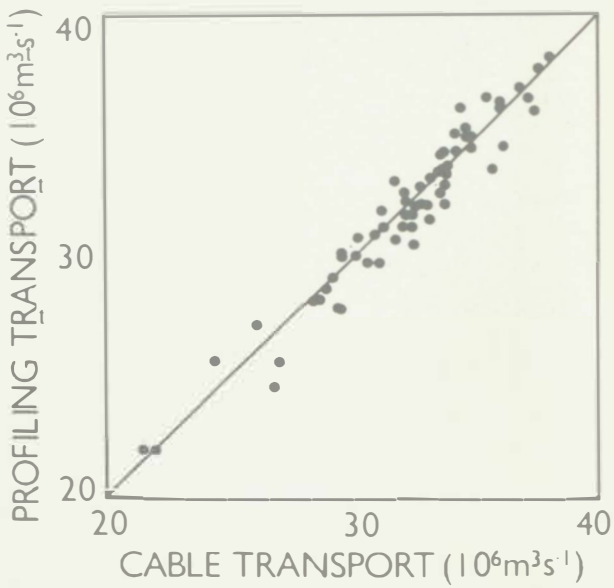


Figure 11
Comparison of transport estimated in the Florida Current from velocity profiling data and from simultaneous daily mean submarine cable voltages that are converted to transport units by multiplying them by the factor 0.02505 $10^6 m^3 s^{-1}$ per millivolt. This scaling factor is computed by fitting the cable data to 63 transport estimates from the profiling data.

WESTERN BOUNDARY CURRENT

Western boundary currents such as the Gulf Stream in the Atlantic and the Kuroshio near Japan are thought to transport a significant amount of heat from tropical to temperate regions. The Subtropical Atlantic Climate Studies (STACS) program of NOAA has the objective of

measuring the oceanic transport of heat in the North Atlantic. At present, the program is focussed on measuring the heat transport in the Florida Current. At PMEL, the use of cross-stream voltage differences to measure volume transport is being explored. A joint University of Washington/PMEL program is underway to study the possible role of the Emperor Seamounts on the dissipation of the Kuroshio. A set of moorings has been deployed and will be recovered in FY 1984.

Subtropical Atlantic Climate Studies

The Florida Current is one of the major poleward transporters of excess heat accumulated near low latitudes. Observations of annual and interannual fluctuations of its transport are meager and new long-term continuous measurements therefore will provide valuable data for ocean climate research. The electromagnetic method of transport measurement is based on the physical law which states that the motion of seawater, an electrolyte, through the earth's magnetic field creates an electromotive force that generates electric charge separation and electric currents at right angles to the flow. A voltage difference across the Florida Straits of about one volt is created. This difference is being measured using a submarine cable that makes seawater contact at Settlement Point, Grand Bahama I. and Jupiter Inlet, Florida.

One of the major problems that has limited the use of cable voltage measurements in the past is the occurrence of large and rapid voltage fluctuations generated by ionospheric and magnetospheric processes. Fortunately most of this geomagnetic noise can now be removed by methods developed at PMEL using remote magnetic observations. Preliminary results of cable voltage (corrected for geomagnetic noise and tides) show that there is a remarkably good agreement with the day-to-day fluctuations in transport estimated by velocity profiling devices. The estimated standard deviation of differences for 63 days is 0.66 x $10^6 m^3 s^{-1}$, which is 2 percent of the mean flow (Figure 11). A time series comparison of profiling transport and calibrated

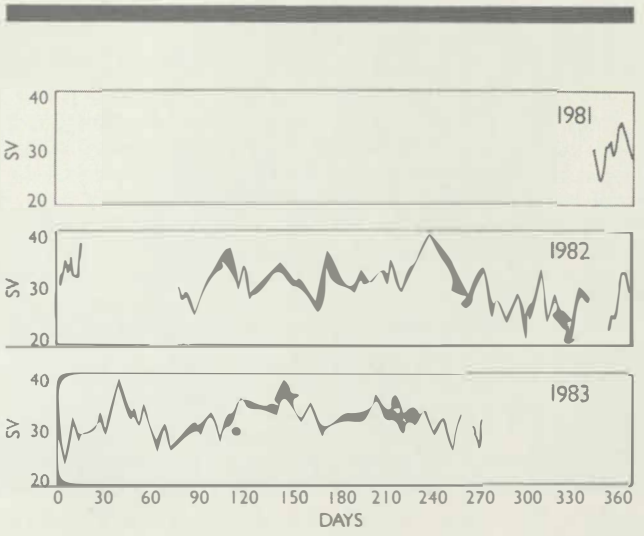


Figure 12
Daily means of the calibrated cable data plotted by one-year segments. Dots represent transport estimated from profiling data.

cable transport is given in Figure 12. The excellent agreement confirms that cable voltage measurements across the Florida Straits give an accurate estimate of the transport of the Florida Current. The cable results show that there are substantial changes in the transport of the Florida Current of up to 15 x $10^6 m^3 s^{-1}$ (50 percent of the mean flow) lasting over durations of up to 40 days. These results are in sharp contrast to previous findings that the variations in the Florida Current transport are mainly confined to periods shorter than 14 days with a small 10 percent annual variation. The transport of the Florida Current is so highly variable that continuous day-to-day recordings of transport are necessary for an accurate measurement. Because of interannual changes many years of observation are needed to accurately determine the annual cycle.

J. C. Larsen

982

FY 1984 PLANS

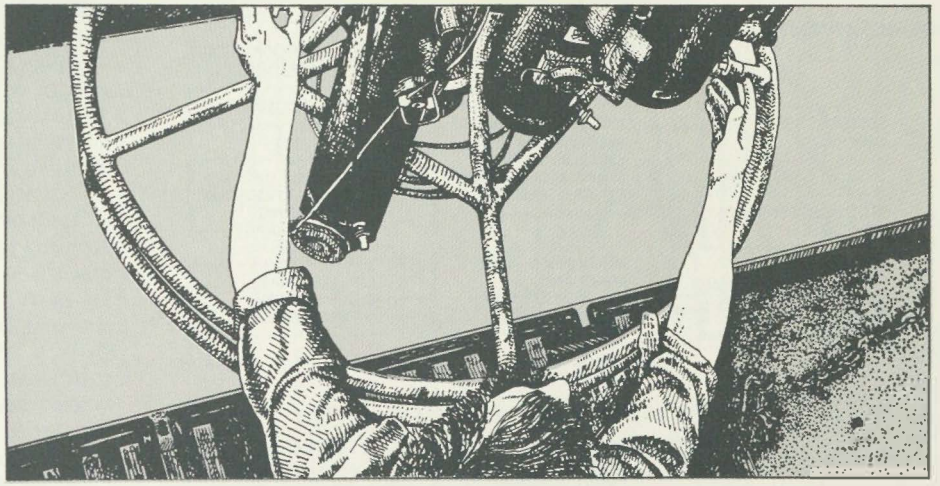
ENSO

- A field program will be launched between 140° and 110°W to study the processes affecting heat content of the upper layer of the ocean along the equator. This program will involve deep-sea moorings with subsurface current meters and thermistors, measurement of surface winds and air temperature, and profiling measurements of temperature, salinity (CTD and XBT), and velocity (TOPS and Ametek-Straza Doppler-shift acoustic current profiler). This EPOCS program is coordinated with the Tropic Heat Program sponsored by NSF.
- The moored current velocity and temperature measurements at 110°W and the sea-level measurements at the Galápagos Is., which were both begun in 1979, will be continued for the study of zonally propagating signals along the equator (EPOCS).
- The best sampled region (Panama-Tahiti shipping lane) of the 100 year historical ocean/atmosphere climate data set will be analyzed to determine the sampling errors in estimating monthly and annual means. These errors will set quantitative bounds on the types of inferences that can be drawn about low frequency climate change in the tropical Pacific.
- Satellite (NOAA) infra-red sea-surface temperatures (corrected for aerosol contamination from El Chichon) in the eastern equatorial Pacific will be analyzed for 1981 and 1982. The development of the warming associated with the 1982-83 El Niño will be documented and related to EPOCS cruise data.
- Calculations of zonal current transport in the tropical Pacific (for the period 1979-83) will be carried out using the XBT data set. In particular, the changes in zonal transport and their effects on re-distribution of heat during the 1982-83 El Niño will be examined. This work will be done jointly with French and Australian investigators.

Western Boundary Current

- Further interpretation of voltage differences over the Florida Straits will be carried out by comparison with new data sets. In addition, the feasibility of utilizing the global network of active AT & T cables for oceanographic research will be assessed.
- Directly measured currents from the Emperor Seamounts region will be analyzed as a part of the study of the effect of the seamounts on the structure of the Kuroshio.

MARD



Herbert C. Curl, Jr., Division Leader

The Marine Assessment Research Division conducts research on the origin, transport, transformation and fate of substances of human and non-human origin in both oceanic and estuarine environments. Special emphasis is placed on substances that are marine or atmospheric contaminants or are tracers of water movement. An interdisciplinary approach is used in the study of biogeochemical and physical processes that affect the transport and fate of trace gases, trace metals and organic compounds. Physical and theoretical oceanographers determine circulation residence times and dispersion rates of materials resulting from a wide range of dynamical processes. Chemical and geological oceanographers measure the distribution, abundance and chemical transformations of pollutant and non-pollutant trace constituents in coastal systems and in the open ocean.

LONG-RANGE EFFECTS

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

The PMEL program is continuously evolving as new questions are identified and old ones resolved. Work over the last year has emphasized 1) a demographic model to identify historical sources of pollutants, 2) a series of studies and models to identify circulation, and particle transport features, along with pollutant-particle studies to assess relative scavenging rates in the water column and diagenesis in the sediments, 3) an integrated experimental and modelling effort to establish pollutant transport and burial rates in the very important bottom boundary layer and 4) marine sediment analysis to identify the fate and historical deposition of pollutants in the sediments.

Pollutant Source Model

The purpose of PMEL's Demographic/Pollutant Source model is to make available in a standardized format, quantitative measures of Puget Sound's historical development. These time series with the records of pollutant deposition are then compared by suitable transformations in the sediments from the sediment core analyses. Three groups of historical variates have been identified and all are now in the process of being loaded into a computer data base. A schematic of the model and its function is shown in Figure 13.

The first variate group consists of actual estimates of the mass rate of discharge of a pollutant into the environment. We have estimated the rate of consumption of lead additives in gasoline on a watershed-by-watershed basis from about 1930 to present. The algorithm from this study will be applied to the historical consumption values to estimate the loadings of the surface runoff. The final product will be a time series of the mass rate on input of lead on a watershed basis.

The second variate group consists of ancillary data that pertains directly to transport processes or that bears a plausible but indirect linkage to pollutant loadings. The mass deposition rates in a sediment core may be related to such measures, and discovering such a relationship would greatly simplify the search for a suitable predictor.

The third variate group consists of measures of economic activity expressed in dollars by "industrial sector." There exists for the region an input/output model with a twenty year time series of industrial activity values. If suitable correlations are found between these measures and pollutant accumulation rates then prediction follows immediately from the routine projections that are made with the regional model.

R. J. Stewart
P. N. Booth

Transport in the Water Column

Studies of the transport of water and particles in estuaries are important because they allow us to evaluate the effectiveness of estuaries as traps for dissolved pollutants as well as particle-borne pollutants and predict the distribution of particulate deposition. These observations indi-

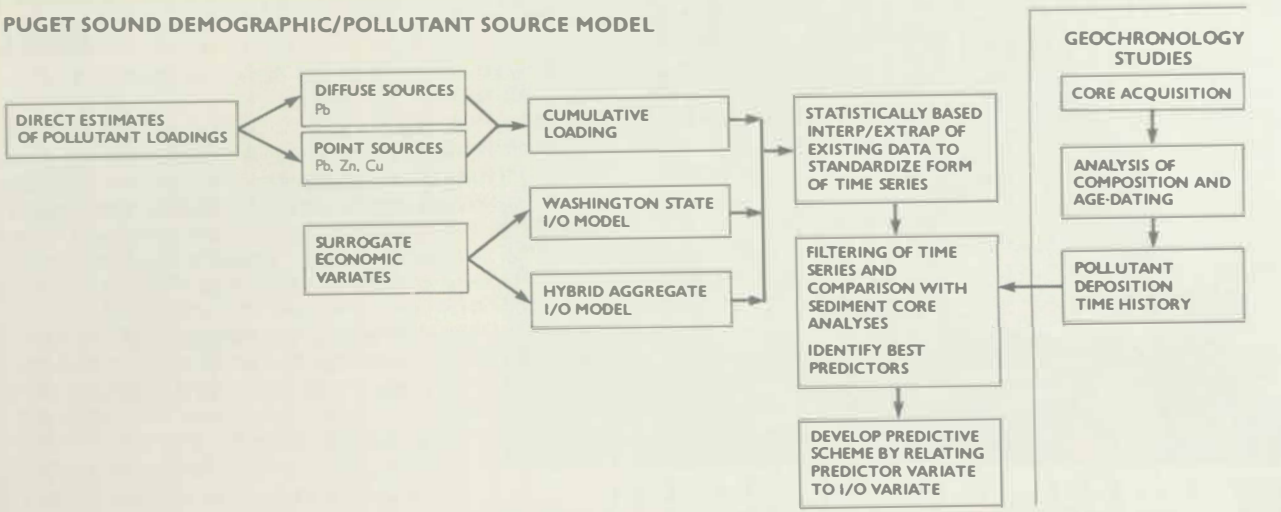


Figure 13
Schematic diagram of the data base and data base management program for the Pollutant Source Model.

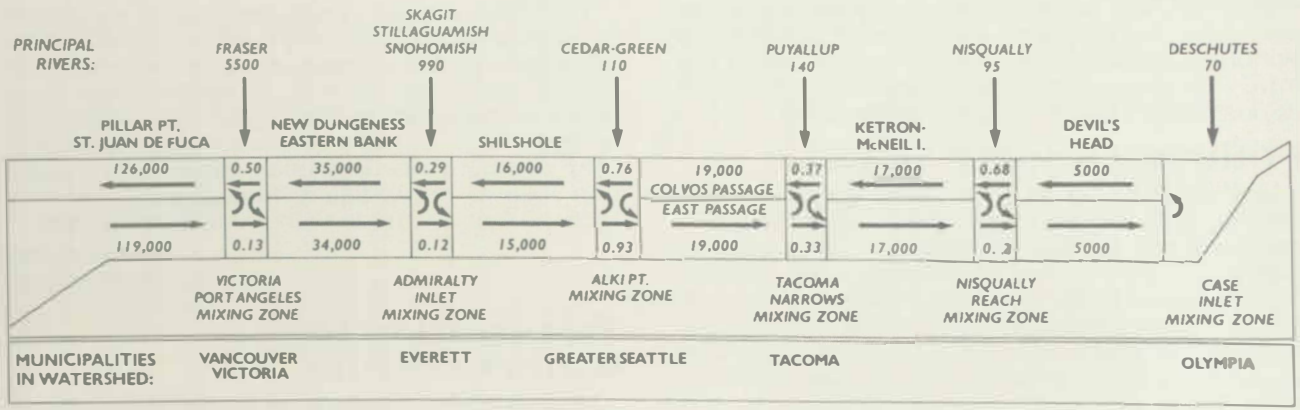


Figure 140
Schematic of Puget Sound mass transport model showing predicted water transport (in m/s^{-1}) in upper and lower layers of to each reach.

cate that a considerable portion (about two thirds) of the seaward flowing surface water does not continue out of Puget Sound, for example, but rather is mixed downward into the deep water at the Admiralty Inlet entrance sill. Such mixing is typical of fjord-like estuaries with sills often found in the northwestern North America and Alaska.

To help assess the consequences of refluxing, a quantitative mass transport model for Puget Sound was developed. This model enables the user to quantify the transport in surface and bottom layers at various locations in Puget Sound based on observations of salt and mass fluxes at a few locations (Figure 14). Transport calculations then allow predictions of the basin-wide distribution of dissolved, conservative substances based on the strength and location of the input. Preliminary results using dissolved copper show that the model, using measured input levels of copper from natural and anthropogenic sources, predicts a concentration level in the Sound close to the observed levels.

Because particles contain the largest portion of the pollutant load in estuaries, we have also undertaken studies specifically addressing the transport pathways of the particles. The transport of pollutants by particles differs from the transport of dissolved substances most dramatically in the transfer of pollutants from the surface water to the deep water and bottom sediments. In estuaries, fine-grained particles are biologically or physically aggregated into larger particles that sink rapidly and provide an efficient vertical transport mechanism. This sinking flux thus provides an additional mechanism for retaining pollutants beyond that created by the circulation refluxing described above.

Sediment trap investigations have been invaluable in quantifying the vertical transport processes. Comparisons of the temporal variability of phytoplankton pigments suspended in the surface water of Puget Sound with the temporal variability of the concentration of these pigments in underlying traps indicates that removal of particles from the surface waters is very rapid (Figure 15). Other sediment trap data suggest that the residence time of particles in the surface waters is only about 10

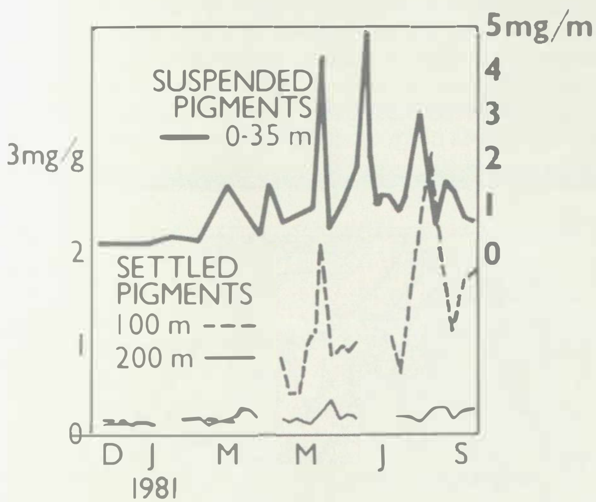


Figure 15
Close temporal agreement between peaks in surface suspended pigments (phytoplankton) and peaks in pigment concentrations in sediment traps indicates rapid vertical transport of this material from the sur-

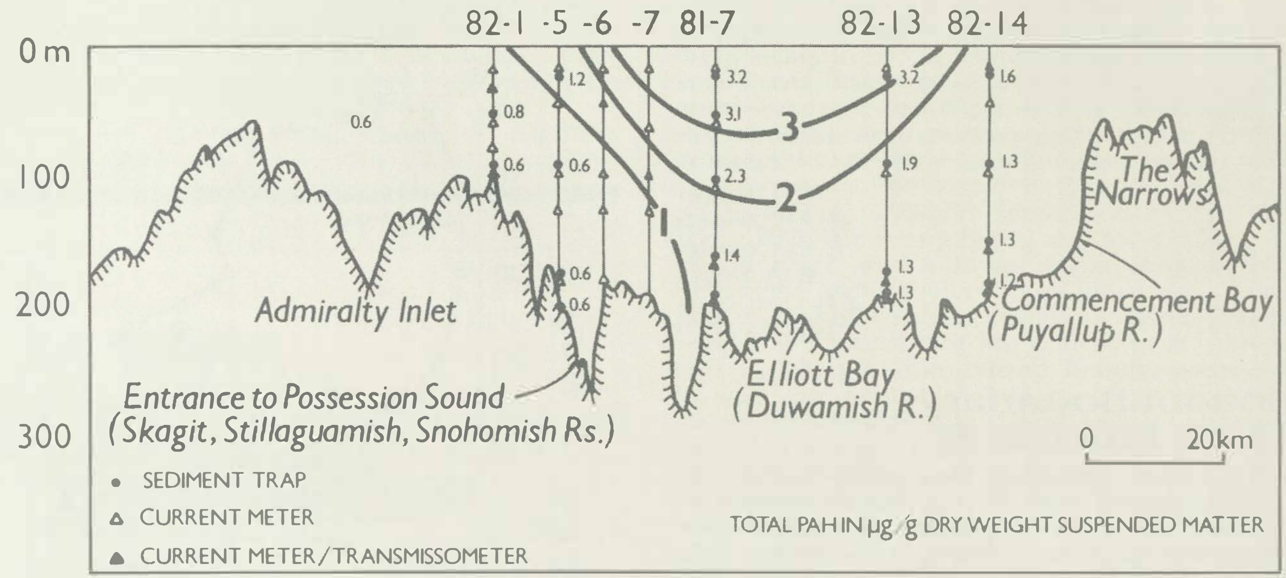


Figure 16
Concentrations (ppm by weight) of nine selected PAH compounds in sediment traps are shown. The large concentrations in the surface waters near Seattle reflect the location of the dominant PAH sources.

days before removal by sedimentation. The rapidity of vertical transport is also illustrated by the basin-wide concentration of polycyclic aromatic hydrocarbons (PAHs) in sediment traps (Figure 16). Concentrations of PAHs are highest in the surface waters near Seattle, the principal source area. Little horizontal distribution of the particle-borne PAHs occurs before they are collected in the sediment traps.

Retention of pollutants in estuarine waters is also enhanced by particulate scavenging of dissolved trace metals. Metals that are enriched in the oxide phase of particles (i.e., manganese, lead, and zinc) have relatively short residence times in the water columns and are rapidly removed from the water column to the sediments (Figure 17). The chemistry of manganese is such that it is resolubilized in the sediments and returned to the water column to aid in the

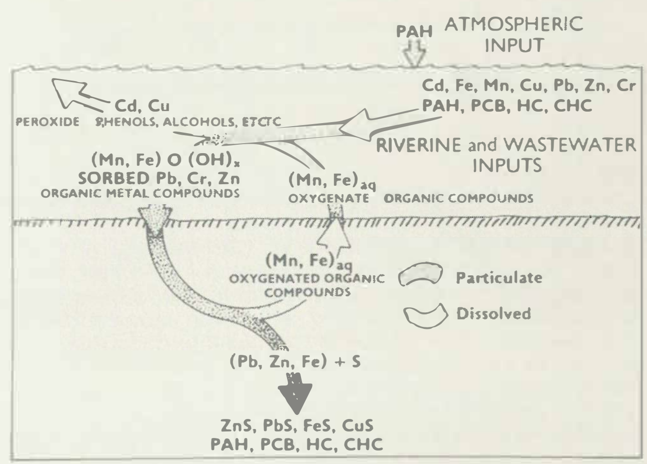


Figure 17
Geochemical cycles for inorganic and organic pollutants in the water column and sediments of Puget Sound. Pollutants adsorbed to organic and hydrous oxide coatings on particulate matter are transported to the sediments where they are ultimately buried. The manganese and iron are remobilized in the sediments and recycled back into the water column to continue the scavenging mechanism.

scavenging of additional quantities of metals such as lead and zinc.

Other metals (i.e., copper and cadmium) are enriched in the organic phase of particulate matter and have much longer residence times. This increase in water column residence time means that a larger proportion of these metals may escape Puget Sound in the dissolved form.

E. T. Baker
G. A. Cannon
E. D. Cokelet
R. A. Feely
J. R. Holbrook
R. J. Stewart

Bottom Boundary Layer Processes

The bottom boundary layer, the region of the water column from the sediment surface to several tens of meters above, plays an important role in the vertical distribution and the horizontal transport of particles. Processes within the boundary layer help determine the areal extent and patterns of contaminants in the water and sediment column and the extent and duration of exposure of biota to contaminants.

Trace metal studies in boundary layers over the past year have been conducted to better understand the role of manganese and iron in removing trace metal contaminants from the water column. Particulate manganese and iron scavenge dissolved trace metal contaminants and transport them by settling to the sediments. In the chemically reducing environment of the bottom sediment, contaminants like lead and copper are reduced to insoluble sulfides, while much of the manganese and iron then reenter the bottom water, adsorb to and/or form particulates, and again scavenge more dissolved trace metal contaminants. The results of this cycle for manganese concentrations (Figure 18) are high dissolved manganese concentrations in the upper sediments and adjacent thin layers of water and elevated particulate manganese concentrations higher up in the water column.

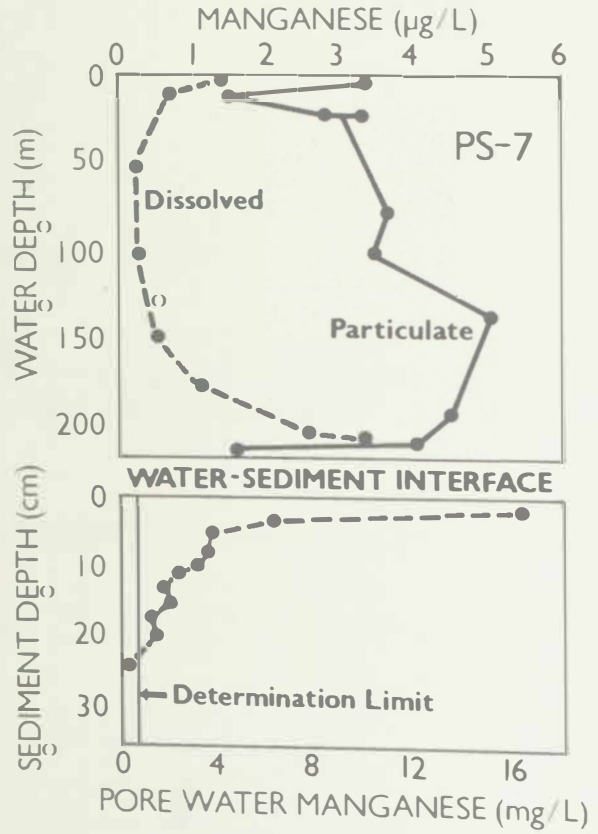


Figure 18
Observed concentrations of dissolved and particulate manganese at a station in Puget Sound. Near the bottom, dissolved manganese precipitates onto or forms fine particles and scavenges dissolved trace metals from the water. After burial in the bottom sediments, diagenetic processes return the manganese to the dissolved state. Much of the dissolved manganese returns to the water column as a diffusive flux across the water-sediment interface, but toxic metals such as copper and lead remain in the sediment as insoluble sulfides. Note that the lower concentration axis is three orders of magnitude larger than the upper one.

The distribution of particles in the near-bottom water column is determined, in part, by the strength of the bottom currents and by the ease with which those currents can erode bottom sediment. Much progress over the past year has been made by substantiating the role of intrusions of oceanic water over the sill at Admiralty Inlet and in transporting particles

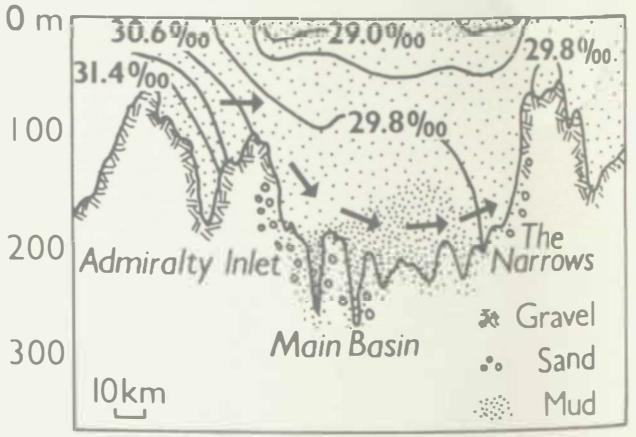


Figure 19
Instantaneous distribution of particle concentration (dots) and salinity (contours) for a near-bottom intrusion into Puget Sound based on observations made during 24-27 May 1980. As the intrusion flows through Admiralty Inlet, its salinity decreases due to tidal mixing with less saline water. The intrusion resuspends sediment in the Main Basin where it flows over the mud bottom. The increase in particle concentration is typically by a factor of three and can extend 100 m above the bottom.

down the main basin of Puget Sound. These density-driven currents (Figure 19) tend to occur at fortnightly periods. When superimposed on tidal currents and net estuarine circulation, this southward flowing water greatly enhances the up-estuary transport of particulate pollutants because stronger currents cause more erosion and provide larger transport distances before the particles resettle.

At a given location in Puget Sound, a typical intrusion is present for five days. As it progresses southward through the main basin, the intrusion's salinity decreases. The largest maximum in near-bottom particulate concentrations occurs off Seattle because the intrusion currents are strong and the bottom sediment is easily suspended. To the north, the coarser bottom allows less sediment to be resuspended while to the south the weaker currents move less sediment even though the sediments are similar to those off Seattle. Bottom accumulation compensates for decreased transport to the south.

Over the past years the combined contribution of intrusions and tidal currents on the erosion of fine sediment of the main basin has been resolved. Current and concentration time series (Figure 20) have been used to infer an *in-situ* erosion rate, the first such result for marine sediments. This would not have been possible without a substantial modelling effort, both of the erosion/deposition process and for the boundary layer flow structure. As an example, one focus of modelling over the past year was on turbulent diffusivity generated by the currents. Both the total loading and the vertical distribution of sediment is dependent on the diffusivity, and therefore its proper characterization is critical. Using a commonly-used closure model, we found that the diffusivity is a sensitive function of the mixing length parameter though the available data favors a particular value. This research has lead to a much more reliable estimate of this parameter (and diffusivity) than was previously possible.

The overall goal of the bottom boundary layer work continues to be quantifying the patterns and redistribution process for contaminants. In the past year, an integration of the work described above was begun via the development of a horizontal transport and deposition-pattern model. The early results show that channel width variations will be reflected in along-channel sediment deposition rates and suggest that the input of sediment to the main basin of Puget Sound from the side slopes must be relatively large.

H. O. Mofjeld
J. W. Lavelle
J. R. Holbrook
G. J. Massoth

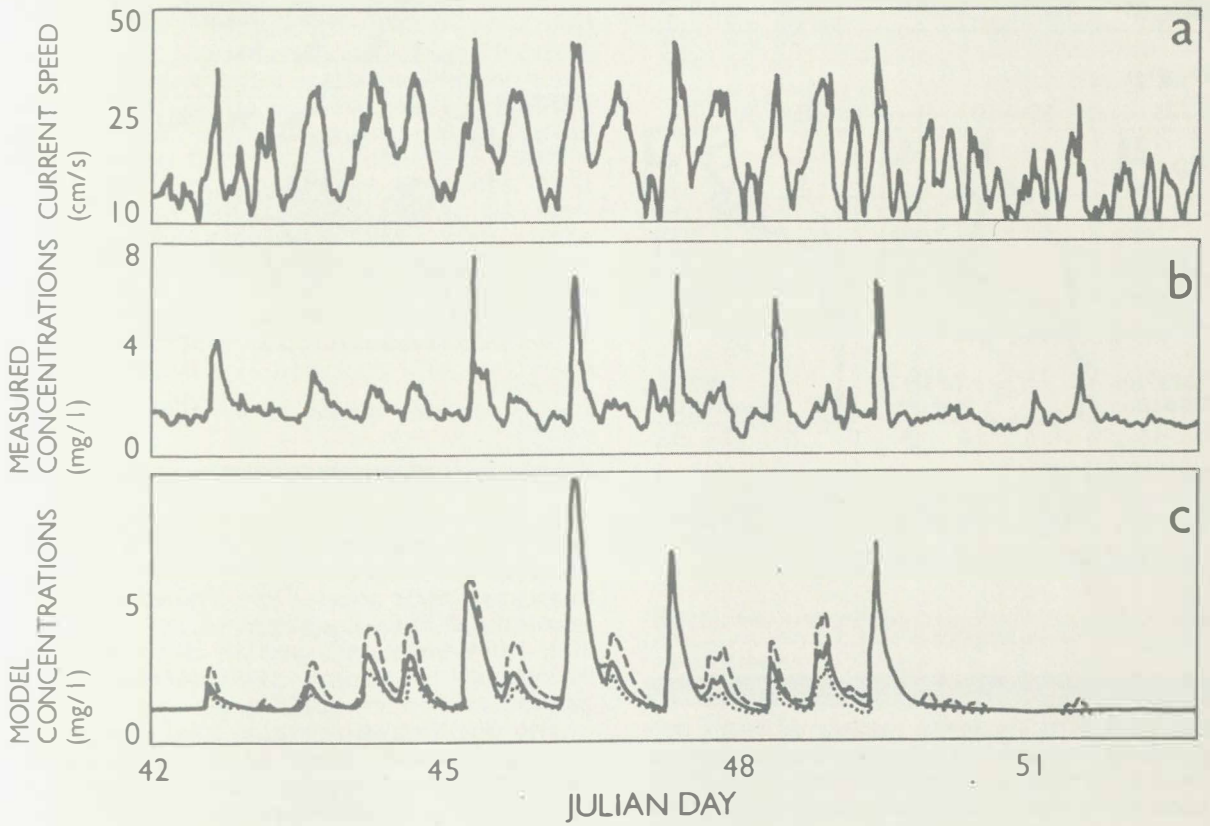


Figure 20
Time series of a) current speed and b) suspended particulate concentration measured 5 m from the bottom off Seattle during February, 1981. Model results using the measured currents as input are shown in c. The solid, dashed, and dotted lines are results using different values for an erosion rate parameter.

Pollutant Accumulation in Sediments

At the present time, municipal and industrial waste effluents comprise the ninth largest input of fresh water to the Puget Sound region. Although these effluents are processed to conform to water quality standards, they still represent an important source of pollutants which may adversely affect ecosystem function and fisheries resources. In order to properly establish a budget for pollutants in the Puget Sound

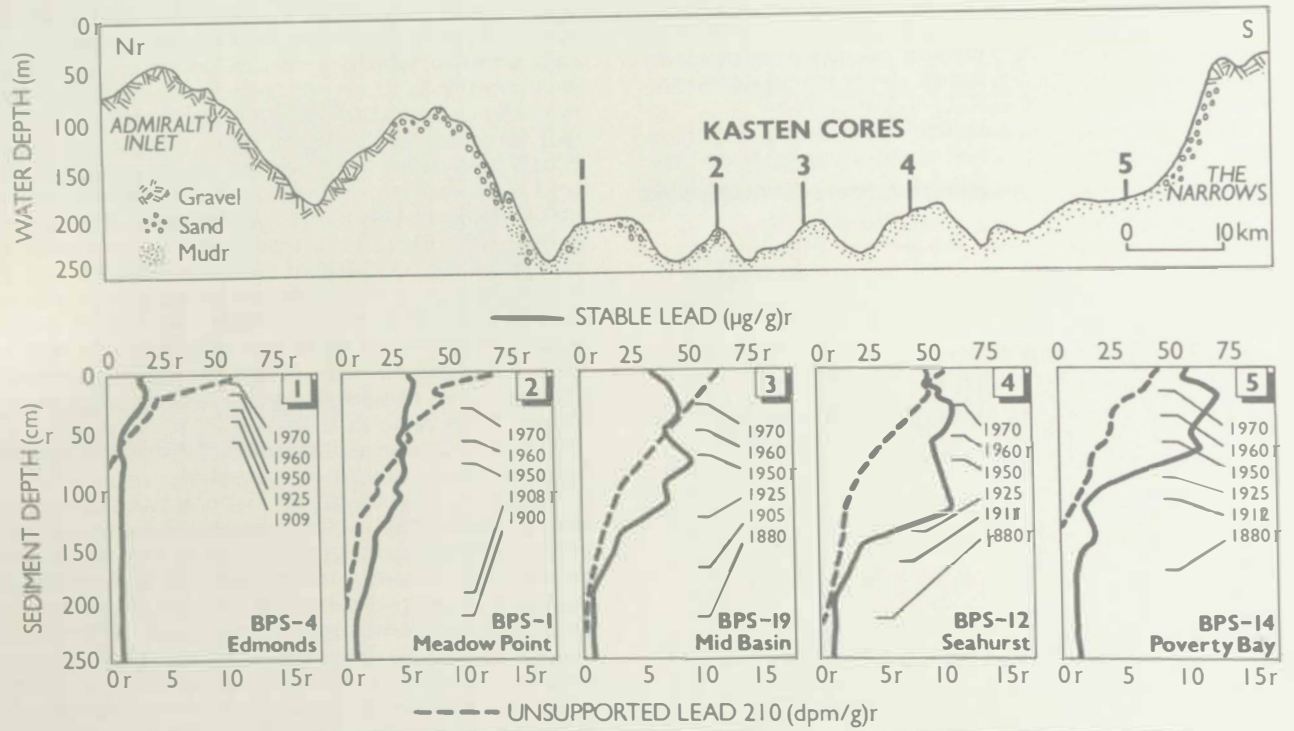


Figure 21
Kasten core sites and trace metal profiles characteristic of Puget Sound sediments. The lead dates are provisional andr have not yet been corrected for bioturbation effects.

region (and thereby make possible forecasts of trends), we are using sediment cores to estimate the historical deposition of pollutants in the system.

In FY 1983, PMEL scientists determined the distributions of two classes of organic pollutants as well as several trace metals, including manganese, iron, nickel, copper, zinc, and lead in sediments from Puget Sound. The organic pollutants include polycyclic aromatic hydrocarbons (PAH), which are polycyclic 3-6 ring compounds,r derived from burning fossil fuels and forest products; and normal and branched alkanes,r which are derived from refined petroleum products. Many of these compounds are mutagenic and carcinogenic and thus pose a significant threat to the marine environment.

The origins of these water insoluble organic compounds are deposition of petroleum products and combustion, riverine input, and wastewater discharge. The distribution of PAH in ther sediments of Puget Sound reflects the increased industrialization and urbanization of the area since the early 1900's. PAH concentrationsr in the sediments increase markedly between the turn of the century and the 1940's, andr then decrease to present-day levels. The concentration maximum in the 1940's is most probably related to the change in home heating fuels from coal to oil, gas, and electricity.r

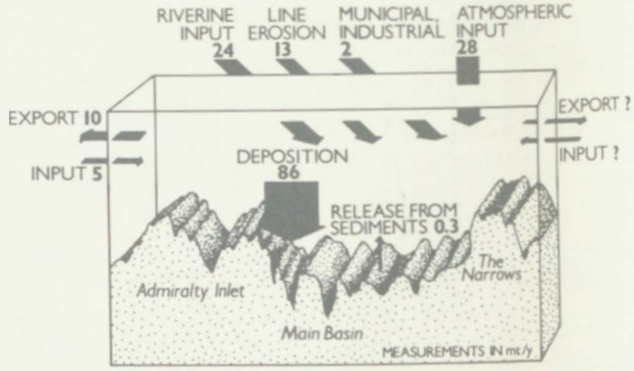


Figure 22
Preliminary lead budget for the Main Basin of Puget Sound

The unresolved complex mixture of branched and cyclic alkanes and the normal alkanesr both show maxima, although not as pronounced, near 1965, the point at which Seattle terminared the discharge of raw sewage into the main basin of Puget Sound and converted to primary treatment which removes some particulate matter.

The distribution of stable lead at six core sitesr in Puget Sound (Figure 21) illustrates the history of trace metal pollution in the Puget Sound region. The lead dates are provisional becauser they are presently being corrected for the effects of bioturbation. The stable lead profiles show an increase starting at about 1900 and increases to a maximum at about 1965-1975r with a slight decrease thereafter. The increasesr roughly correspond to the history of atmospheric lead contributions to the Puget Sound region.r

which suggests that their input histories are recorded in the sediment.

The sediment lead data have been combined with other data on lead inputs and outputs to Puget Sound to provide a preliminary lead budget for the region (Figure 22). This preliminary budget for lead indicates that anthropogenic sources are the major source for lead and sediment is the major sink for lead. Over 85% of the lead is deposited there. Furthermore, the sources and sinks for lead roughly balance each other which suggests we have accounted for most of the lead transport in Puget Sound. The data are somewhat sparse and potentially significant errors exist for sedimentation, riverine input and shoreline erosion. The lead inputs and outputs have been revised downward in this analysis because of better analytical data for lead in Puget Sound and because we now have a much better understanding of the recirculation processes. The data for several of the other trace metals also indicate that the major sink is the sediments. These preliminary results appear to indicate that contaminant concentrations in estuarine sediments can be predicted from their input rates.

R. A. Feely
J. D. Cline
G. J. Massoth

ACID RAIN

In recent years there has been increasing interest in the role of the oceans as a source of excess sulfur to the atmosphere. This interest has developed from concern over acid rain which results from both natural and industrial sulfur sources, and the influence of marine and terrestrial sources of organic sulfur on the chemistry of precipitation. A clear understanding of natural sources, both regional and global, is required to assess the relative significance of anthropogenic emissions on the chemistry of precipitation. During the past year PMEL has continued measurements of oceanic acid rain precursors. The most abundant oceanic acid rain precursor is the reduced sulfur compound, dimethylsulfide (DMS). DMS concentrations have been measured on cruises throughout the

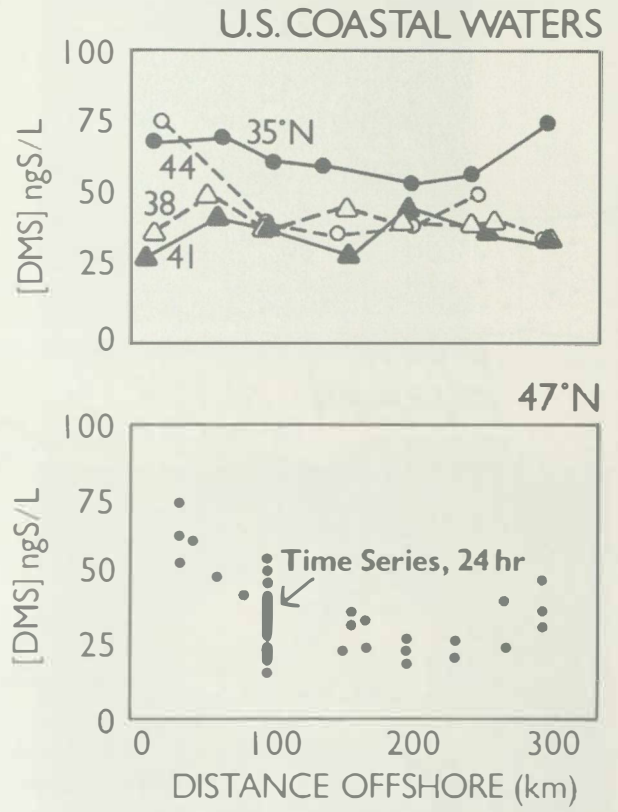


Figure 23
Dimethylsulfide (DMS) concentrations along the West Coast of the United States.

north Pacific Ocean in an effort to estimate the oceanic source strength of sulfur to the atmosphere. These observations are the first DMS measurements ever made along the west coast of the United States. The coastal zone is biologically productive, especially during upwelling and should constitute an intense source of organic sulfur compounds.

DMS concentrations in the central north Pacific Ocean average 30 ng S/L. Higher concentrations (average 85 ng S/L, n=270) were found in the more productive eastern equatorial waters. These concentrations, however were lower than those found last year (Spring 1982) in the western equatorial Pacific (average 100 ng S/L). This is a result of the El Niño which caused a significant decrease in biological productivity in 1983. In the absence of an El Niño we would expect higher biological productivity and thus higher concentration of DMS in the east than in the west. DMS concentrations along the West Coast of the United States averaged 50 ng S/L during this same period (Figure 23). These measurements were used to calculate the flux of DMS to the atmosphere along the West Coast extending 1000 km offshore (1.8×10^6 km^2). This flux (0.15 Tg/yr) is approximately equal to the sulfur emissions from Mt. St. Helens during 1981, and four times the annual emission of the Tacoma copper smelter, the major anthropogenic point source in the Pacific northwest.

J. D. Cline and T. Bates

OCEAN CLIMATE DYNAMICS

Marine Carbon Dioxide

Carbon dioxide, water vapor and a number of other trace gases in the atmosphere affect the balance between incoming and outgoing light and heat radiation. Carbon dioxide (CO_2), generated by the combustion of fossil fuels, is increasing steadily in the earth's atmosphere and affects the radiation balance and thereby the long-term global climate. The major repositories for fossil fuel-derived CO_2 (excess CO_2) are terrestrial vegetation, the atmosphere and the oceans; each of the latter two contains close to 50% of the excess according to current estimates. The buildup rate of atmospheric CO_2 depends critically on the oceanic uptake rate of carbon dioxide, which is controlled by diffusive and convective mixing processes, by the reaction of excess CO_2 with carbonate phases, and by air-sea exchange rates.

The research at PMEL is designed to improve our understanding of the vertical transport of CO_2 across the oceanic thermocline, evaluate

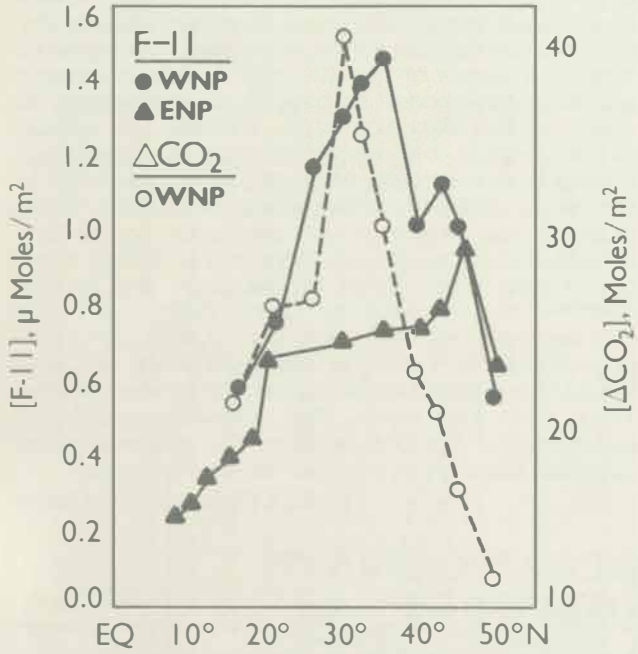


Figure 24
Freon-11 accumulations beneath the subtropical gyre, with a deeper penetration in the western North Pacific Ocean. Concentration of excess CO_2 beneath the subtropical gyre.

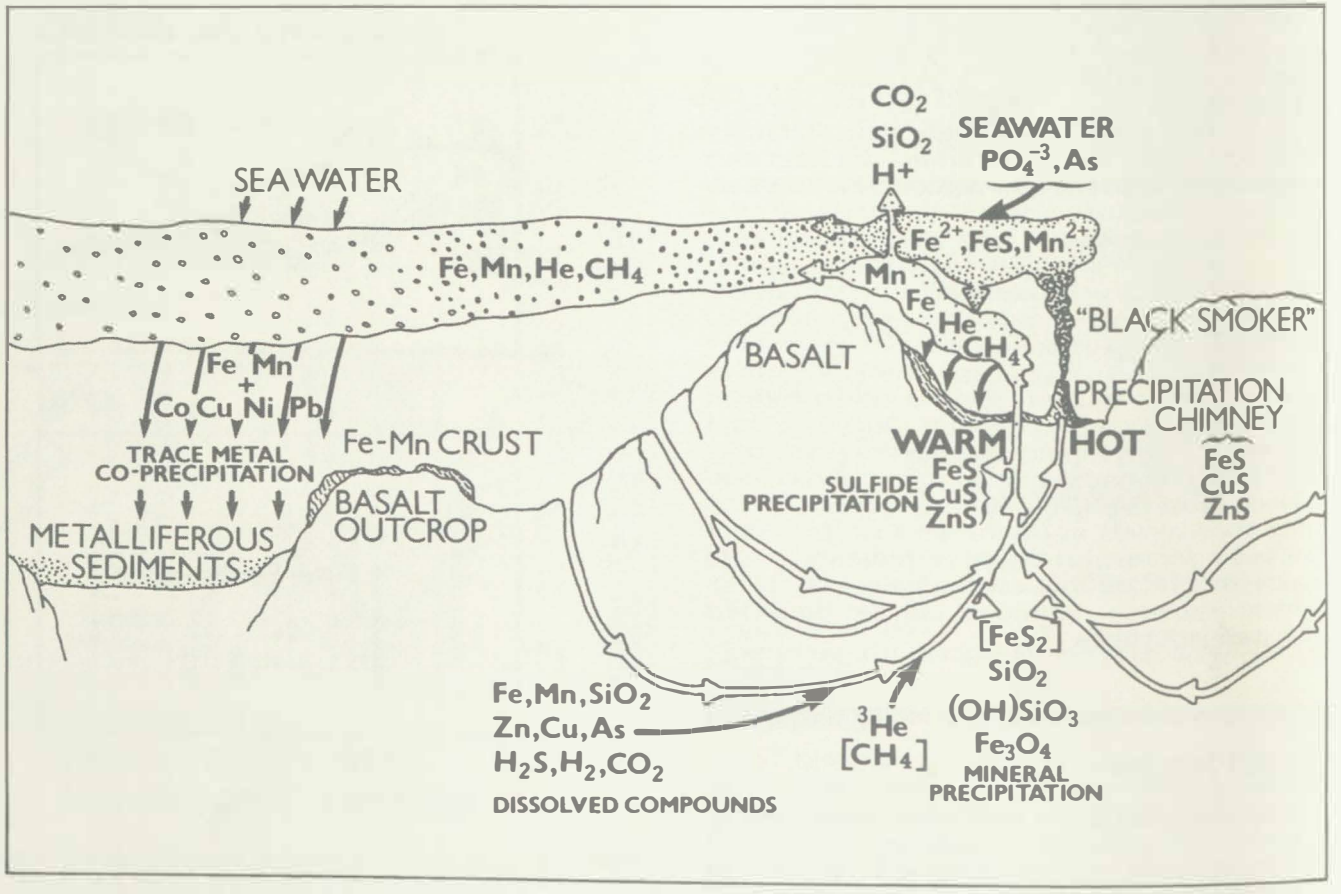


Figure 25
A conceptualization of a hydrothermal plume as it might exist over a ridge crest spreading center. Several of the plume constituents used as "hydrothermal sensors" by researchers at PMEL are identified as are some of the more important hydrothermally related deposits.

the significance of excess CO_2 on the carbonate chemistry of the oceans and to improve our analytical capability for the detection of excess CO_2. The first task permits a prediction of the oceanic CO_2 assimilation rate, based on the atmospheric source function. The second research task focuses on the reactions of excess CO_2 with solid carbonate phases, a reaction that affects the ocean's capacity to assimilate CO_2. The third task, direct measurement of excess CO_2 inventory in the ocean and its growth rate in the future, are of paramount importance in evaluating the ocean's role in the assimilation of CO_2.

In March and April, 1983, a meridional section was occupied in the central North Pacific in which measurements were made of the following parameters: total carbon dioxide, alkalinity, freons, bomb tritium and carbon-14, salinity, temperature, nutrients, and oxygen. Freon-11 and -12, like CO_2, are gases, and have been increasing steadily in the earth's atmosphere in response to global industrial growth. Assuming that the freons and excess CO_2 are linearly correlated via their respective atmospheric source functions, the inventory of excess CO_2 in the oceans can be scaled from the measured distributions of freons. The greatest accumulations of freon-11 occur beneath the subtropical gyre, with a deeper penetration in the western North Pacific. By way of comparison, the largest water

column burden of excess CO_2 also occurs beneath the subtropical gyre (Figure 24). The deep penetration of both gases beneath the subtropical gyre is due to winter cooling in the vicinity of the subarctic front (e.g., 35-45°N), which significantly enhances their solubility. Both gases are then distributed within the gyre by isopycnal mixing and geostrophic transport.

Measurements in the western North Pacific indicate that the subtropical gyre is highly supersaturated with respect to aragonite (up to 400%), while the colder surface waters of the subarctic gyre are nearing saturation. Our calculations suggest that continued atmospheric buildup of CO_2 will result in aragonite undersaturation in the surface waters of the North Pacific as early as the second half of the next century, at which time the surface ocean's ability to absorb additional amounts of CO_2 will begin to diminish. Undersaturation of surface waters will continue to spread to lower latitudes as more CO_2 is released to the atmosphere.

While we are now approaching the time when the inventory of excess CO_2 may be estimated directly, the man-made transients provide the only short-term procedure for evaluating the transport of excess CO_2 between the surface layers and the oceanic thermocline. Our efforts in the North Pacific (i.e., north of 40°N) focus on the use of freon-11, tritium, and temperature to quantify the vertical transport parameters so that meaningful CO_2 transport rates can be made.

J.D. Clinee
R. A. Feelye

MARINE RESOURCES

Sea-Floor Spreading Processes

Six years ago the first direct observation of hydrothermal venting was made at the Galápagos spreading center. This event and several that transpired over the next three years initiated a quest for a detailed understanding of the geochemistry of hydrothermal venting processes. Central to this geochemical inquiry are

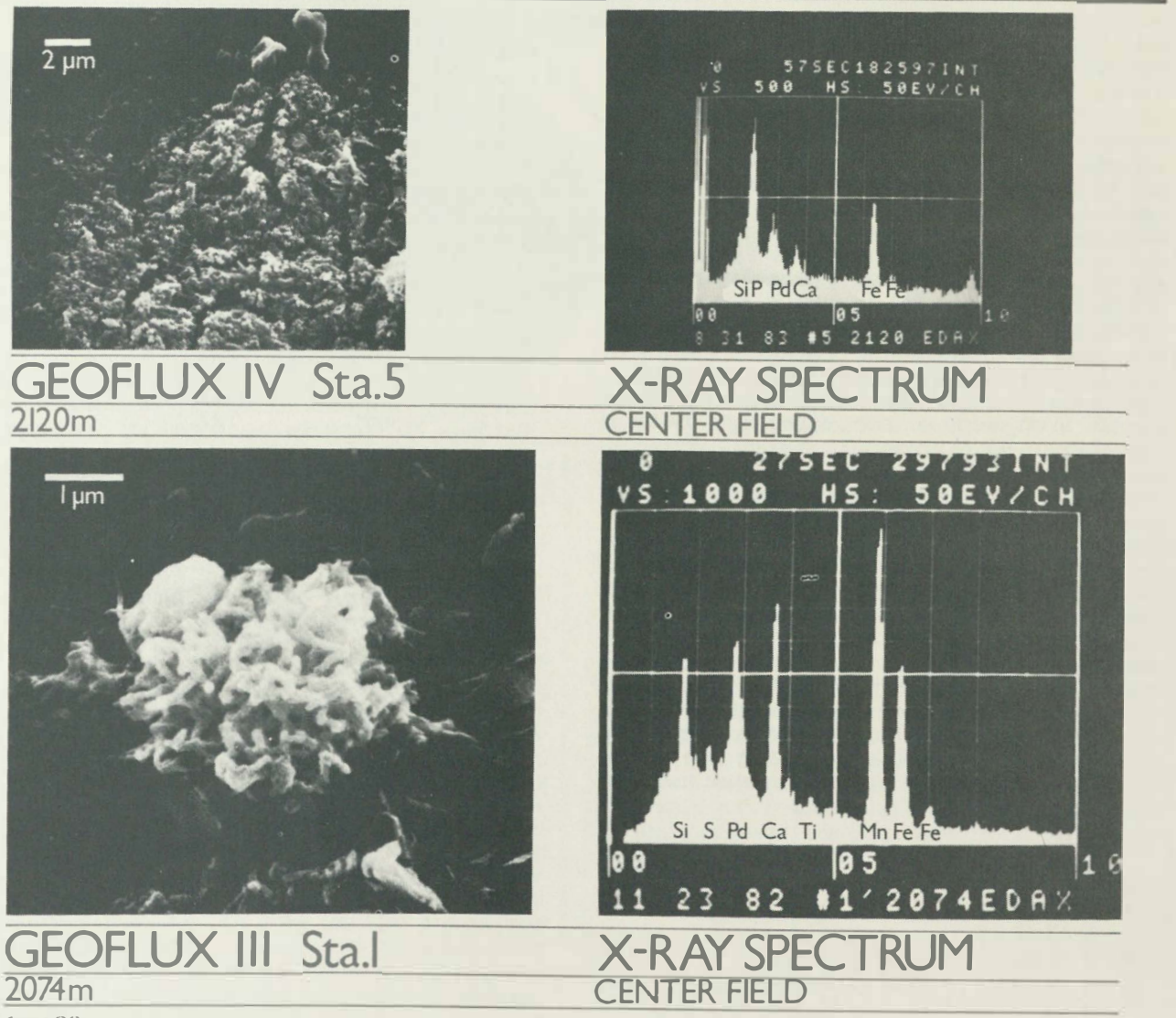


Figure 26
SEM micrographs and X-ray energy spectra for particulates collected from within the hydrothermal plume over the southern Juan de Fuca Ridge. Top: iron-enriched particles ubiquitously cover the Nuclepore filter used for sample collection. Bottom: a manganese-enriched particle (centerfield) rests on a bed of typical oceanic water column debris. Note the contrasting morphology and size of the differently enriched particle types.

determinations of the relationships of venting processes to: 1) the formation of massive sulfide deposits, 2) the depositional patterns of hydrothermal plume borne metalliferous particulates, and 3) the global distributions and implications of the hydrothermally associated elements (Figure 25).

Since 1980, PMEL researchers have conducted hydrothermal research on the Gorda and Juan de Fuca Ridges, which are located partially within the Exclusive Economic Zone off the coasts of Washington and Oregon. Our studies have focused on the distributions of hydrothermal plumes (as identified by elevated concentrations of helium, methane, manganese, iron, zinc, lead, and arsenic), and the processes that are occurring within them (e.g., dissolved-to-particulate phase changes, scavengingt oft metals from vent or sea water, and settling processes). Hydrothermal plumes were observed and sampled over both ridges. Highly enriched iron and manganese values observed at several sites on the Juan de Fuca Ridge suggest that some samples were collected in very close proximity (possibly within 1 km) to "hot" vents (Figure 26). Knowledge of vent end-member concentrations is requisite to understanding plume distributions and processes and is possible only by sampling from a submersible. In 1984, our first opportunity to capture fluids and gases from within a vent is to occur by coordinating our studies with those of other NOAA investigators in the use of the research submersible *ALVIN* on the Juan de Fuca Ridge.

H.tCurl, Jr.t
R. A. Feelyt
G. J. Massoth

FY 1984 PLANS

Long Range Effects

- tComplete assemblage of pollutant-input datat base for Puget Sound and complete inputt model algorithms for the region. Predictions oft inputs to the system will be made based ont Puget Sound Council of Governments demographic projections.t
- tDeVelop a numerical tidal model for Pugett Sound and couple it to a model of sedimentt erosion and deposition in the bottom boundary layer. The Puget Sound mass transportt model will be expanded to evaluate the distribution of non-conservative substances.t
- tBecause of continuing concern about the efficiency of sediment traps under varying current flow conditions, we will conduct fieldt studies to determine relative trappingt efficiencies.t
- tIn order to improve our understanding oft benthic boundary layer processes, second-order closure flow models will be built fort time-dependent and shallow water regimes.t The progression of density intrusions downt the main basin of Puget Sound will bet modeled since they obviously result in majort relocations of surficial, non-cohesive sediments.t
- tPMEL scientists will continue to study thet sediment histories of pollutants in Pugett Sound by expanding our use of geochronometers to include long-lived isotopes tot delineate deep-mixing processes. These datat will be combined with sediment pollutantt inventories to provide an adequate data baset for relating pollutant source strengths to timet histories in sediments.t

Acid Rain

- tConduct laboratory solubility and diffusivityt measurements for dimethylsulfide to obtaint better flux estimates of acid-rain precursors across the airtsea boundary.t

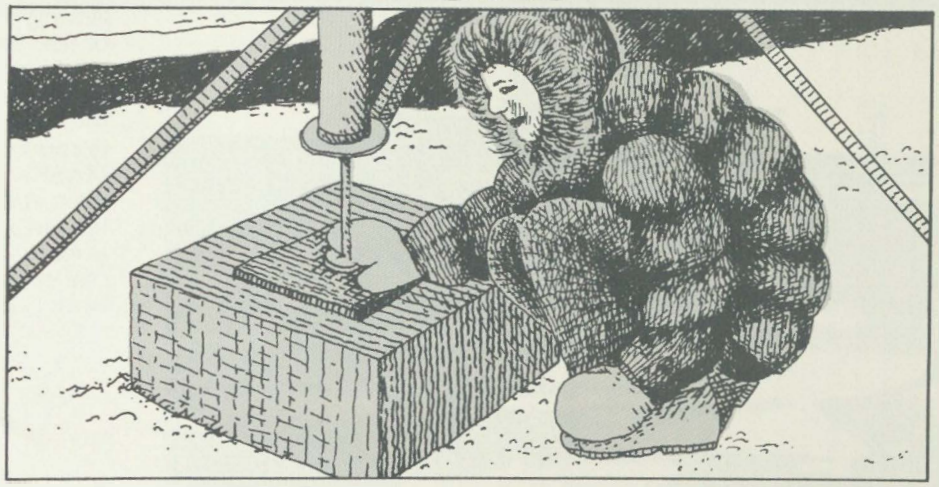
Marine Carbon Dioxide

- tConduct measurements in the South Pacific to assess the uptake of CO_2 in the Antarctic Intermediate Waters and Western Boundary Current. Complete an assessment of the uptake of excess CO_2 in the waters of the Northt Pacific subarctic gyre and begin monitoring of CO_2 components at a station off the Washington coast to describe secular trends.t

Sea-floor Spreading Processes

- tContinue our near-field hydrothermal vent-sitet studies on the southern Juan de Fuca Ridge.t We will extend our sampling grid to encompass the distant-field hydrothermal plume andt we will initiate water-column investigations in the Blanco Trough, a deep and partially enclosed hydrothermal system.
- tParticipate in a NOAA-wide cooperative study of the Juan de Fuca Ridge using the research submersible *ALVIN* to collect hydrothermalt fluids from several venting sites along the Ridge in order to define "end-member" hydrothermal plume constituent values.
- tDetermine the net circulation over ourt southern Juan de Fuca Ridge study site. Year-long deployments of moored current meters and nephelometers will be the focus of thist effort.t

MSRD



James E. Overland, Division Leader

The Marine Services Research Division studies coastal meteorolgy, physical oceanography, and sea-ice processes by means of a combination of field measurements, remote-sensing techniques, and numerical modelling. The Division's purpose is to improve meteorological forecasts by conducting descriptive studies and providing interpretive models to operational components of NOAA, such as the Ocean Service Centers and the Joint Ice Center. Studies of sea-ice processes are also applicable to NOAA's climate research.

SEA ICE PROCESSES

MIZEX-WEST Experiment

The most thorough field study of the Bering Sea marginal ice zone (MIZ) attempted to date was conducted during February 1983. This study was part of a larger program addressing processes which control interactions among the atmosphere, ice and oceans in the northern hemisphere MIZ's. The program was conducted in the vicinity of St. Matthew Island and employed the following research platforms: 1) The NOAA Ship *DISCOVERER* (Figure 27) for CTD, upper air, and surface meteorological measurements and for small boat deployments of instruments on the broken ice along the ice edge, 2) the U.S. Coast Guard ice breaker *WESTWIND* for CTD, upper air, and surface meteorological measurements and for helicopter deployments of satellite stations and other instruments on the interior pack ice, 3) the NOAA WP-3D research aircraft for turbulence, flight-level, and lower air measurements and for observing surface roughness and ice conditions on a local scale, and 4) the NASA CV-990 Airborne laboratory for passive microwave and infra-red imaging and for observing ice conditions on a regional scale.

PMEL researchers were active in obtaining meteorological and CTD measurements from both ships, deploying drifting satellite stations on the sea ice, and directing measurements from the WP-3D aircraft. A set of eight satellite-tracked ARGOS buoys, deployed by PMEL scientists, drifted westward and southward approximately 350 km in 15 days while the ice edge advanced about 50 km (Figure 28). Two of the buoy sites were equipped with an anemometer, current meter, and air and water thermistors. These geophysical measurements were recovered through the GOES satellite. Comparison of the drift data with winds adjusted to 10 m shows that the ice floes initially drifted 3.5% of the wind speed, increasing to 7% of the wind speed within 30 km of the ice edge. At approximately the same time, the ice began to diverge, at first randomly dispersing and then organizing into bands and further dispersing in the outer marginal ice zone.

The meteorological observation program focused on boundary layer processes associated with passage of cold air from the ice cover out over open water and on vertical fluxes of heat, moisture, and momentum over the ice and water. Surface observations obtained from both vessels and two ice stations included air temperature, humidity, wind speed and direction, and pressure. Upper air observations taken included temperature and humidity. Gust probe measurements taken during five flights of the WP-3D aircraft will allow estimations of vertical fluxes of heat, momentum, and moisture. Upward- and downward-looking radiation measurements were made to estimate radiative fluxes. Comparison of the meteorological measurements in the boundary layer with a theory previously proposed by researchers at PMEL suggest that initial acceleration and divergence of the ice floes are caused by acceleration of the wind from the ice to open water due to the change in roughness of the surface from the rough ice to the smooth water and due to the change in boundary layer air temperature from cold ice to warm water (Figure 29). Combined wind, ice, and water motion observations should also be adequate to test previous drag coefficient values which relate wind speed to ice drift.

C. H. Pease
R. M. Reynolds
J. E. Overland
B. A. Walter

Ice Extent Forecasting Model

A forecasting model for sea ice extent for the Bering Sea was put in place at the National Meteorological Center (NMC) of the National Weather Service. The model balances ice advection (Figure 30) and thermodynamic processes to determine a new ice edge location

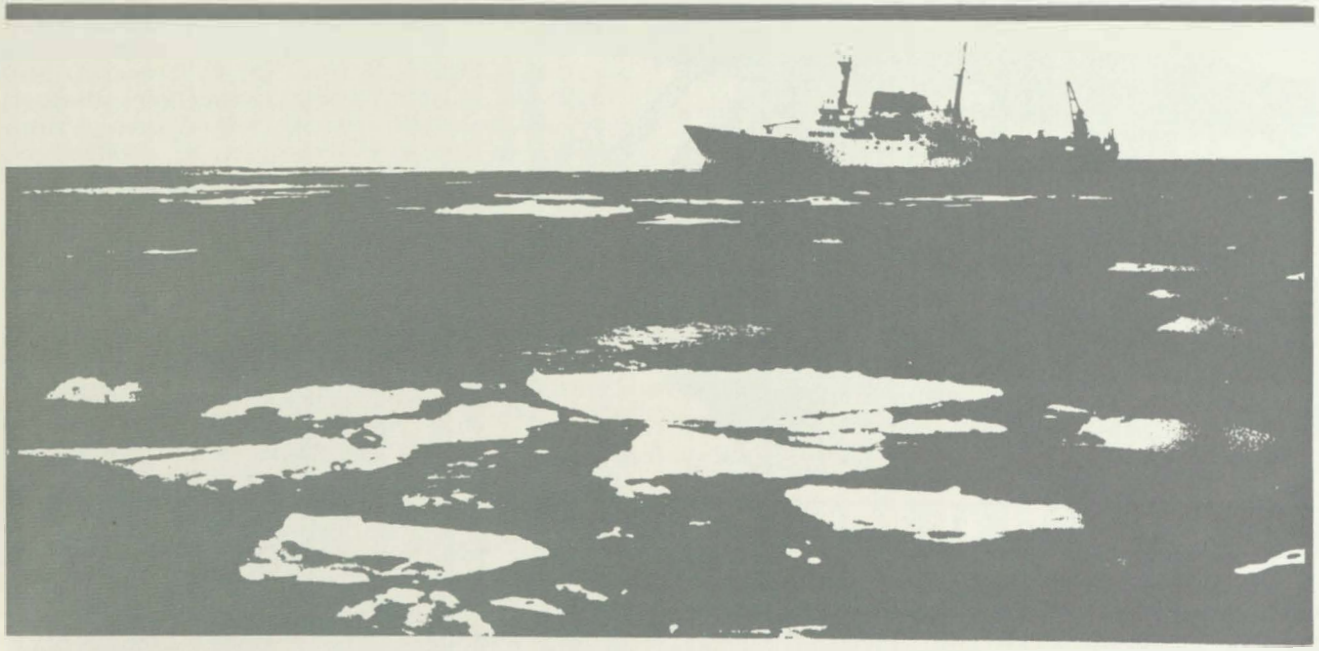


Figure 27
NOAA Ship *DISCOVERER* making CTD, upper air, and surface meteorological measurements in the broken pack ice along the ice edge during the MIZEX WEST experiment during February 1983.

and is driven by winds and air temperatures derived from the NMC spectral atmospheric forecast model. Sea-surface temperatures are taken from the Bering Sea regional analysis and initial ice extent and conditions will be hand-digitized by the Navy/NOAA Joint Ice Center Analysts. The model will be run for 72-hour forecasts on Monday, Wednesday, and Friday using the 12 GMT meteorological forecast for same-day transmittal to Anchorage and Seattle Ocean Service Centers. Also the model will be run for 144-hour forecast using the 00 GMT meteorological forecast for following day availability.

Final verification and documentation of the code is being conducted by MSRD researchers at PMEL and the Marine Products Branch of NMC using 1983 winter forecast products. The results of these model runs will be compared to ARGOS buoy drifts and satellite-derived ice extents from the February MIZEX-WEST experiment. The model is the first step toward improved polar services based on research from PMEL.

C.H. Peaser
J. E. Overland

COASTAL WINDS AND WAVES

The PMEL Program in coastal winds and waves focuses on phenomena of particular importance to coastal regions. Research on wave phenomena has focused on improving our understanding of life-threatening waves at the Columbia River Bar. The primary emphasis of the winds research in FY 1983 was in support of the ice program in the Bering Sea. This included studies of the behavior of the planetary boundary layer both over the ice pack, near the ice edge and over the open water south of the edge. In addition MSRD participated in the mesoscale air-sea exchange (MASEX) study carried out off the east coast during January 1983. MASEX was a pilot atmospheric and oceanographic study carried out during a cold air outbreak. Its aims were to study the effects of the large transfer of energy to the atmosphere in such conditions and to study the growth of offshore waves under high-wind fetch limited conditions.

B.rWalterr
R.rM. Reynoldsr
J. E. Overlandr
S. A. Macklin

Hazardous Waves

An evaluation has been completed of existing wave forecast procedures for the Columbia River Bar and coastal region. Wave measurements obtained both on the Bar and 12 km offshore were compared with the corresponding operational forecasts issued by the National Weather Service. The operational Bar forecasts are made by applying a transformation to the offshore coastal wave forecasts to account for wave-current interactions. The analysis indicated that this procedure tended to overestimate low wave conditions, but underestimate high wave conditions. The majorr source of error was inaccurate forecasting of the wave period, a critical parameter in the transformation used to compute the Bar wave amplification factor.

The Bar wave transformation and its dependence on sea and swell period has been investigated further. An improved forecast procedurer for predicting waveheights has been developed for the Columbia River Bar, a region of intense wave-tide-current interactions. The theory on which the new algorithm is based accounts forr wave shoaling, bathymetric refraction, and momentum transfer from currents to waves. The wave height on the Bar (i.e., the entrance to the river) is a function of surface currentr

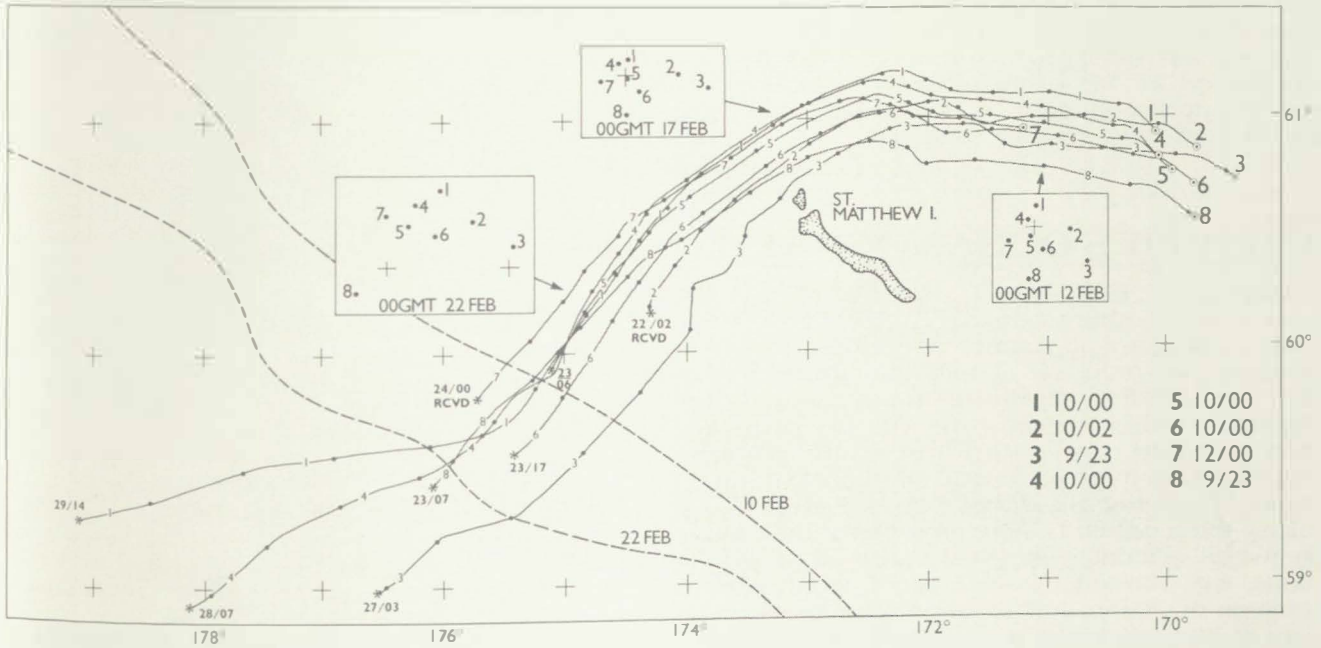


Figure 28
Drift of eight ARGOS buoys deployed on ice floes in the eastern Bering Sea during February 1983. The two dashed lines represent the extent of sea ice on the 10th and 22nd of February. All the buoys except 2 and 7 stopped transmitting whene they melted out.

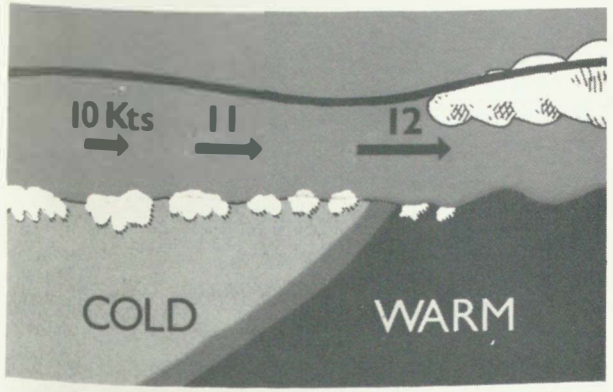


Figure 29
Acceleration of the wind from ice-covered to ice-freee water is caused both by decreased roughness and by warming the air from below.e

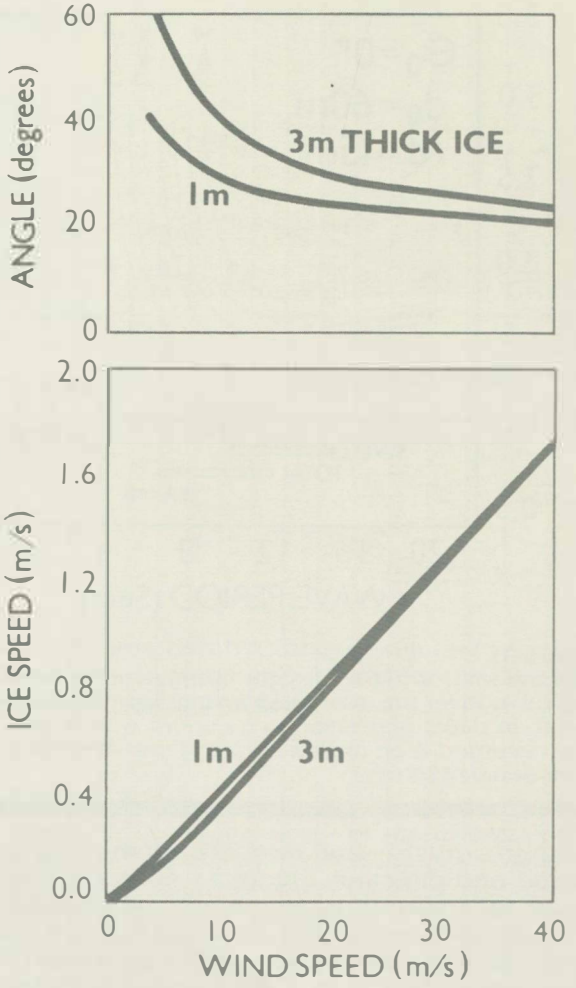


Figure 30
Response of the ice velocity for a range of wind velocities for the NOAA forecasting model for sea ice extent for the Bering Sea. The upper graph shows the turning of the ice to the right of the wind. The lower graph shows the change in ice speed with respect to wind speed.

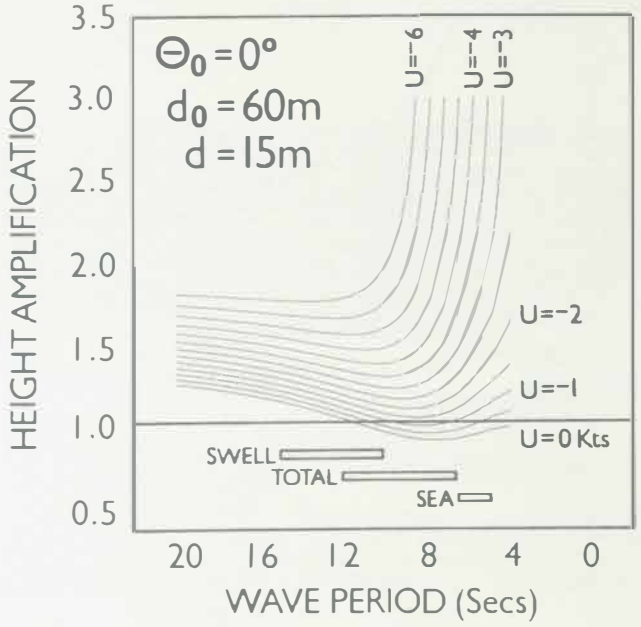


Figure 31
Nomogram for wave height amplification at the Columbia River Bar, assuming an incident wave direction Θ_o in direct opposition to a current with speed U. Also assumed is an offshore water depth of 60 m and a Bar depth of 15 m.

strength on the Bar and the offshore wave period and direction. Figure 31 shows a nomogram for estimating Bar wave heights from offshore waves which propagate from due west; similar nomograms were prepared for other wave directions. Each curve corresponds to a different ebb tidal current speed, and its intersection with a vertical line corresponding to a particular offshore wave period provides the estimate of wave height amplification (i.e., percentage increase as the waves propagate from offshore onto the Bar). The ranges of swell, sea and total mean wave period typical for the Columbia River are also indicated. The min- in the center of the curve emphasize the importance of considering swell and local wind wave events separately, since the behavior at the curves are quite different in each case. When tested against three weeks of wave observations at the Columbia River, the model accounted for 70% of the observed variance in significant waveheight at peak ebb, a 25% improvement over previous methods.

F. I. Gonzalez
M. Mulhern

FISHERIES OCEANOGRAPHY

During FY 1983, PMEL and the Northwest and Alaska Fishery Center (NWAFC) jointly initiated a program in fishery oceanography. The goal of this program is to relate variations of fish and shellfish stocks of the Alaskan Continental Shelf to variations of the physical environment. Understanding such relations could improve resource utilization and management. The program developed simultaneously along three paths: 1) increased communications between scientists at PMEL and other institutions, e.g., NWAFC, University of Washington's College of Ocean and Fishery Sciences, University of Alaska's Institute of Marine Sciences, the International Pacific Halibut Commission, etc., 2) synthesis of existing knowledge of the region's physical environment, and 3) development of a computer system which can easily access an ever-expanding data base. The complexity of questions whose answers address the goal of this program requires that a multidisciplinary approach to solutions be employed. A key to successful communications among specialists has been the NWAFC's Ecosystem Working Group. This group, whose membership was expanded to include PMEL, provides an excellent example of a forum for communications and fertile grounds for future directions.

To further our understanding of the physical environment, existing knowledge was synthesized to permit the identification of gaps in data and/or understanding (which can then become objectives for future studies) and establishment of preliminary hypotheses which relate variations in year-class abundance to those in the physical environment. To refine such hypotheses, all relevant environmental data have to be made accessible so that long-term mean conditions and anomalies about the mean can be computed and used to form indices. These can then be related to indices of abundance of various animals. To attain this goal, a Fishery Oceanography Cooperative Users System was developed as a comprehensive distributed data base system, and is presently being used to examine historical data.

J. D. Schumacher
R. K. Reed
D. McConaghy

TSUNAMI

From April 1982 to November 1983, two pressure gauges were deployed near the Galápagos Islands. One instrument measured pressure fluctuations in 3571 m depth, while the second measured changes in 15 m water. During this deployment period, several features of long wave "climatology" were observed including:

three small tsunami, long waves generated byt hurricane Fabio (July 1982), and very long period changes which may be associated witht planetary waves. This successful experimentt with one deep gauge demonstrated that tsunami could be measured in the deep oceanic environment.

In FY 1983, the Office of U.S. Foreign Disastert Assistance (OFDA) of the Agency for International Development funded PMEL to direct a pilott study known as THRUST (Tsunami Hazard Reduction Using System Technology). The THRUST project team is made up of personnelt from OFDA, three elements of NOAA, and two scientific research firms. The goal is to demonstratet that regional tsunami warning systems can be assembled using existing satellite and microcomputer technology, and integrated intot established disaster warning and relief infrastructures in developing nations. The three year program is based on an earlier study (by PMEL)t showing thatt such systems are technically feasible.t The site selected for the pilot programt is Valparaiso, Chile because of its high tsunami risk.

E. N. Bernard
H. Milburn

FY 1984 PLANS

Sea Ice Processes

- Cooperative evaluation between PMEL and operational units of the NOAA Bering Sea Ice Edge Forecast Model.
- An improved algorithm for superstructure icing of vessels in northern waters will be developed and disseminated.

Coastal Winds and Waves

- Cooperative evaluation between PMEL and operational units of the Columbia River Bar nomogram.

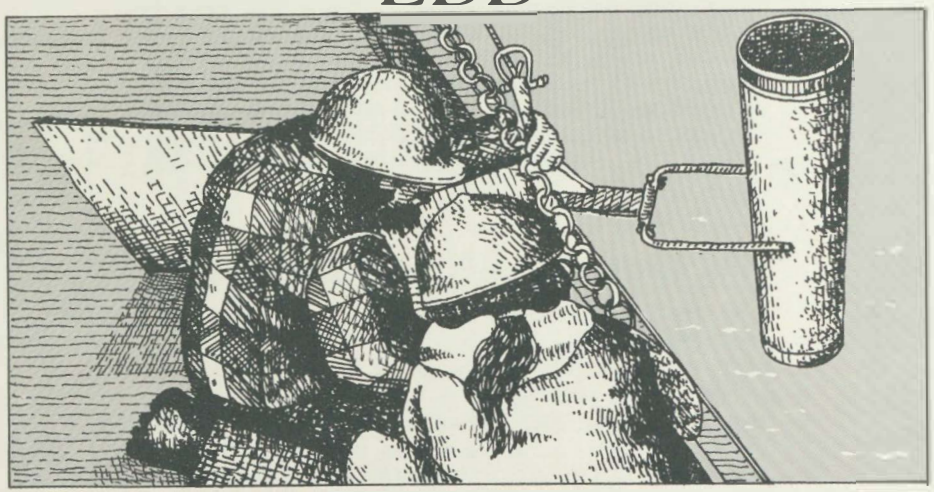
Fisheries Oceanography

- The fisheries oceanography data base will be used to test two hypotheses relating fisheries indicators to interannual variation in physical oceanographic processes.

Tsunami

- Deploy a triangular array of three deep pressure transducers in the equatorial Pacific to accurately track the passage of a tsunami in the deep ocean. These gauges will be concurrent with current meter moorings used in EPOCS. The experiment will last six months, long enough to also detect the passage of a planetary wave. By locating these pressure gauges close to current meter moorings, the dynamics of a wide spectrum of waves may be better understood.
- Complete first year activity of THRUST which includes historical data assembly, numerical modeling of hypothetical tsunami, and incorporation of results into the Chilean warning network.

EDD



Hugh B. Milburn, Division Leader

The Engineering Development Division is a multidisciplinary activity which supports the laboratory research effort through innovations in the fields of electronics, mechanics, materials, and software engineering. The staff is responsive to the needs of a broad range of investigators, and the nature and scope of projects vary accordingly. The emphasis is on expanding and refining our measurement capability in the marine environment through project engineering. Technical support is also provided during the field operations of many projects.

ARGOS WIND SYSTEM

The EPOCS near-surface current and meteorological measurement program in the eastern equatorial Pacific was enhanced by the recent development of the ARGOS Wind System (AWS). This package of sensors is mounted on a surface buoy and telemeters near real-time data via the ARGOS satellite system. An onboard microprocessor computes vector averaged wind speed and direction, time averaged air temperature and sea surface temperature, and other parameters as needed. These traditionally difficult to measure parameters are of particular importance in the on-going climate studies, and the reporting nature of these systems will become more valuable as moorings are deployed over greater areas of the oceans. The basic design emphasizes reliability, moderate costs, and expandability. Additional sensors are easily accomodated and are envisioned as the system evolves.

ELECTRIC FIELD DATA ACQUISITION SYSTEM

A major element of the Subtropical Atlantic Climate Study (STACS) is the measurement of the transport of the Florida Current as it carries equatorial heat to higher latitudes. An effort at PMEL is underway to estimate and monitor the transport from the crossstream voltage potential that is generated by the flow utilizing a submarine cable that spans the current from Jupiter Inlet, Florida to Settlement Point, Grand Bahama Island (Figure 32). Sea water flowingt through the earth's magnetic field produces ant electromagnetic field, which can be measuredt as a function of velocity, conductivity, andt magnetic field intensity. Electric potential re-t corders have been placed on the ends of thet submarine cable, and the variations in thet signals are processed to reveal changes in thet net transport. The local magnetic field ist monitored with a 3-axis flux gate magnetometert located at Jupiter, Florida. All amplifiers andt recorders are low power units designed fort long-term unattended operation in remotet areas. Initial comparisons of these cross-stream potential measurements with traditional current meter and velocity profiling measurements show a strong correlation, and justify a planned upgrade of the data acquisition systems.

THERMISTOR CHAIN

PMEL's climate related studies require knowledge of the upper ocean temperature structure in the areas of field research activities. Consequently, an effort has been made to develop a low cost buoy system capable of measuring air and sea-surface temperatures to 500 m and telemetering the data ashore via the ARGOS satellite. Although difficulties with the telemetry and interface systems have precluded maintaining an operational system, a viable design has evolved. A robust sea cable with appropriate strain reliefs and active temperature measuring components has been developed. The buoy/cable connectiont has been given careful attention, and combined with the laboratory's well-proven mooring technology, the major project obstacles have been overcome.t

ACOUSTIC DOPPLER PROFILING

To augment traditional near surface velocity measurements in the EPOCS area, an Ametek Straza DCP-4400/115 Acoustic Doppler Profiler was installed aboard the NOAA Shipt *DISCOVERER*. The system is comprised of a hull mounted three beam acoustic transducer,

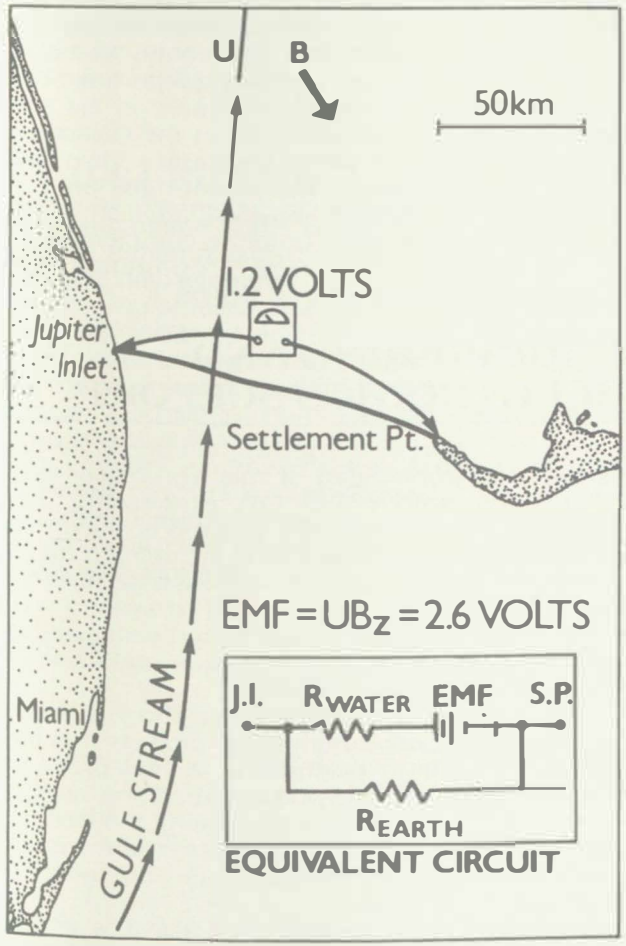


Figure 32
Schematic of submarine cable cross-stream voltage measurement system monitoring fluctuations in the Florida Current.

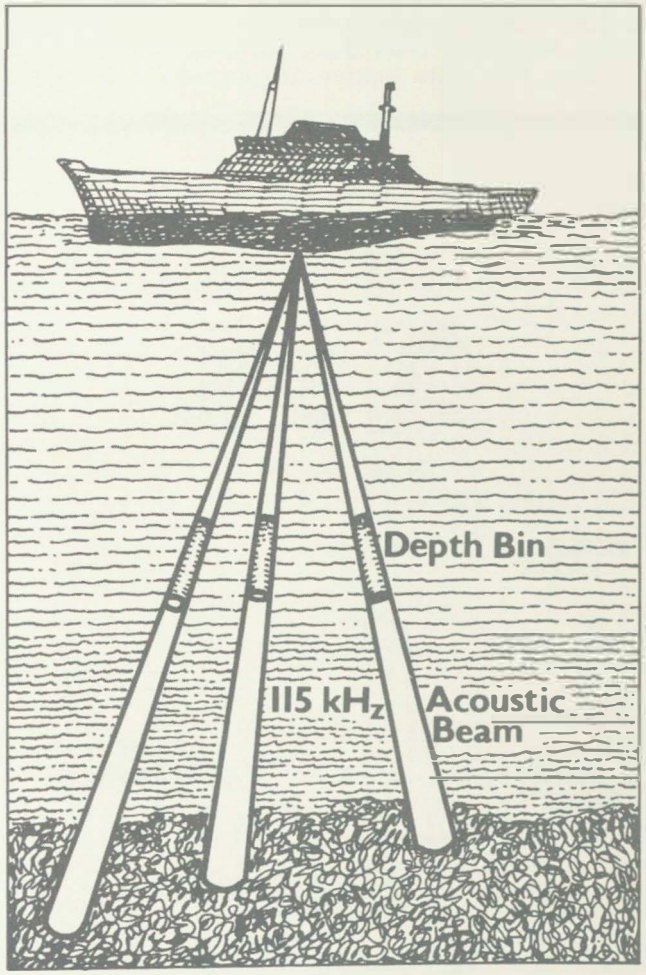


Figure 33
Subsurface current profiling by use of acoustic doppler technique.

a junction box and command module, and a computer for data acquisition and storage. In operation, the system transmits short pulses of acoustic energy at 115 kHz in three beams at 30° from the vertical (Figure 33). A fraction of the energy is returned from scatterers within the water column, and the frequency of the return signal, partitioned into discrete depth windows, is examined for a Doppler shift. Any change in frequency is caused by relative motion of the source and the scatterers, and through large statistical sampling, the velocity structure relative to the vessel motion can be determined. Although the operational depth limitation is approximately 200 m and the inherent noise of the signal necessitates averaging hundreds of samples (gathered at a 1 Hz rate), the system provides a unique method of measuring velocities while underway and without interference with other shipboard operations. Future efforts will concentrate on calibrations and intercomparisons with other measurements.

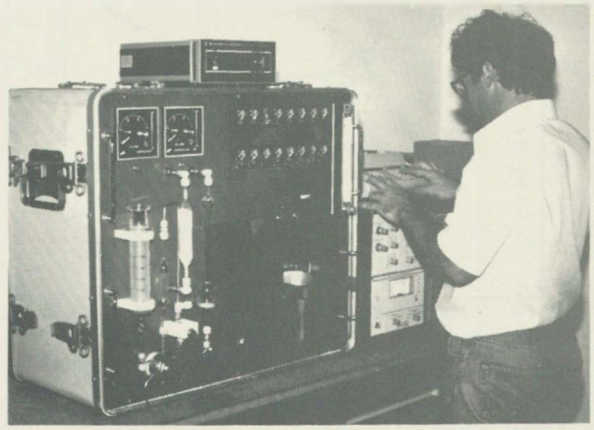


Figure 34
Nitrous oxide trace gas stripper system.

N_2O STRIPPER BOARD

Utilizing the methodology previously developed to collect and prepare sea water samples for analysis of chlorofluoromethanes (freons), a semiautomated system was de-

signed and fabricated for nitrous oxide (N_2O) studies (Figure 34).

Water samples are entered from glass syringes, gasses are stripped from the water, and through a series of valves and traps, the sample is prepared for injection to a gas chromatograph. A commercially available microprocessor based controller is incorporated to handle the routine operations. This type of system greatly decreases the demands on the sea-going chromatographer, and improves the uniformity in the handling of replicate samples and the insertion of standard gases. The system was used successfully at sea and provides a sophisticated tool for laboratory analysis.

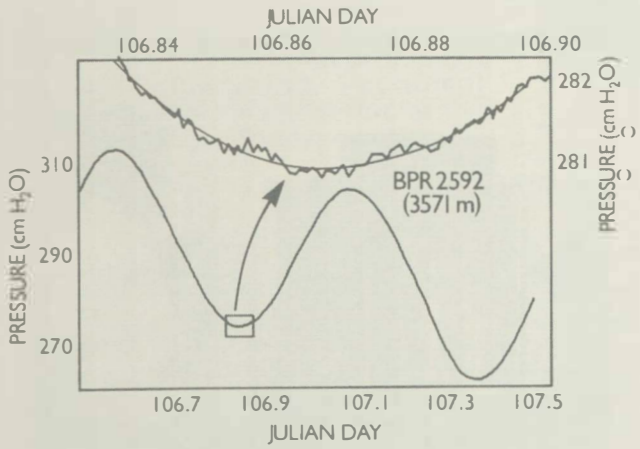


Figure 35
Sample data from deep water tsunami gauges showing high resolution capability.

TSUNAMI OBSERVATION

An effort is underway at PMEL to attain the signature of passing tsunamis in the open ocean with the use of bottom mounted pressure gauges. Recorders have been maintained at 3°S, 95°W for over a year, and the data have shown the viability of the techniques employed. Three small tsunami have been observed, and pressure disturbances from other surface effects have been seen. Sensor and electronic RMS noise is less than 0.3 cm of water heights (Figure 35). The instruments are comprised of a Paros Scientific Digiquartz pressure transducer coupled to a data logger, an acoustic release, a mooring platform, an expendable anchor, and the requisite buoyancy element for recovery (Figure 36). The instruments free-fall to the bottom and remain undisturbed on the sea floor for six months prior to recovery. Additionally a shallow water tsunami gauge has been maintained in 15 meters of water on the east side of San Christobal Island in the Galápagos Archipelago. (Four pressure gauges have also been maintained in the Galápagos area in support of the EPOCS sea-level variation study.) The deep and shallow data are complementary in the study of tsunami propagation and topographic effects on long waves.

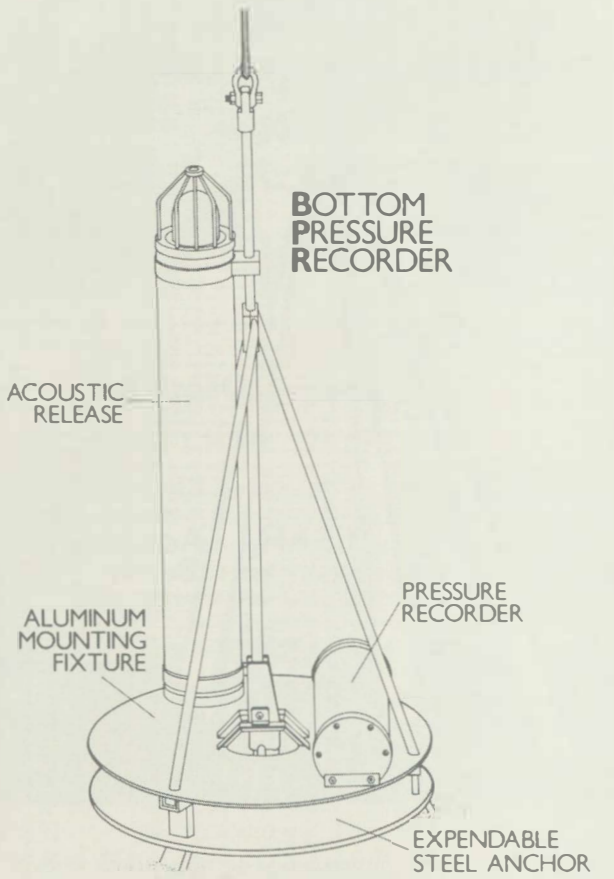


Figure 36
Instrumentation system used in open ocean tsunami observation experiment.

ENGINEERING AND ELECTRONICS SUPPORT

A major effort in the group has been directed toward the application of micro-processor technology for data collection, processing, and storage. The development process is aided with essential support equipment, including a microcomputer, which supports a cross-assembler for the development and testing of system software. The computer is also linked with cassette tape readers to provide a unique and versatile data-tape translation facility.

A machine and fabrication shop is maintained to support engineering projects and the Laboratory's field operations. A high-pressure test chamber, a cable-pull test machine, and an environmental chamber are among the facilities that are available for predeployment testing and calibration of instruments and mooring systems.

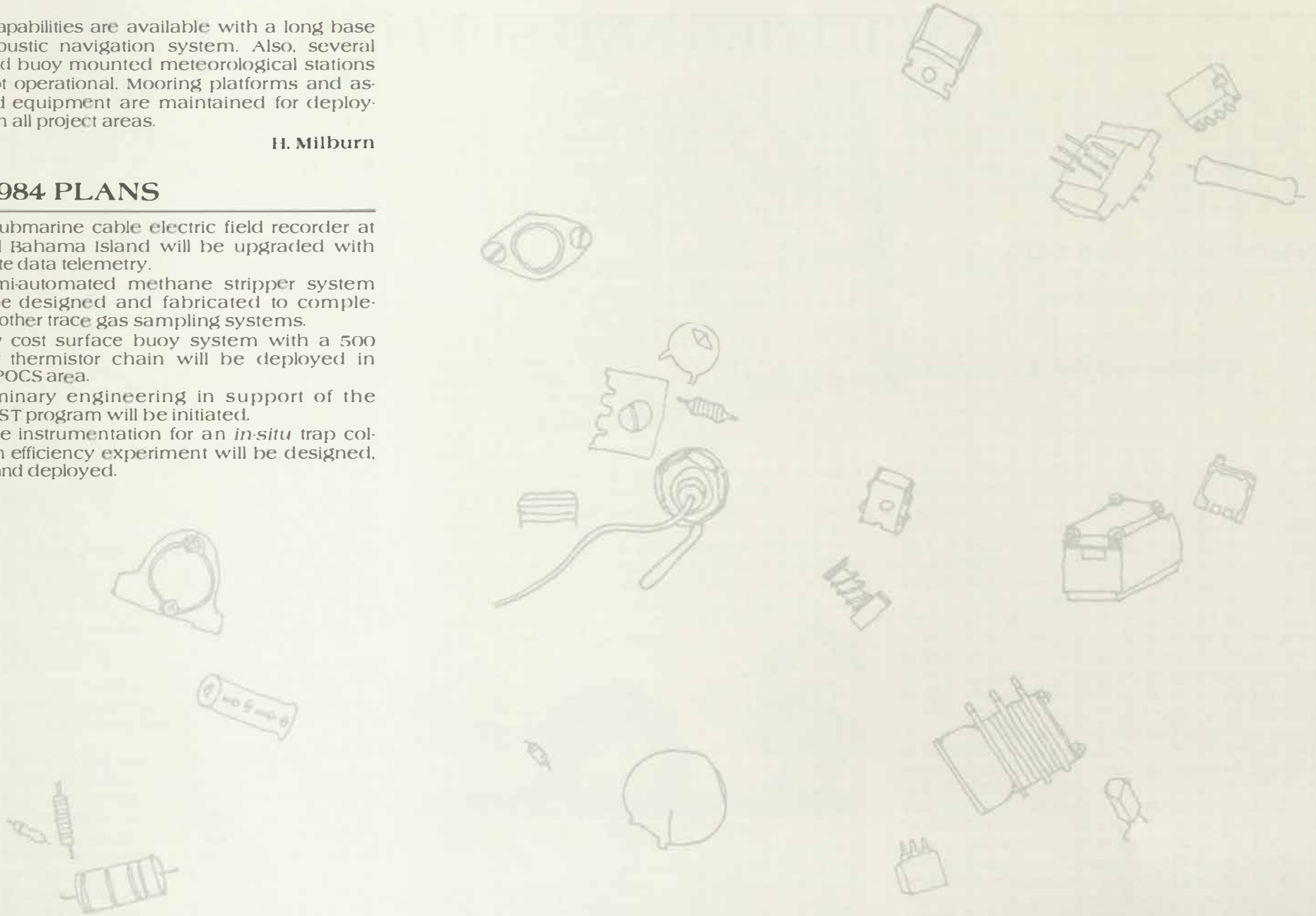
In addition to the engineering activities, technicians are involved in the service, maintenance, and assembly of the large inventory of equipment used in PMEL field programs. This includes four types of current meters for different mooring environments, acoustic releases for deep and shallow water, and conductivity/temperature chains. Sediment traps, transmissometers, and nephelometers are supported for the suspended particulate matter program and three conductivity/temperature/depth (CTD) systems are maintained. Precise position

fixing capabilities are available with a long base line acoustic navigation system. Also, several land and buoy mounted meteorological stations are kept operational. Mooring platforms and associated equipment are maintained for deployments in all project areas.

H. Milburn

FY 1984 PLANS

- The submarine cable electric field recorder at Grand Bahama Island will be upgraded with satellite data telemetry.
- A semi-automated methane stripper system will be designed and fabricated to complement other trace gas sampling systems.
- A low cost surface buoy system with a 500 meter thermistor chain will be deployed in the EPOCS area.
- Preliminary engineering in support of the THRUST program will be initiated.
- Unique instrumentation for an *in-situ* trap collection efficiency experiment will be designed, built and deployed.



FACILITIES AND SUPPORT

PMEL Staff and research facilities were consolidated at the new NOAA site at Sand Point in the summer of 1983. PMEL research, management, engineering, and computer facilities are located in Building 3, while machine shop, diving, and cruise staging operations are conducted in Building 8.

COMPUTER SUPPORT

Paul Lu, Group Leader

The Computer Support group maintains and operates a general purpose computer system intended to serve many of the computing needs of the researchers and administrative staff at PMEL. The group also offers system consulting services and computer user training sessions. System support includes installation and maintenance of common software packages and system software, the procurement and installation of additional hardware components, the operation of the computer equipment, and the maintenance of a computer user area. Development of special applications, on the other hand, is generally the responsibility of the individual projects in the Laboratory.

The computer facilities consist of a remote job entry (RJE) station, a VAX 11/780 mainframe, an intelligent communications switch, and a satellite image processing system. PMEL's investigators are currently relying upon RJE to receive printed and graphic output from NOAA's Cyber computer in Boulder, Colorado. Many of the local processing needs, however, are being satisfied by the VAX, which was installed in July of 1983. Local processing on the VAX includes the reading of data tapes, the graphic interpretation of data, development of programs, and administrative computing. Local processing on a PDP-11 consists primarily of the manipulation and display of images collected at previous times by satellites.

The majority of the computer users at PMEL gain access via terminals hardwired to the intelligent communications switch. At the beginning of a terminal session, the user selects toe establish communications with the VAX, thee Boulder Cyber (via a statistical multiplexer ande leased telephone line), or another remotee computer (via automatic dial-out modems). Dial-in communication with the switch is alsoe available.e

PMEL's RJE station has an operator's console, a card reader, tape drive, line printer, and NOVAe microcomputer as well as a plotter (Calcomp 36-inch drum plotter with four pens). Userse accessing the Cyber system by terminal or through the RJE card reader can have their job output listed on the RJE line printer, and their plot files spooled on the RJE's tape drive. No jobs are executed or tapes processed directly on the RJE equipment.

The VAX 11/780 computer system has 4 Mbytes of memory and a floating point accelerator. On-line peripherals include two 456 Mbyte fixed-head disks, three dual-density 9-track tape drives, a P300 dot-matrix printer, and a V80 electrostatic printer/plotter. The VAX system also shares the use of the Calcomp pene plotter with the RJE station.e

ADMINISTRATION AND TECHNICAL SERVICES

Cynthia L. Loitsch, Administrative Support Officer

The Administrative Support group provides technical and general administrative support to the research staff of PMEL. It functions as the liaison between Laboratory personnel and the Western Administrative Service Center, the central support staff of the Environmental Research Laboratories, and other administrative bodies. The Division is subdivided into functional sections: photography, graphics, procurement, travel, budget, and central administration.

In the publications section, manuscripts are entered into the word processing system, proofread, and when appropriate, edited and assembled with graphics or photographic illustrations in preparation for publication. The PMEL publications list for FY 1983 includes 60 titles. Recently, the preparation of camera-ready copy for journals, as well as ERL publications, has also been done on a limited basis. Other services include mailing lists and labels for mass mailings, and distribution of some PMEL publications. PMEL has three IBM OS/6 keyboards for recording material on diskettes and two high-speed, ink-jet printers

PMEL's photographic and graphics staffs provide illustration for the Laboratory's research results.

The photo-lab personnel provide specialized scientific services, including contrast enhancement, multispectral false color, digital false color, mosaic, and composite photographs, in addition to general photographic services such as black-and-white and color slides from original art, photo-mechanical transfer (PMT) copies of line originals, precision enlargements and reductions, field documentation, photo copies of continuous-tone material, and duplicate slides.

The graphics staff is responsible for translating computer and investigator-originated plots, maps and sketches, as well as abstract concepts, into camera-ready illustrations using a wide range of techniques and materials. It handles the Laboratory's typesetting and multicolored slide needs, prepares original artwork exhibits and designs and produces the Annual Report.

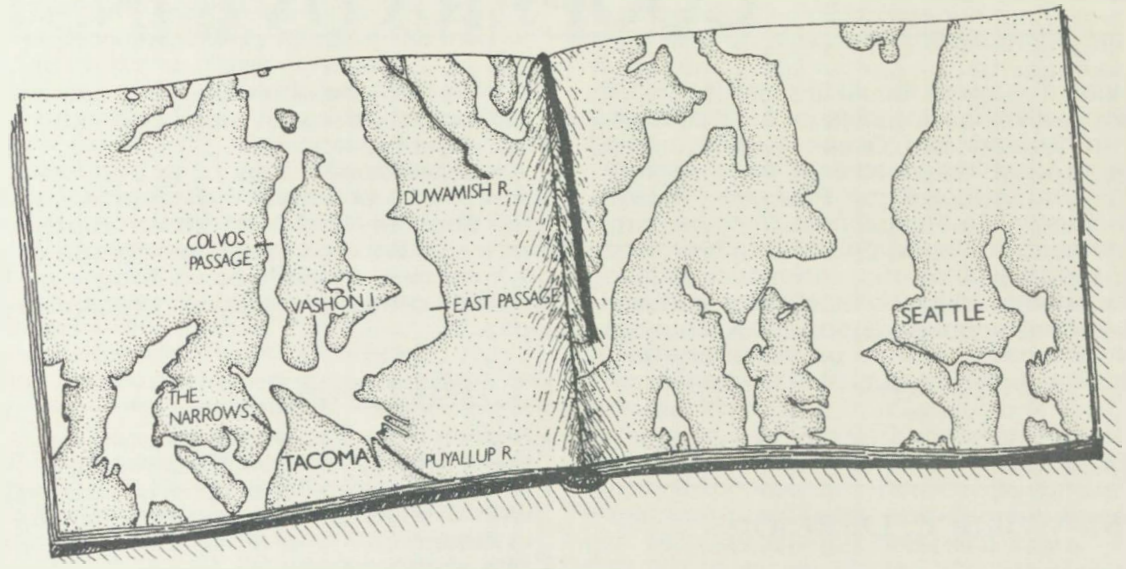
The procurement section assists Laboratory personnel in the procurement of goods and services through such mechanisms as petty cash, purchase orders, contracts, and grants. Documents are monitored through all steps in their evolution and the procurement clerk works with PMEL staff, WASC personnel, and vendors to solve any problems that arise during the procurement process.

Complete arrangements for domestic, invitational, as well as foreign travel are made through the PMEL travel section. The PMEL travel clerk is the focal point for travel orders, travel voucher review, hotel and rental vehicle reservations, airline tickets, and government passport information.

The Administration Group regularly provides PMEL management with fiscal and budgetary analyses to assist them in the decision making process. The Administration Group reviews both Operations, Research and Facilities (OR&F) accounts, as well as other agency projects to monitor spending patterns and assure PMEL compliance with budgetary ceilings and spending restrictions. Other services include: property management; GSA vehicles and vehicle maintenance; central desk top supplies; mail distribution; copying facility; personnel management, and general administration.

DIVING UNIT

The PMEL diving unit established in FY 1979 continues to support the diving requirements of several Laboratory projects. Current meter and sediment trap moorings, as well as individual water level gauge stations are periodically serviced by divers for the Puget Sound L-RERP research effort. As part of EPOCS, PMEL has maintained pressure-temperature gauges in the Galápagos Islands for the past five years, with divers replacing these sensors annually.



PMEL divers have participated in several NOAA-sponsored advanced training courses, including Emergency Medical Technician (EMT) and Diver Medical Technician (DMT) training. Diver proficiency is maintained by all PMEL divers with frequent working dives to inspect and maintain valuable equipment left in the field.

PMEL presently has five NOAA-certified divers.

D. Herlihy

LIBRARY

The NOAA Northwest Regional Library, at the west end of NOAA Building 3, is operated by NESDIS, Library and Information Service Division and serves PMEL researchers. The collection holds more than 3000 volumes and emphasizes physical oceanography, marine chemistry, meteorology and pollution studies. The Library subscribes to more than 150 journals, maintaining current issues on browsing shelves for users, and archiving many titles on microfilm. Reader printers are available for Library users.

Computer-assisted literature searches can be performed on any subject using the Library's computer terminal. The Library has access to all of the major bibliographic data bases such as DIALOG, NEXIS, Legislate, Chemical Substances Information Network, Institute for Scientific Information, and Chemical Information System.

Holdings are cataloged on line, using the OCLC System. Records in the NOAA Union Catalog, available on both film and fiche, can be accessed by all NOAA Libraries, as can the holdings of other selected libraries. An on-line catalog is under development as part of the NALIS System (NOAA Automated Library and Information System) and is presently available in prototype form.

In 1980, the Library was dedicated in memory of Robert L. Charnell and N. Patrick Laird, two PMEL scientists who were lost at sea on the *HOLO HOLO* in 1978.

B. Keck

COOPERATIVE INSTITUTES

Fiscal year 1983 was the sixth year of PMEL's association with the Joint Institute for the Study of the Atmosphere and Ocean (JISAO) at the University of Washington, and the Joint Institute for Marine and Atmospheric Research (JIMAR) at the University of Hawaii. These institutes provide a structure for research collaboration and training in areas of mutual interest to NOAA and the academic community. A series of distinguished visiting scientists is supported through the institutes each year to present seminars and interact with the institute staff and graduate students.

JISAO

John M. Wallace, Director

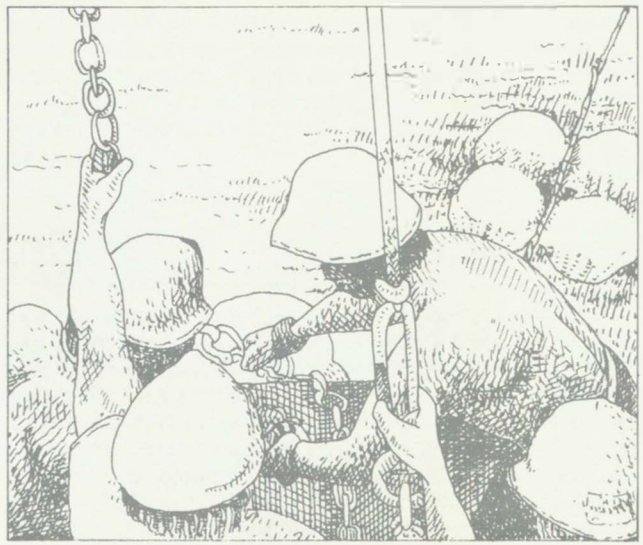
The main areas of emphasis within JISAO continue to be climate dynamics, estuarine processes, and environmental chemistry, with climate dynamics continuing to be dominant. Research in climate dynamics during FY 1983 involved a variety of topics, including descriptive studies of the remarkable 1982-83 El Niño event; participation in the FOCAL (French Program Ocean-Climat Atlantique Equatorial) and SEQUAL (Seasonal Response of the Equatorial Atlantic) programs designed to study the seasonal variability of subsurface temperature, currents and heat content in the equatorial Atlantic; theory of the vertical propagation of equatorially trapped waves forced by low-frequency fluctuations in surface wind stress; the design of observing networks for monitoring currents and thermal structure in the upper layers of the ocean; analysis of data on finestructure within the equatorial thermocline in relation to the vertical exchange of heat and momentum; and experiments with a simple numerical model designed to simulate recurrent atmospheric circulation regimes.

The planned research in the area of environmental chemistry did not get underway during FY 1983 because of a delay in the arrival of the postdoctoral research associate who will be involved in this activity.

JISAO sponsored, fully or in part, visits by 41 scientists, 15 of whom were from foreign countries. Seminars included 26 on climate-related topics, 13 on environmental chemistry and 1 on estuaries. In addition, 3 long-term visiting scientists carried out research on climate-related topics.

FY 1984 Plans

- Research on the oceanographic topics listed in the previous section will continue.
- A project on atmospheric dynamics will begin with the arrival of a new postdoctoral fellow in January.
- The environmental chemistry project on the absorption of metals and metalloids onto oxides in natural systems will commence.
- Active visitor programs are planned for both the climate dynamics and environmental chemistry areas.



JIMAR

Dennis Moore, Director

The principle research interests of JIMAR are climate, equatorial oceanography, and tsunami. Activities sponsored fully or in part by JIMAR include eleven short-term visiting scientists, one long-term visiting scientist, three postdoctoral appointments, nine seminars and a tsunami workshop.

Studies of cirrus surges were expanded to include the period 1976-1981, developing a climatology of surge duration. It was found that most surges were apparently triggered by passing 500 mb troughs. The results, linking surges and mainland tornadic outbreaks, will be reported at the 13th Conference on Severe Local Storms.

Regression analysis demonstrated that Hawaiian rainfall appears to be related to the Southern Oscillation Index in January and February but not in December. This is probably because the large-scale upper tropospheric circulation over Asia and the Pacific undergoes a seasonal change between early and late winter. Thus the model of Horel and Wallace might be applicable only in late winter.

Analysis of SAWINS (Satellite Winds) and the climatic shear-derived surface winds has continued and the various associated trade wind indices were maintained. The averaging period has been shortened (one month to one-half month) and the space resolution has been increased (5° to 2½°). By merging mean resultant ship winds in the western Pacific with the SAWINS fields, the analysis has been extended across the whole tropical Pacific.

Historical Sea Surface Temperature and Pressure data for the area east of the Phillippines (10°-20°N; 130°-150°E) were analyzed. The existence of a 1.3°C spurious diurnal temperature rise stemming from local ship heating was confirmed. It was found that in the deep tropics cold, relatively dry downdrafts do not significant-

ly enhance sensible and latent heat losses from the ocean surface. Although the most accurate, representative measurements are those of air temperature and dew point made at night, it is unlikely that present or planned instrumentation will provide estimates of latent and sensible heat flux accurate enough to enable climate change to be detected, except possibly through applying pattern-recognition techniques.

The convergence zone over the central and eastern Pacific during the FGGE (First GARP Global Experiment) was described. After using satellite pictures to stratify the convergence zone by intensity, the climatological structure along meridional and vertical axes was then defined using omegasonde data. Standard deviations within each class were surprisingly small.

Equatorial Oceanography

On July 11, 1983, *R/V MACHIAS* returned to Honolulu, marking the end of the data collection phase of the Line Islands Profiling component of PEQUOD (Pacific Equatorial Ocean Dynamics). *MACHIAS* had been away from Honolulu since February 19, 1982 and in that time had made 21 cruises from Fanning Island, collecting 529 profiles of velocity and temperature from ocean surface to bottom. This project is a major component of the PEQUOD program.

The strong and unusual El Niño event that began in summer, 1982 and continued throughout the remainder of the project greatly increased the value of the data. This is the first time that currents in the equatorial band have been measured regularly during the onset and maturity of an El Niño. The most striking observation is that the Equatorial Undercurrent, a strong subsurface eastward current that had previously been considered a permanent feature of the central equatorial Pacific, virtually disappeared in September, 1982. It was replaced for a couple of months by a westward subsurface current, then by an intense surface eastward jet that may be similar to the monsoon transition jet in the Indian Ocean. In January, 1983, the Undercurrent abruptly reappeared, together with a strong westward South Equatorial current at the surface. The dynamics of these dramatic changes are not yet known. Analysis of the Line Island Profiling data set is expected to make a major contribution to our understanding of the role equatorial currents in El Niño. The bulk of the Line Islands Profiling Project was funded by NSF. A two month extension, resulting in three additional cruises, was funded jointly by NSF and NOAA.

Pacific sea level data were used to study the annual and interannual variability of the energy levels of equatorial 30-day waves. The energy level of the 30-day oscillations in the central Pacific seems to be strongly correlated with the Southern Oscillation Index. The FGGE Tahiti Shuttle data were used to estimate the absolute and potential vorticity distributions for the Undercurrent.

PEQUOD data have been used to begin studying the 1982-1983 El Niño event. Sea level and sea surface temperature (SST) at Jarvis Island, along with meteorological and SST observations from the *MACHIAS*, give some insight into the evolution of El Niño. SST at Jarvis began to rise at the rate of 5°C per year in January, 1982. This increase in SST extended at least over the latitude band from 3 degrees South to 3 degrees North. The rise in sea level at Jarvis associated with the El Niño did not occur until July, 1982. Anomalous winds and convective activity in the Line Islands were not observed until September, 1982. This sequence of events clearly indicates that remote forcing plays a major role during the onset of El Niño.

Studies of equatorial Kelvin wave beams were continued and a study of the structure of dispersive Rossby waves was initiated. A number of data analyses were pursued to assess the role of Kelvin waves in the advection of SST anomalies, and to determine how well Kelvin waves can be detected in island and coastal sea level data.

Tsunami Research

Hurricane Iwa was used as a realistic opportunity to exercise our post-event monitoring capability. Navy and Civil Air Patrol aircraft made photo reconnaissance flights over the areas of Oahu and Kauai which were most affected by storm waves. Good results were obtained. Data were also obtained by questionnaire and interviews, and used as input to several reports on the hurricane. Evidence of an unusual storm surge, akin to a tsunami in several respects, was found on the west coast of Oahu.

An infrared photography capability was added to the survey procedure. A straightforward method for using this type film was developed and tested. Several trial exercises involving both aircraft and ground photo-observers were held, with generally satisfactory results. An additional monitoring site was established on Hawaii.

The large (6" OD) digital tsunami gauge suitable for testing in a wave tank was nearly completed. This version has oversized batteries and plug-in circuit boards for ready experimentation. It incorporates both hydraulic and electronic low pass filters, and can be operated at one or eight second sampling rates. The fast rate allows easier testing and evaluation than the slower eight second rate.

A smaller (3") field test prototype is 80% complete. This model is intended to be deployed near-shore. It will either fast sample to sense swell, or slow sample to measure the tide, as an example of a wave analogous to a tsunami. This version has small batteries (12 hour lifetime) and a single circuit board. Both gauges record the wave data permanently on an EPROM (Eraseable Programmable Read Only Memory) which is then removed and read via a digital to analog converter onto a strip chart. The digital data may also be analyzed directly on a computer.

FY 1984 Plans

- Investigation of the structure of the eastern Pacific near-equatorial convergence zone and of tropical Pacific cirrus "surges" will be combined to study tropical-midlatitude interactions. It is hoped, thereby, to determine whether deep amplitude midlatitude troughs trigger "surges", whether an active convergence zone is a necessary condition for "surge" generation, and whether the tropics

initiate poleward energy flux or whether merely comprise a passive resevoir responding to extratropical forcing.

- Explanations will be sought in the context of teleconnections between rainfall over Hawaii and the Southern Oscillation.

- Investigations of the expanded marine data deck will focus on the problems associated with surface heat exchange and atmospheric circulation in trying to identify small areas with unequivocal climate signals.

- The PEQUOD and NORPAX Shuttle Data will be compared in detail. Special attention will be given to the structure and evolution of deep equatorial jets. This should be especially interesting in light of the 1982-83 El Niño event which was clearly evident in the PEQUOD data.

- The detection of Kelvin waves by sea level data will be further examined as will the role of Kelvin waves in the advection of SST anomalies.

- The effect of coastal geometry on equatorial waves in the Indian Ocean will be studied.

- A model of interannual variability of the tropical Atlantic will be developed.

- We will continue to maintain and upgrade JIMAR's tsunami monitoring capability. The prototype tsunami gauge will be completed and tested. An initial production of 12 gauges will begin. A strategy for deploying these gauges in case of a pending tsunami will be developed. We will also cooperate with the new NOAA/AID THRUST program development.

- A model for local tsunami effects in the Hawaiian Island chain will be developed. We hope that the same model will be useful for studying local storm surges of the type generated by hurricane Iwa. We will also continue to be involved in the development of the University of Hawaii Natural Hazards Group which was started last year.

PMEL STAFF

The success of the PMEL research program is totally dependent on the talents and dedication of its staff. The permanent PMEL staff includes 37 professionals with master's or doctoral degrees, and 40 junior and support level personnel. Personnel from the NOAA Corps are given rotational assignments at PMEL in research related to their areas of expertise. Through the National Research Council Research Associateship Program, postdoctoral scientists pursue individual research in conjunction with PMEL programs for periods of up to two years. In addition, visiting scientists to JISAO and JIMAR work closely with Laboratory scientists in cooperative programs.

The Laboratory participates in several employment programs that provide opportunities for university students at both graduate and undergraduate levels to gain research experience in science and engineering. This includes the Cooperative Education Program (Coop), the Federal Junior Fellowship Program, the College Work-Study Program, and graduate research assistantships through the joint institutes.

PMEL's scientific staff is active outside the Laboratory in the local, national, and international scientific communities. Ten Laboratory scientists hold affiliate faculty appointments at the University of Washington, and one scientist holds both an affiliate appointment at the University of Hawaii and at Scripps. In this capacity, they teach graduate courses and serve on graduate committees. PMEL scientists chair or serve on the scientific steering committtees for several major NOAA or interagency research programs, including EPOCS, STACS, IRIS, Sea Use Council, and the U.S.-U.S.S.R. Bilateral Agreement on Large-Scale Ocean-Atmospheric Studies (SCOR Working Group 56). Papers are presented at national and international professional meetings.

In FY 1983, Dr. Rudolph Preisendorfer held the George J. Haltiner chair in meteorology at the Naval Postgraduate School in Monterey, California, and Dr. Jimmy C. Larsen was awarded the Green's fellowship at Scripps Institute of Oceanography. Dr. James Schumacher was appointed Affiliate Associate Professor in the Department of Oceanography and Dr. James E. Overland was appointed Affiliate Associate Professor in the Department of Meteorology, both at the University of Washington.

OFFICE OF THE DIRECTOR
Eddie N. Bernard, Director

Behn, Richard	THRUST Project Coordinator (NOAA Corps)
Cantwell, Kevin	Computer Programmer
Darchuck, Eugenie K.	Secretary
Holbrook, James R.	Deputy Director, Oceanographer
Jensen, Mary F.	Secretary (Stenographer)
Loomis, Harold G.*	Mathematician
McConaghy, David	Data System Manager (NOAA Corps)
Turnbull, William*	Acting Deputy Director (NOAA Corps)
	Program Specialist

COMPUTER SUPPORT
Paul Lu, Group Leader

Barzell, Ron	Student Aid
Beach, Reginald A.*	Student Aid
Borg-Breen, David R.	Computer Programmer
McCarty, Laura C.	Computer Assistant
Parsons, Lawrence*	Computer Specialist (NOAA Corps)
Tagliani, David M.	Student Aid

TECHNICAL AND ADMINISTRATIVE SUPPORT
Cynthia L. Loitsch, Program Support Officer

Anderson, James W.	Photographer
Chatfield, N. Jean*	Editor
Collins, Beverly J.	Management Support Assistant
Cooke, Florence K.	Travel Clerk
Curl, Gini	Illustrator
Elkins, Gayle L.	Procurement Clerk
Hathorn, Sheila A.*	Clerk-Typist
Hutchens, Phyllis A.	Clerk-Typist
Leong, Calvin G.	Photographer
Lim, Robert W.	Motor Vehicle Operator
Lu, Lai K.	Data Management Clerk
Lyons, Hae Sook*	Clerk-Typist
Perry, Richard M.	Warehouse Worker
Register, Joy G.	Illustrator
Smith, Claudia	Photographer
Thomasson, Norma H.	Program Support Supervisor
Whitney, Ryan L.	Data management Clerk

OCEAN CLIMATE RESEARCH DIVISION
Bruce A Taft, Division Leader

Duley, Eugene J.	Mechanical Engineering Technician
Freitag, Howard P.	Ocenographer
Gifford, Eunice E.	Secretary
Halpern, David	Oceanographer
Hayes, Stanley P.	Oceanographer
Larsen, Jimmy C.	Oceanographer
Mangum, Linda J.	Computer Programmer
McCarty, Margie	JISAO
Mobley, Curtis	Institute Scientist (JISAO)
Newell, Scott J.	Engineering Technician
O'Neill, Kathleen	NRC Post Doctorial Investigator
Pietrowski, Walter	Computer Programmer

Preisendorfer, Rudolph W.	Supervisory Mathematician
Pullen, Patricia E.	Oceanographer
Shepherd, Andrew J.	Electronics Technician
Soreide, Nancy N.	Computer Programmer
Withrow, John A.*	Ocean Engineer (NOAA Corps)
Wright, Peter	Institute Scientist (JISAO)
Wright, Timothy	Physical Scientist (NOAA Corps)

MARINE ASSESSMENT RESEARCH DIVISION
Herbert C. Curl Jr., Division Leader

Agy, Sharon	Secretary
Baker, Edward T.	Oceanographer
Bates, Timothy S.	Chemist
Booth, Pieter N.	Biological Technician
Boudreau, Maureen L.	Physical Science Technician
Cannon, Glenn A.	Oceanographer
Cline, Joel D.*	Oceanographer
Duffin, Ruth*	Secretary
Feely, Richard A.	Oceanographer
Fletcher, Richard A.	Physical Science Aid
Geiselman, Terri L.	Oceanographer
Gendron, James F.	Chemist
Grigsby, Michael W.	Physical Scientist
Hamilton, Susan E.*	Chemist
Herlihy, Daniel R.	Geologist (NOAA Corps)
Kachel, David G.	Computer Programmer
Kelly-Hansen, Kimberly C.	Oceanographer
Landsteiner, Mary	Oceanographer (JISAO)
Lavelle, J. William	Oceanographer
Martens, Donald E.*	Physical Science Aid
Massoth, Gary J.	Oceanographer
Mofjeld, Harold O.	Oceanographer
Murphy, Paulette P.	Oceanographer
Pashinski, David J.	Oceanographer
Paulson, Anthony J.	Oceanographer
Roberts, Marilyn F.	Physical Science Technician
Runo, Diane T.	Physical Science Technician
Russell, Lisa M.	Biological Science Student Trainee
Schibig, Louis M.*	Physical Science Student Trainee (Junior Fellow)
Stewart, Robert, J.	Oceanographer
Stolov, Amy L.*	Physical Science Technician
Tennant, David A.	Oceanographer
Walker, Sharon L.	Oceanographer
Wisegarver, David P.	Chemist
Wright, Sharon L.	Physical Science Technician

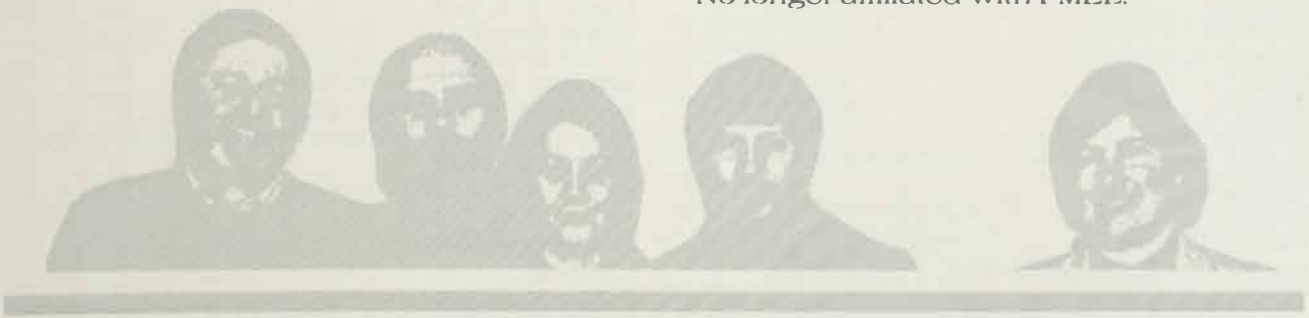
MARINE SERVICES RESEARCH DIVISION
James E. Overland, Division Leader

Brown, Rebecca L.	Engineering Aid
Cokelet, Edward D.	Oceanographer
Gonzalez, Frank I.	Oceanographer
Gray, Judith	Meteorologist (Coop)
Kaiser, Theodore C.	Buoy Operations Officer (NOAA Corps)
Long, Virginia L.	Physical Science Technician
Lynagh, Marion J.*	Secretary (Typing)
Macklin, Stewart A.	Meteorologist
Moen, Paul D.	Physical Scientist (NOAA Corps)
Mulhern, Martin	Research Engineer/Oceanographer (NOAA Corps)
Pease, Carol H.	Oceanographer
Reed, Ronald K.	Oceanographer
Reynolds, R. Michael	Oceanographer
Schoenberg, Sally A.*	Meteorologist (Coop)
Schumacher, James D.	Oceanographer
Turet, Philip	Physical Science Aid
Walter, Bernard A.	Physical Scientist
Wilson, Belle	Secretary

ENGINEERING DEVELOPMENT DIVISION
Hugh B. Milburn, Division Leader

Delizo, Stan W.	Enginnering Technician
Holzer, Dennis E.	Machinist
Jackson, Thomas G.	Electronics Technician
McLain, Patrick D.	Electronics Engineer
Nakamura, Alex I.	Electronics Engineer
Newman, Roy	Electronics Technician
Parker, William J.	Electronics Technician
Stapp, Michael F.	Electronics Technician
Wood, Emerson G.*	Electronics Engineer (NOAA Corps)

*No longer affiliated with PMEL.



SEMINARS

PMEL SEMINARS

DATES	NAME AND AFFILIATION	SEMINAR TOPIC
1982		
28 Oct	Dr. Peter Betzer University of South Florida	Aragonite and calcite fluxes from tropical, temperate and arctic waters of the North Pacific — preliminary results from free drifting sediment
9 Nov	Dr. Douglas McLain Pacific Environmental Group NMFS	Can an oceanographer have MOODS (Master Oceanographic Observations Data Set)
1983		
10 Feb	Dr. John Robbins GLERL/NOAA	^{7}Br and ^{137}Cs: Tracers of seasonal transport in the Great Lakes
8 April	Drs. William Hooke, WPL, and Leonard Fedor, ERL	Ocean microwave remote sensing
21 April	Dr. R. Michael Reynolds PMEL	Ice edge meteorology — theoretical notions and field observations
20 April	Dr. Richard Barber Duke University Marine Lab	The 1982/1983 El Niño
16 May	Dr. John Lupton Marine Science Institute University of California Santa Barbara	Helium isotopes, submarine hydrothermal activity, and deep ocean circulation
12 Aug	Dr. K.-P. Holz Institut fur Stromungsmechanic, Hannover, Fed. Rep. of Germany	Models of sediment transport and channel infilling
25 Aug	Dr. Steve Thorpe Institute of Oceanographic Sciences Wormley, England (visiting OSU)	Acoustic detection of bubbles, and related phenomena
19 Sept	Peter Wright JISAO	The Southern Oscillation

26 Sept	David McConaghy PMEL	FOCUS: An environmental data accessing system for Alaskan fishery oceanography investigation

JISAO SEMINARS

DATES	NAME AND AFFILIATION	SEMINAR TOPIC
1982		
4 October	Dr. Gregg Holloway IOS Sidney, BC	Two odd notes: Effects of velocity fluctuations on vertical distribution of phytoplankton. Possible effects of marginal ice cover on long wave propagation
28 Oct	Dr. Peter Betzer University of South Florida	Aragonite and calcite fluxes from tropical, temporate and Arctic waters of the North Pacific — preliminary results from free-drifting sediment
1983		
11 Jan	Douglas R. MacAyeal GFDL/NOAA	Tides, tidally driven circulations, and the formation of tidal fronts below the Ross Ice Shelf, Antarctica
19 Jan	Dr. Edward Sarachik Harvard University	Seasonal variations in equatorial oceans
20 Jan	Dr. Edward Sarachik Harvard University	SEQUAL
4 Feb	Dr. J. Shukla NASA/Goddard Laboratory for Atmospheric Sciences	Physical basis for monthly seasonal prediction
23 Feb	Dr. Lynne D. Talley Oregon State University	Radiating quasi-geostrophic instability
1 March	Dr. William R. Young Scripps Institution of Oceanography	Ventilated and unventilated models of the general circulation
2 March	Dr. William R. Young Scripps Institution of Oceanography	On the three-dimensional circulation in a vertically well-mixed estuary
18 March	Dr. Pat Hatcher USGS Reston, VA	Application of solid state C-13 NMR spectroscopy for studies of organic chemical processes in chemicals

9 March	Dr. Peter S. Ray National Severe Storms Laboratory ERL/NOAA	Three-dimensional microphysical and kinematic structure of a New Mexico thunderstorm from single Doppler Radar observations
11 March	Dr. Peter S. Ray National Severe Storms Laboratory ERL/NOAA	Comparisons of observed and numerically simulated deep convection
11 March	Dr. Mike Hoffman California Institute of Technology	The chemistry and physics of urban fog
15 April	Dr. Kenneth Hopper University of Delaware	HPLC techniques open new avenues of organic geochemical research
20 April	Dr. Richard Barber Duke University Marine Laboratory	The 1982/1983 El Niño
22 April	Dr. Patrick Brezonick University of Minnesota	Acid precipitation and its effects on soft water seepage lakes
2 May	Dr. Ronald Hites Indiana University	Sources and fates of toxic organic compounds in the Great Lakes
3 May	Dr. P. L. McCarty Stanford University	Movement and fate of hazardous organics in ground water
19 May	Prof. Bruce Morton Monash University Australia	The birth and death of vorticity
20 May	Prof. Bruce Morton Monash University Australia	Vortex wakes behind hills
25 May	Dr. Pedro Ripa CICESE Mexico	Nonlinear effects on the propagation of Kelvin pulses across the Pacific
26 May	Prof. Jih-Ing Chao Academia Sinica PRC	Filtered anomaly model for making monthly and seasonal forecasts
31 May	Dr. Peter Haynes University of Cambridge England	A mechanism for planetary wave growth in the winter stratosphere
2 June	Dr. W. K. Melville MIT	Instabilities and breaking in deep-water gravity waves

14 June	Dr. Ed Harrison MIT	Dynamics of the onset of the 1982 equatorial Pacific warming event
15 June	Dr. Mark Cane MIT	Modeling of sea-level changes during El Niño
22 June	Dr. Peter Rhines Woods Hole Oceanographic Institution	Ocean circulation of potential vorticity homogeneity
22 June	Dr. B. Jaehne University of Heidelberg	Gas transfer between atmosphere and water bodies
29 June	Dr. Chandran Kaimal ERL/NOAA	Remote sensor applications to meteorology

JIMAR SEMINARS

DATES	NAME AND AFFILIATION	SEMINAR TOPIC
1982		
26-27 Aug	Dr. Kansuke Takeuchi Dept. of Geophysics Hokkaido University, Japan	"Interannual Variability in the Westernn Tropical Pacific"
27-29 Sept	Roddam Narasimha Dept. of Aeronautical Engineering India Institute of Science	"Results from an Atmosphere Boundary Layer Experiment During the 1980 Solar Eclipse"
6-8 Oct	Dr. Robert Chervin NCAR	"A Computer Animated Look at the FGGE Data"
27-29 Oct	Dr. Donald W. Beran DirectorPROFS	"Results of Real-Time Testing of the Proto-Type Regional Observing and Forecasting Service, Colorado, Summer, 1982"
15-19 Nov	Dr. E. Bernard DirectorPMEL.n	Tsunami Workshop
7-11 Dec	Dr. Eric Kraus CIRES University of Colorado	"The Interactive Evolution of then Oceanic and Atmospheric Boundary Layer in the Source Region of the Tradesn

1983

9-19 Feb	Dr. Joseph Fletcher NOAA/ERL	"Variability of Surface Climate Over the Ocean Since 1960"
4-5 April	Dr. Allan Clarke Department of Oceanography Florida State University	"The Dynamics of Large-Scale, Wind-Driven Variations in the Antarctic Circumpolar Current"
22-25 May	Dr. Mark Luther Meteorology Annex Florida State University	"Response of the Arabian Sea to Monsoon Wind Forcing"
26-27 June	Dr. James Miller Dept. of Meteor. & Phys. Ocean. Cook College, Rutgers University	"Sea Surface Wind Speed from Satellite Microwave Radiometers"

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APPENDIX

GLOSSARY OF ACRONYMS

AID: Agency for International Development
CIREs: Cooperative Institute for Research in Environmental Sciences
CMOS: Complementary Metal Oxide Semiconductor
CTD: Conductivity, Temperature, Depth
CUEA: Coastal Upwelling Ecosystems Analysis
DOMES: Deep Ocean Mining Environmental Study
EOF: Empirical Orthogonal Function
EPOCS: NOAA Equatorial Pacific Ocean Climate Studies
EPROM: Eraseable Programmable Read Only Memory
EQUA: PMEL Equatorial Studies Program
ERL: Environmental Research Laboratories
FGGE: First GARP Global Experiment
FOCAL: French Program Ocean-Climat Atlantique Equatorial
FOCUS: Fisheries Oceanography Cooperative Users System
FRONTS: Study of Large-Scale Frontal Zones
GARP: Global Atmospheric Research Program
GC-MS: Gas Chromatograph-Mass Spectrometerr
GOES: Geostationary Operational Environmental Satelliter
ICES: International Council for Exploration of the Sear
IRIS: International Recruitment Investigations in the Subarcticr
ITCZ: Intertropical Convergence Zone
JASIN: Joint Air-Sea Interaction Experimentr
JIMAR: Joint Institute for Marine & Atmospheric Research
JISAO: Joint Institute for the Study of Atmosphere & Oceanr
L-RERP: Long-Range Effects Research Programr
MESA: Marine Ecosystems Analysisr
MILE: Mixed Layer Experimentr
MIZEX: Marginal Ice Zone Experimentr
NCAR: National Center for Atmospheric Research
NEC: North Equatorial Current
NECC: North Equatorial Countercurrentr
NMFS: National Marine Fisheries Servicer
NOAA: National Oceanic and Atmospheric Administrationr
NOS: National Ocean Survey
NORPAX: North Pacific Experiment
NSCC: Northern Subsurface Countercurrent
NSF: National Science Foundation
NWAFC: Northwest and Alaska Fisheries Center
NWS: National Weather Service
OCSEAP: Outer Continental Shelf Environmental Assessment Program
OMPA: Office of Marine Pollution Assessment
PEQUOD: Pacific Equatorial Ocean Dynamics
PMEL: Pacific Marine Environmental Laboratory
PROFS: Prototype Regional Observing and Forecast System
PTG: Pressure Temperature Gauge
PVC: Polyvinyl Chloride
RJE: Remote Job Entry
SAI: Science Applications Incorporated
SAR: Synthetic Aperture Radar
SCOR: Scientific Committee on Oceanic Research
SEC: South Equatorial Current
SEQUAL: Seasonal Response of the Equatorial Atlantic
SLAR: Side-Looking Airborne Radar
SPM: Suspended-Particulate Matter
STACS: Subtropical Atlantic Climate Study
STREX: Storm Transfer and Response Experiment
SST: Sea Surface Temperature
THRUST: Tsunami Hazard Reduction Using System Technology
UCM: Unresolved Complex Mixture
USCG: United States Coast Guard
USGS: United States Geological Survey
UV-B: Ultraviolet-B
UW: University of Washington
VACM: Vector-Averaging Current Meter
XBT: Expendable Bathythermograph

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