Pacific Marine Environmental Laboratory

ANNUAL REPORT

Fiscal Year 1976 & 1976T

U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
ENVIRONMENTAL RESEARCH LABORATORIES
SEATTLE, WASHINGTON
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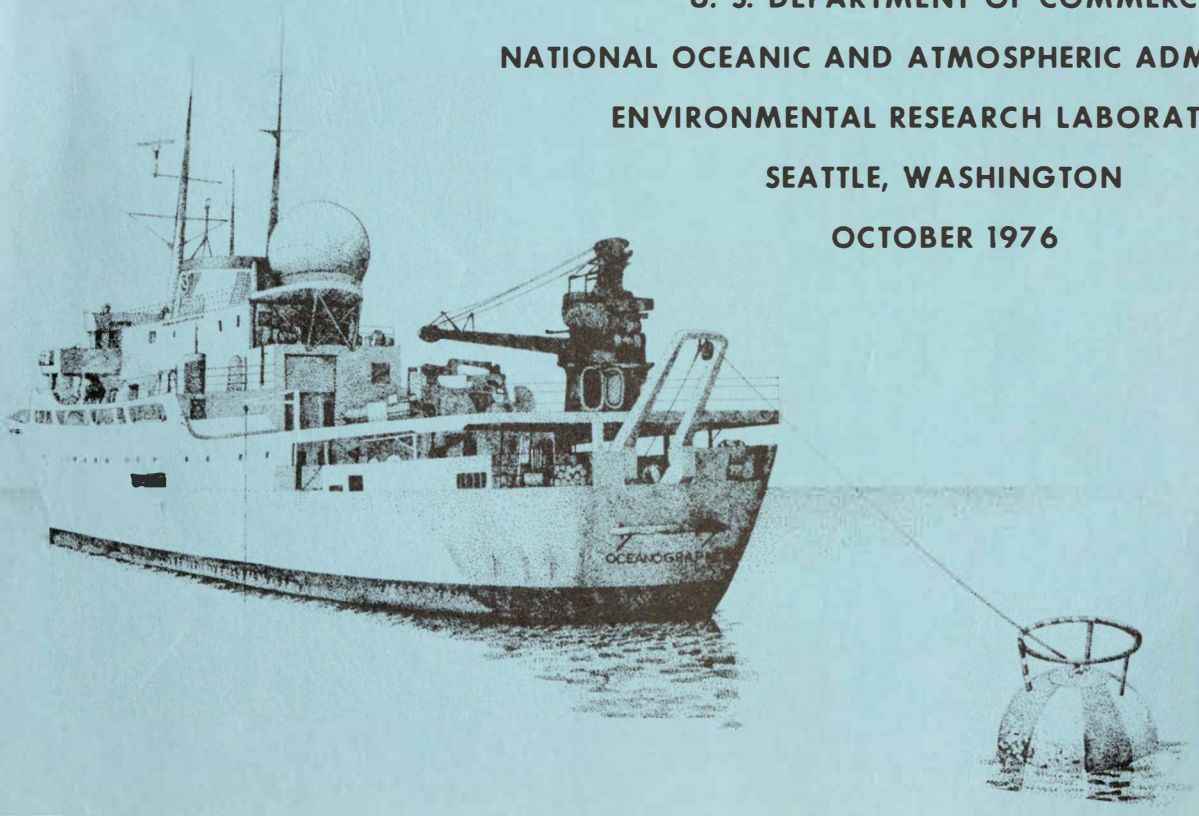

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PACIFIC MARINE ENVIRONMENTAL LABORATORY

John R. Apel, Director

I. MISSION AND ORGANIZATION

The Pacific Marine Environmental Laboratory (PMEL) is an interdisciplinary Federal research laboratory carrying out scientific investigations and surveys in the fields of oceanography, marine meteorology, and marine ecosystems studies. Its missions are to assist NOAA and other Federal agencies (1) by conducting basic research on oceans and atmospheres so as to provide increased understanding of Earth's fluid environment, and (2) by conducting applied research and environmental assessments so as to provide information and improved services on problems of national concern. To this end, the Laboratory maintains experimental, theoretical, and numerical modeling programs as follows:

1. It conducts investigations into tides, tsunamis, surface and internal waves and their effects upon the near-shore environment, and develops models for long and short wave behavior.

2. It investigates the nature of open-ocean, coastal, and estuarine circulation as driven by gravitational and atmospheric forces and topographic effects.

3. It conducts studies of global and regional climatic changes and the relationship such changes bear to variations in the transport of heat, momentum, and energy by the sea.

4. It studies the concentration, motion, dispersal, and fate of ice, sediments, oil, pollutants, chemicals, and other substances introduced into the oceans by man and nature.

5. It attempts to understand the short- and long-term effects of pollutants, sediments, and other natural and man-induced changes on marine ecosystems.

6. It carries out supporting programs that evolve and make use of new scientific instruments, technologies, and methodologies in such areas as *in situ* instrumentation, remote sensing techniques, computer science, modeling, and mathematical analysis.

In addition, the Pacific Marine Environmental Laboratory:

1. Transfers its scientific findings into technologically useful products and services for the Federal Government;

2. Manages and coordinates interdisciplinary programs and projects of national and regional relevance; and

3. Provides advisory consultative services in its areas of expertise to NOAA and other agencies.

Because of the interdisciplinary nature of its tasks, the Pacific Marine Environmental Laboratory is organized in two orthogonal ways, the first being the traditional discipline-oriented group characterized by a vertical staff structure. These groups are:

1. Coastal Ocean and Estuarine Research - COER

2. Environmental Remote Sensing Studies - ERSS

3. Joint Tsunami Research Effort - JTRE

4. Marine Life and Geochemical Studies - MARLAGS

5. Modeling and Simulation Studies - MASS

6. Ocean-Atmosphere Response Studies - OARS

The second method of organization is via tasks into horizontal projects and is necessitated by the across-discipline coordination requirements of an environmental assessment program. The current PMEL projects are:

1. Deep Ocean Mining Environmental Study - DOMES/PMEL

2. Outer Continental Shelf Assessment Program - OCSEAP/PMEL

3. Puget Sound MESA - MESA/PMEL

4. Seasat-A Studies - SAS/PMEL

5. Marine Services Research

6. North Pacific Experiment - NORPAX/PMEL

7. Long-Term Effects

Each project is headed by a Manager or Coordinator. In addition, administrative technical and plant support functions are administered from the office of the Director via:

8. Administration, Level III - ADM

9. Base Operations Support Services - BOSS

II. HIGHLIGHTS OF THE PMEL PROGRAM

During the 15 months of the 1976-76T fiscal year, the reorganization of PMEL, started in the previous year, was modified and solidified, as illustrated above. The appointment of the Laboratory's first permanent director, the establishment of clear scientific goals, the assignment of new resources, and the promise of a more permanent fiscal base to the organization have given it a sense of direction.

The sources of PMEL's funding are quite diverse and include a modest NOAA base, transfers from the Administrator's Trust Fund and ERL Director's reserve, plus funds from BLM, DOMES, MESA, EPA, GATE, NASA, Navy, DARPA, and NSF.

The largest single activity in the Laboratory has been the Outer Continental Shelf Environmental Assessment Program in Alaska, which accounted for approximately 28% of the total effort. Regional circulation, atmospheric forcing, plankton, hydrocarbons, and suspended particulates were studied in the waters adjacent to Alaska and their distributions and temporal behavior determined; both fieldwork and numerical modeling contributed to the understanding.

Next in size has been the Puget Sound MESA and EPA effort, which occupied approximately 13% of the total. Here again, circulation studies in the Sound and the Strait of Juan de Fuca illuminated the importance of tidal and atmospheric forcing in establishing the surprisingly rapid flushing rates for these bodies. Baseline data on planktonic distributions in the Strait are also being gathered.

Open-ocean investigations have proceeded largely under the aegis of the Deep Ocean Mining Environmental Study (DOMES). The Laboratory effort was both in the technical management of the program and in field studies in support of its objectives. Plans, proposals, and research led to the writing of a draft report on Phase I toward the end of the transition quarter, with a final report due in mid-year of 1977. PMEL experiments reported therein included measurements of particulate and planktonic distributions in the three potential mining sites, and determinations of near-surface and near-bottom circulation; surface wind and microstructure measurements also helped to elucidate the probable rate of the dredge spoil dispersal.

The tsunami research effort continued with a joint U.S.-U.S.S.R. generation experiment near the Kuril Islands and the emplacement of a large array of bottom pressure gauges and current meters in the equatorial Pacific. Theoretical and numerical studies of tsunami propagation and amplification also continued.

Occupying smaller fractions of the Laboratory effort were studies of coastal upwelling, internal waves, mixed layer dynamics, equatorial and Antarctic circulation, marine meteorology, tidal currents, and Gulf Stream dynamics.

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Several new programs were started during the reporting interval, the largest of which is an environmental remote sensing project. This effort will center on the use of Seasat and NOAA satellites in oceanography and marine meteorology and brings with it a sophisticated minicomputer system for handling images and graphical data. Other new activities include a marine services program conducted jointly with the National Weather Service, the modeling of ice dynamics on the Alaskan North Slope, a reprogramed effort in the role of the oceans in climate dynamics, and a significant numerical modeling activity that necessitated access to the large computer at the Geophysical Fluid Dynamics Laboratory.

Support operations enlarged to assist in the sizable increase in administrative workload, field operations, and plant maintenance functions. PMEL's three locations in Seattle--the Showboat Apartments on the University of Washington campus and the Tower Building and Building 32 at Sand Point--compound the administrative and plant support problems, which have been exacerbated by the Laboratory's rapid growth.

Awards and Publications

During the 15 months of the reporting period, two members of the PMEL scientific staff were notified of Department of Commerce awards. Dr. Gaylord Miller of JTRE received a Commerce Gold Medal for the establishment of that group and for his research in tsunamis. Dr. Jerry Galt of MASS received a Commerce Silver Medal for his efforts in understanding circulation in the Gulf of Alaska oil leasing sites. Three PMEL scientists received distinguished authorship awards for research into internal waves: Dr. John R. Apel, Mr. H. Michael Byrne, and Mr. Robert L. Charnell. Mr. Michael Grigsby was selected for the NOAA Science Intern Program for study in oceanography. Ms. Louise Johnson, Ms. Virginia I. Johnson, and Ms. Ruth A. Brown received ERL Woman of the Year awards.

The PMEL staff published 97 articles, papers, or sections of books during that interval; the publications are listed at the rear of this report.

III. ACCOMPLISHMENTS AND PLANS

The accomplishments of the eight groups comprising PMEL during the 15 months of June 1975 through September 1976 are summarized in the following section; their plans for Fiscal Year 1977 are also included.

A. COASTAL OCEAN AND ESTUARINE RESEARCH (COER)

Robert L. Charnell, Group Leader

Mission

The COER group carries out research projects designed to investigate and understand the physical bases for the oceanic processes of advection and dispersion in coastal and estuarine waters. Both field programs and theoretical research focus on understanding the physical processes that drive circulation and control redistribution of natural and man-made substances. The program includes meteorological studies that relate atmospheric effects to coastal and estuarine circulation and studies of the offshore oceanographic regime which provide better understanding of appropriate boundary conditions for coastal waters.

The COER group is carrying out research in coastal and estuarine waters of the Pacific Northwest and Alaska on synoptic and subsynoptic scales.

Accomplishments, FY-76

In the Puget Sound MESA program, emphasis has been on characterizing and understanding advective and diffusive processes in the central basin. Observations of currents and water properties at several levels continued near Seattle's major sewer outfall, and a 2-month summer experiment was carried out to evaluate cross-channel variations. Data from winter 1973 showed that deep water cools via fortnightly step decreases of temperature and is quickly replaced by less dense water at about 2-week intervals, a process that depends upon the magnitude of the tide at the entrance sill.

In the Strait of Juan de Fuca, an interdisciplinary investigation of petroleum redistribution and its biological implications was initiated jointly with the OARS and MARLAGS groups. Flow and water properties were monitored across a section at the junction of the eastern and western Strait.

Analysis of earlier data from the Strait of Georgia resulted in a clearer picture of regional circulation north of the San Juan Islands. The circulation is dominated by outward flow along the western edge and inward flow along the eastern side of the Strait (fig. 1). Wind events which modulate the western regime result in major perturbations in the eastern regime.

COER continued its efforts in the Gulf of Alaska and Bristol Bay and initiated a new program in the northern Bering and Chukchi Seas; their objectives are to define the regional circulation and understand the driving mechanisms. These programs are conducted jointly with the

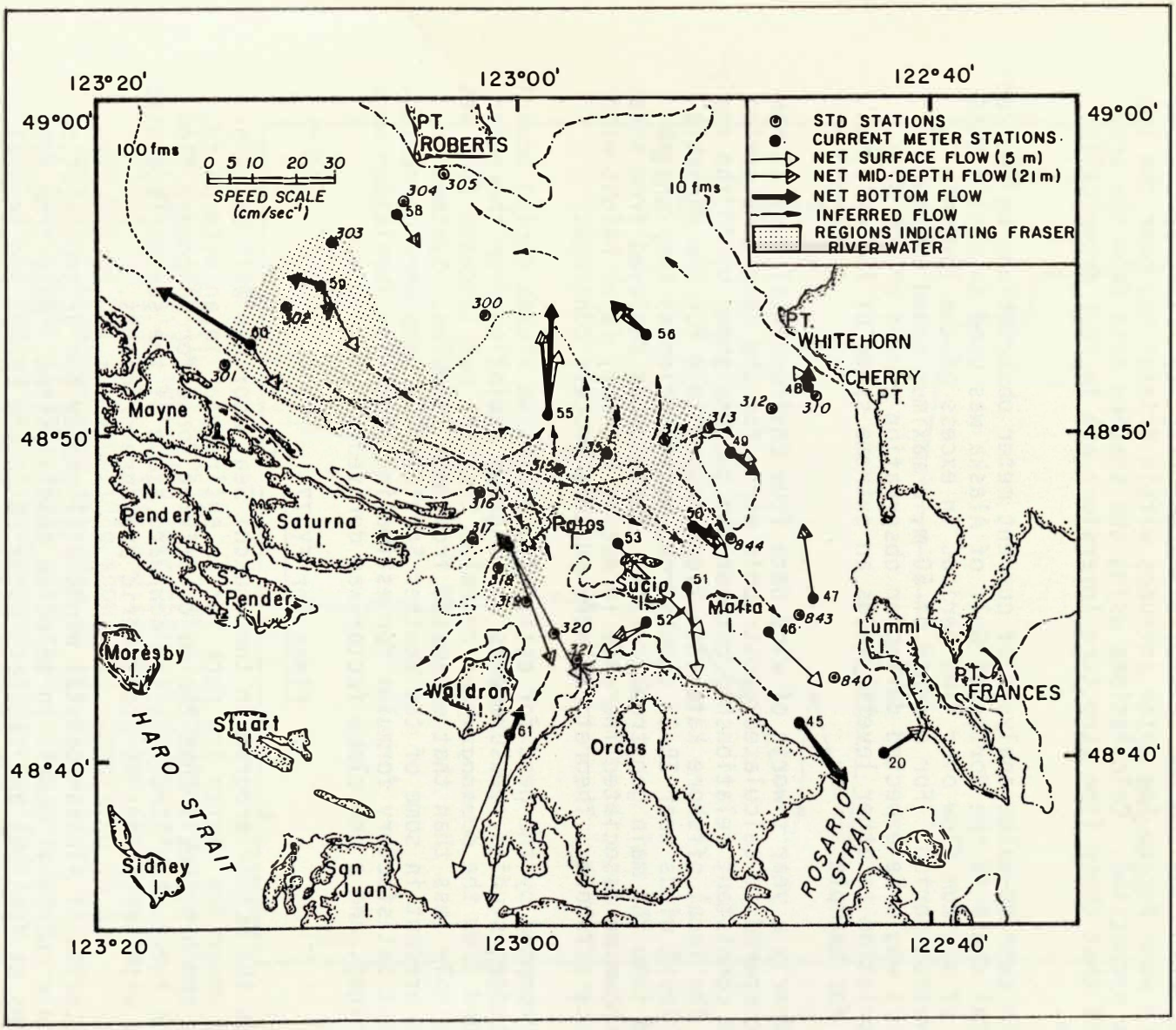

Figure 1. Net circulation in the southern Strait of Georgia as determined from CTD and current meter measurements (February-April 1975).

Universities of Washington and Alaska and other groups at PMEL. Over 50 current meter and 400 CTD stations were occupied on seven cruises. A 100-km subsurface layer with density inversions of order 55 x 10^6 m^{-1} was observed during March 1976 in the zone of interaction between waters of the Bering Sea and the Bristol Bay shelf (fig. 2). The layer appears to form when Bering Sea water intrudes within Bristol Bay near the top of the pycnocline. Calculations using the station data from the area suggest that these fine structure inversions are in fact dynamically stable.

An extreme-value analysis of current meter observations on the continental shelf in the Northeast Gulf of Alaska was used to obtain estimates of maximum flow over time periods in excess of the 15-month observation period. For a depth of 50 m, a maximum speed of about 112 cm/s would be expected during an observation period of 500 days. Extrapolation to other levels yields an extreme speed of 155 cm/s at 10 m, for example.

Nearly a year's worth of wind data from Environmental Buoy 33 has been compared to calculated geostrophic winds for the same time period and no consistent relationship between the two has shown up in the analysis. The local offshore katabatic flows responsible for the variable lower level winds near EB-33 show strong modification as they are absorbed into the main geostrophic flow. Radiosondes deployed from ships have shown an associated increase in marine boundary layer height with distance offshore. Theoretical work on this process continues.

Prompted by the need for estimating radiative fluxes during oceanic heat budget studies, measurements of longwave radiation from the ocean obtained from the *Oceanographer* revealed that the net longwave flux was appreciably less than that estimated from most formulas. Systematic errors present in some of the Weather Service flux data were corrected, the most satisfactory formulas for estimating clear-sky insolation were determined, and a new cloud factor was derived.

Plans for FY-77

In the OCSEAP program in the Chukchi Sea, moorings will be maintained under the winter ice pack for an entire year in an attempt to verify the hypothesis that the major driving force for northward flow through the Bering Strait is the downward slope of the sea surface associated with variations in atmospheric pressure gradients.

Studies of Alaskan coastal winds will employ one or two existing mesoscale numerical models in selected coastal sites. Data from NWS stations at Yakataga and Yakutat, buoys EB-33 and EB-03, and several remote land stations will be employed to verify model output. A 2-week winter field experiment in the same area will be conducted to study the strong drainage winds which flow out from Icy and Yakutat Bays. An

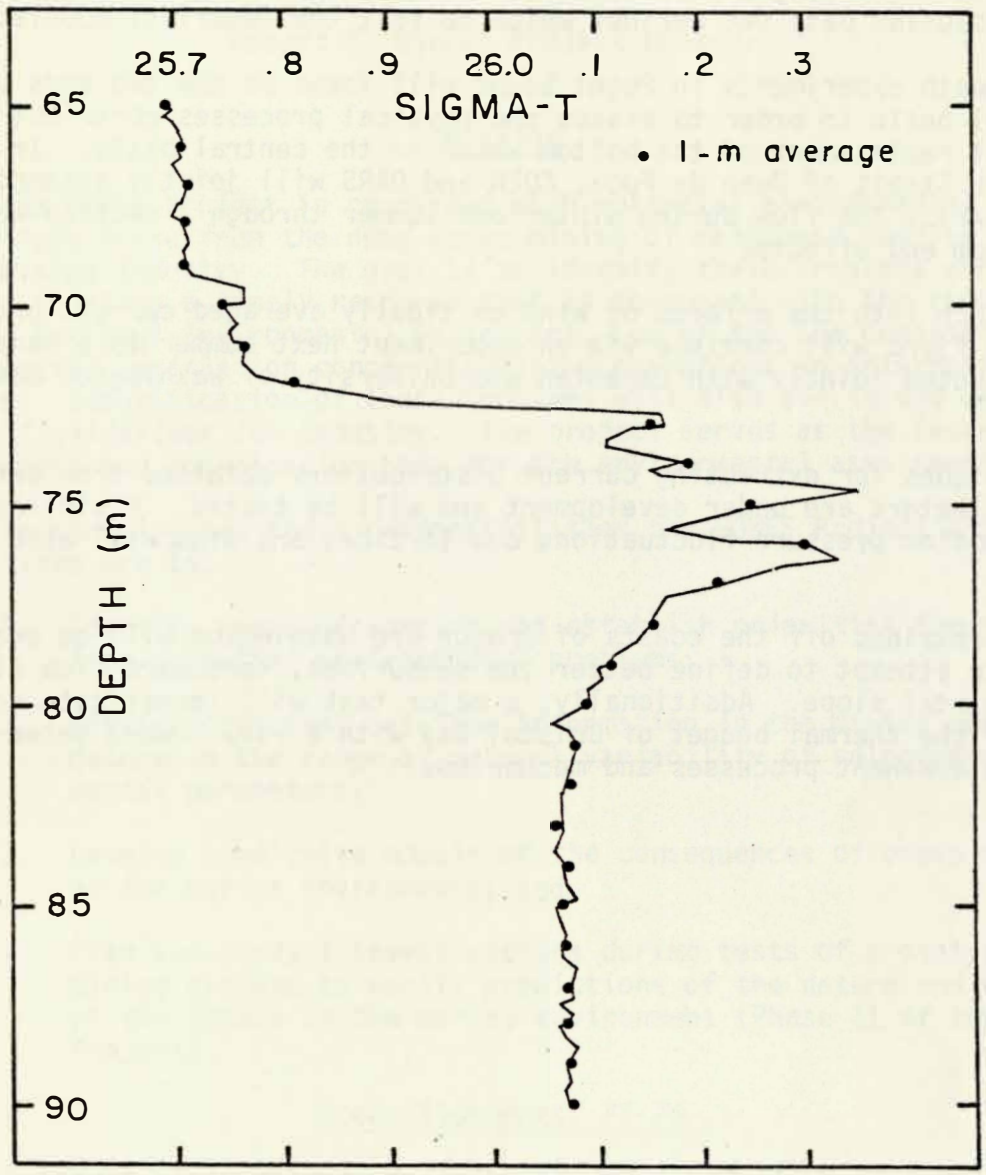

Figure 2. Profile of density (sigma-t) showing probably the largest density inversion ever observed under natural conditions in the ocean. This and several other stations in the Bering Sea in March 1976 show what appears to be a transient phenomenon at the edge of the winter ice. Prior to these observations, north winds had pushed the ice farther south than previously observed; this resulted in a circulation that induced landward flow in the thermocline.

instrumented fixed-wing aircraft and a NOAA ship will be used to obtain a high resolution data set against which to test the numerical models.

One-month experiments in Puget Sound will focus on the two ends of the central basin in order to assess the physical processes contributing to the fast replacement of the bottom water in the central basin. In the western Strait of Juan de Fuca, COER and OARS will jointly attempt to characterize the flow during winter and summer through a section well-removed from end effects.

Research into the effects of wind on tidally averaged current profiles in a fjord will continue via an experiment next summer in a Canadian fjord conducted jointly with Canadian and University of Washington oceanographers.

Techniques for extracting current distributions obtained from arrays of current meters are under development and will be tested. A similar study of bottom pressure fluctuations due to tides and wind will also be continued.

Data obtained off the coasts of Oregon and Washington will be analyzed in an attempt to define better the subsurface, northward flow along the continental slope. Additionally, a major task will investigate some aspects of the thermal budget of Bristol Bay with a view toward determining the dominant processes and mechanisms.

B. DEEP OCEAN MINING ENVIRONMENTAL STUDY (DOMES)

Robert E. Burns, Project Manager

Mission

The DOMES Project is concerned with potential environmental problems that might arise from the deep-ocean mining of manganese nodules by the U.S. mining industry. The goal is to identify these problems early enough to allow a timely response that is consonant with the requirements of the National Environmental Policy Act, Law of the Sea negotiations, or domestic legislation concerning mining operations in international waters. Identification of these problems will also aid in the development of guidelines for industry. The project serves as the technical management and coordination body for the environmental assessment activity.

In carrying out these responsibilities the DOMES Project's basic objectives are to:

1. Identify areas of concern and establish priorities for research into potential environmental problems;

2. Obtain sufficient baseline information in the mining region to determine the range of natural variability of selected environmental parameters;

3. Develop predictive models of the consequences of ocean mining on the marine environment; and

4. Plan and conduct investigations during tests of prototype mining systems to verify predictions of the nature and extent of the impact on the marine environment (Phase II of the DOMES Project).

Accomplishments, FY-76

Although some related research was conducted in FY-74 and FY-75, the project began officially in FY-76. The planning and conduct of the project was reviewed periodically by the Deep Ocean Mining Environmental Study Advisory Panel, a subcommittee of the Department of Commerce Marine Petroleum and Minerals Advisory Committee. Meetings were held with the panel in December 1975 and in February and June 1976 to review ongoing research, predictive models, reporting formats, and plans for investigations during testing of prototype mining systems (Phase II of the DOMES Project).

Principal investigators and their staffs were selected in late FY-75 and early FY-76 from several universities and from research groups within

PMEL to form a multidisciplinary team to conduct investigations into the baseline conditions and ranges of natural variability.

Additional investigators were chosen to review existing information on fishes and the smothering of deep-sea benthic communities by natural disasters, and to provide a comprehensive literature search for relevant oceanographic information.

Integrated multidisciplinary investigations were conducted from the NOAA ship *Oceanographer* in August-October 1975 and February-March 1976 to obtain information on the distribution and interrelationships of the various parameters and their seasonal variations in the upper water column. Observations were made concerning phytoplankton and primary productivity, temporal and spatial variations of zooplankton, nutrient chemistry, distribution and composition of suspended particulate matter, and structure and movement of the surface waters.

Field operations from March to May focused on lower water column investigations: water chemistry, suspended particulate sampling, zooplankton sampling, and recovery of bottom arrays for the IDOE Manganese Nodule Project.

Proposals for a literature survey were received in response to requests. They were reviewed and final selection of one proposal was made in April 1976.

Field operations from the *Oceanographer* resumed between July and September and were concentrated on near-bottom circulation studies and benthic organism sampling using baited traps.

A draft Preliminary Report on Phase I of DOMES was completed by the DOMES staff in August 1976; this report included estimates of the effects of mining operations on the biology of the DOMES area.

Plans for FY-77

The Phase I DOMES fieldwork on baseline environmental assessment will be completed in November 1976. This will allow principal investigators to complete final reports by June 1977.

Comments generated by circulation of the Phase I Preliminary Report will be reviewed as work begins on the Final Report of Phase I, to be published in early 1978.

As proposed in the Phase II Draft Project Development Plan, the first field operations will begin sometime near the middle of FY-77 and will be centered on real-time measurements of the nature and fate of the perturbations to the environments resulting from test mining activities.

C. ENVIRONMENTAL REMOTE SENSING STUDIES (ERSS)

John R. Apel, Acting Group Leader

Mission

Environmental Remote Sensing Studies (ERSS) conducts research into such aspects of the ocean and atmospheric boundary layers as may be carried out using techniques of remote or indirect sensing of environmental parameters in combination with classical *in situ* measurements. To this end, the group provides a center of expertise in the remote sensing disciplines; it works jointly with other PMEL groups in field investigations and develops new techniques for indirect measurement of environmental parameters.

1. ERSS conducts evaluations and assessments of new remote sensing instruments such as are carried on the Seasat, Nimbus, and Tiros satellites, and it uses the data in studying geophysical processes.

2. It uses visible and infrared systems on spacecraft to determine the distributions of surface temperatures, chlorophyll, sediments, and surface and internal waves; it relates these to surface observations and attempts to deduce the role of various physical processes in establishing the phenomena at hand.

3. It uses active and passive microwave systems on spacecraft for measurements of the marine geoid, geostrophic currents, surface winds, and wave spectra, and synthesizes these measurements into global fields.

Accomplishments, FY-76

The ERSS group was formed at PMEL and various equipment was transferred from the Atlantic Oceanographic and Meteorological Laboratories and installed at the Laboratory.

A major seagoing experiment, IMIGE, was executed on the continental shelf break south of Block Island, New York, to determine the relationship between tidal forcing and generation of internal waves near the shelf. Such waves had been studied earlier using spacecraft imagery, acoustic echo sounders, and thermistors (fig. 3).

The first phase of the Laboratory for Image Analysis and Research (LIAR) was completed and was successfully producing digitally enhanced satellite images for various users including PMEL, AOML, the Naval Undersea Center, and the Department of Meteorology at M.I.T.

Considerable guidance and consultation was provided to NASA on its Seasat-A program through two instrument team specialists. ERSS members were also instrumental in shaping the NOAA Seasat Program Development Plan.

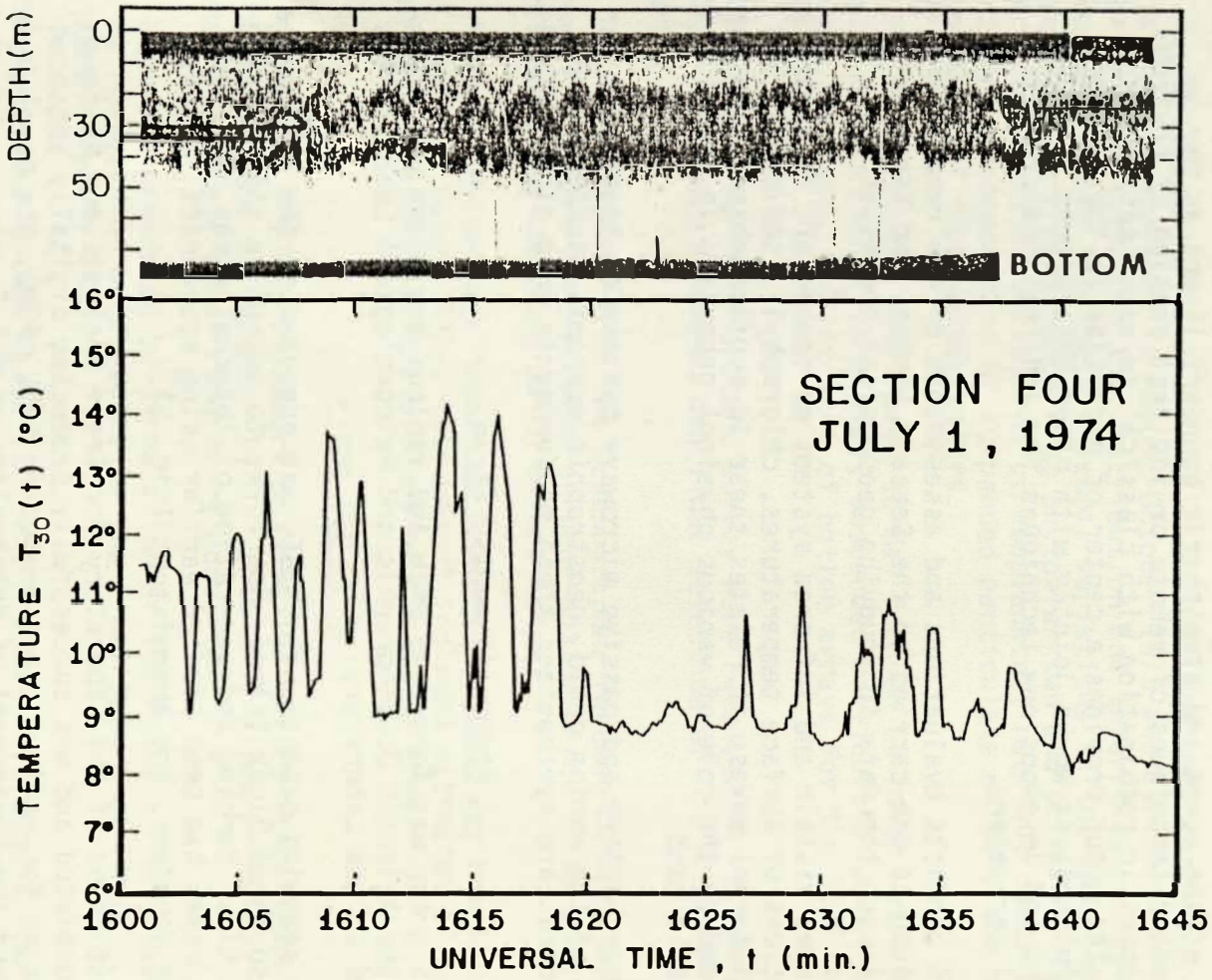

Figure 3. (Upper) Acoustic echo-sounder trace of internal waves on the continental shelf, showing oscillations having amplitudes of about 8 m and wavelengths of approximately 500 m. (Lower) Temperature oscillations at 30-m depth made simultaneously with the acoustic trace.

An atlas of internal wave observations from the Landsat spacecraft was assembled and published. The atlas summarizes data on internal waves off the North American northeast coast during the summers of 1972-74 (fig. 4).

Plans for FY-77

The internal wave work will analyze the results of the IMIGE cruise and concentrate on understanding the physical processes of generation and energy transfer from tidal to internal wave frequencies and non-linear mechanisms. Analysis of spacecraft data will be continued and the scope of the project broadened to include aircraft side-looking radar images of internal waves.

Analysis of GEOS-3 data for information on wave height and spectra and sea surface topography will be completed. The resulting data reduction techniques and algorithms will form an important input into the Seasat-A program. Wave heights, spectra, temperature, and sea surface topography will receive major attention.

The LIAR, now complete through Phase I and currently supporting most of the satellite efforts of ERSS, will be completed through Phase II by the addition of scene-handling and two-dimensional fast Fourier transform capabilities. The LIAR will be the major ERL resource for processing Seasat-A Synthetic Aperture Radar data, and will operate in a production mode supporting all PMEL research that requires manipulation of spacecraft data.

A concerted effort, carried out jointly with the National Environmental Satellite Service, will begin in the development of a global sea surface temperature data set. This data set will be used to analyze relationships between upper ocean temperatures and short-term climatological events in the central and northern Pacific. An atlas of sea surface temperatures will be developed which will incorporate data from the Seasat, NOAA, GOES, and DMSP spacecraft. Validation and calibration of the temperature fields will be accomplished by comparison of the satellite data to selected *in situ* measurements from NORPAX investigations, XBT files and oceanographic cruises.

Consultation of and guidance to the NASA and NOAA Seasat programs will increase as the efforts of the experiment teams become better defined.

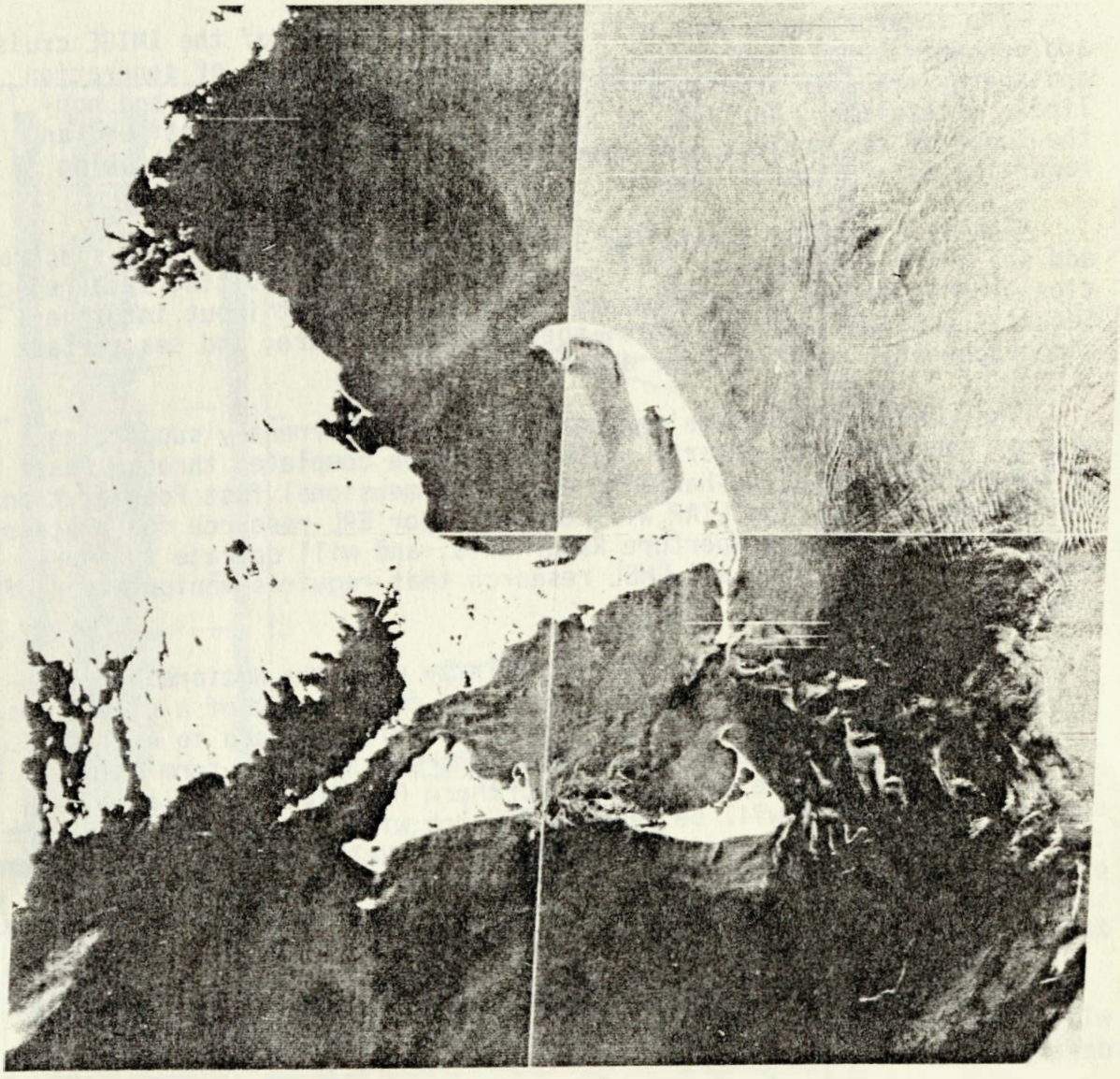

Figure 4. Landsat-1 image enhanced by digital techniques, showing large internal waves east of Cape Cod, Massachusetts.

D. JOINT TSUNAMI RESEARCH EFFORT (JTRE)

Gaylord R. Miller, Director

Mission

The Joint Tsunami Research Effort is a cooperative effort between the National Oceanic and Atmospheric Administration and the University of Hawaii. It is the Hawaiian component of PMEL and the principal unit of the Federal Government for conducting tsunami research. Two major objectives of JTRE are to improve the Tsunami Warning System and to establish the techniques for determining tsunami hazards to coastal areas. In achieving these objectives JTRE: (1) conducts basic and applied research in tsunami generation, propagation, and terminal effects; (2) furnishes advisory and consultative services to industry and to other government and nongovernment organizations; and (3) performs scientific liaison with other countries exposed to tsunami hazards in order to advance and disseminate knowledge in this field.

Accomplishments, FY-76

The staff of JTRE has traditionally emphasized research in hydrodynamics and numerical fluid dynamics of tsunamis. This work has continued and specific research topics have included: (1) finite height solitary waves and other nonlinear processes related to tsunamis; and (2) the development of a numerical Green's function computational scheme, which permits one to do a single computation for all possible source regions and runup regions. The results of this can be combined into a tsunami simulation, given the net ground deformation in the generation region. Documentation of all of the tsunami runup heights in the Hawaiian Islands was completed and an extensive survey of the wave effects of the earthquake of November 29, 1975, was made.

A cooperative experiment was conducted between the U.S. and the U.S.S.R. in which pressure-measuring devices were installed at the sea floor off the Hokkaido and southern Kuril regions. The wave recorders were placed in an array that extended from relatively near shore in a few hundred meters' water depth out past the trench to depths of almost 6 km. The intent of the experiment was to measure a tsunami in deep water and to study the transformations which occur as it approaches the shoreline. Unfortunately no tsunami occurred during the 40-day duration of the experiment; however, papers have been written on the tsunami directional wave spectrum, on the tides, on meteorologically induced pressure fluctuations at the sea floor, and on the seismic velocity anomalies in the region. In addition, an extensive cruise report has been published. The result of this study is that in the tsunami frequency band the main energy in the Kuril-Hokkaido region is in the form of a southwest-propagating edge wave. The tides diminish very slightly

as one goes offshore and a new set of regional cotidal charts have been derived from the data obtained. The bottom pressure fluctuations due to the passage of a typhoon over the measurement area are not what one would expect for a largely compensated inverted barometer but rather show the importance of dynamic effects, in agreement with work conducted during MODE. There is a high seismic velocity area going down the dip of the subducting plate. In connection with a cooperative program with the U.S.S.R., visitors from Novosibirsk and Sakhalin were present at JTRE for approximately half the year.

Theoretical studies were conducted on large-scale water motion in various semi-enclosed bodies of water off the coast of Alaska, and a new technique was developed for modeling large-scale water motions. A computer model of the Tsunami Warning System was developed and is in the process of being verified and documented. Operation of the electric field measurement system at the Honolulu Observatory continues and analyses of the large-scale water motions from these data were made. Modifications and the refurbishment of eight deep ocean tsunami/tide gauges and four current meters were made, and a large array experiment is currently being conducted at the equator at longitude 155°. Work on the mass transport velocity for cotidal waves was completed along with the mass transport velocity within the bottom boundary layer.

Overall the instrumentation and field measurement of JTRE was rather greatly expanded as compared to previous years (fig. 5). The theoretical and numerical hydrodynamics efforts were not diminished owing in part to the presence of two post-doctoral fellows.

Plans for FY-77

The general research level on analytic nonlinear hydrodynamics will continue, and application of the numerical Green's function computational technique will be made in an attempt to model specific past tsunamis. The study of the relative susceptibility of the various coastlines of Hawaii to tsunamis will be completed. In this study, input waves of a variety of frequencies and directions are made into a computational model from which a directional amplitude response function is derived. A detailed numerical simulation of the tsunami that occurred on November 29, 1975, will be attempted, in which all of the current state-of-the-art computational techniques will be applied.

Final analysis and publication of the papers derived from the U.S.S.R.-U.S. cooperative experiment should be completed. The analysis of the data from the August-September 1976 equatorial experiment, in which an array of eight tsunami/tide gauges has been deployed, should be completed and prepared for publication. The construction of a mid-ocean tsunami reporting system should be completed. In that system, pressure recording from the bottom will be transmitted to the surface acoustically and thence via stationary satellite to the ground station. This will provide real-time tsunami data from mid-ocean.

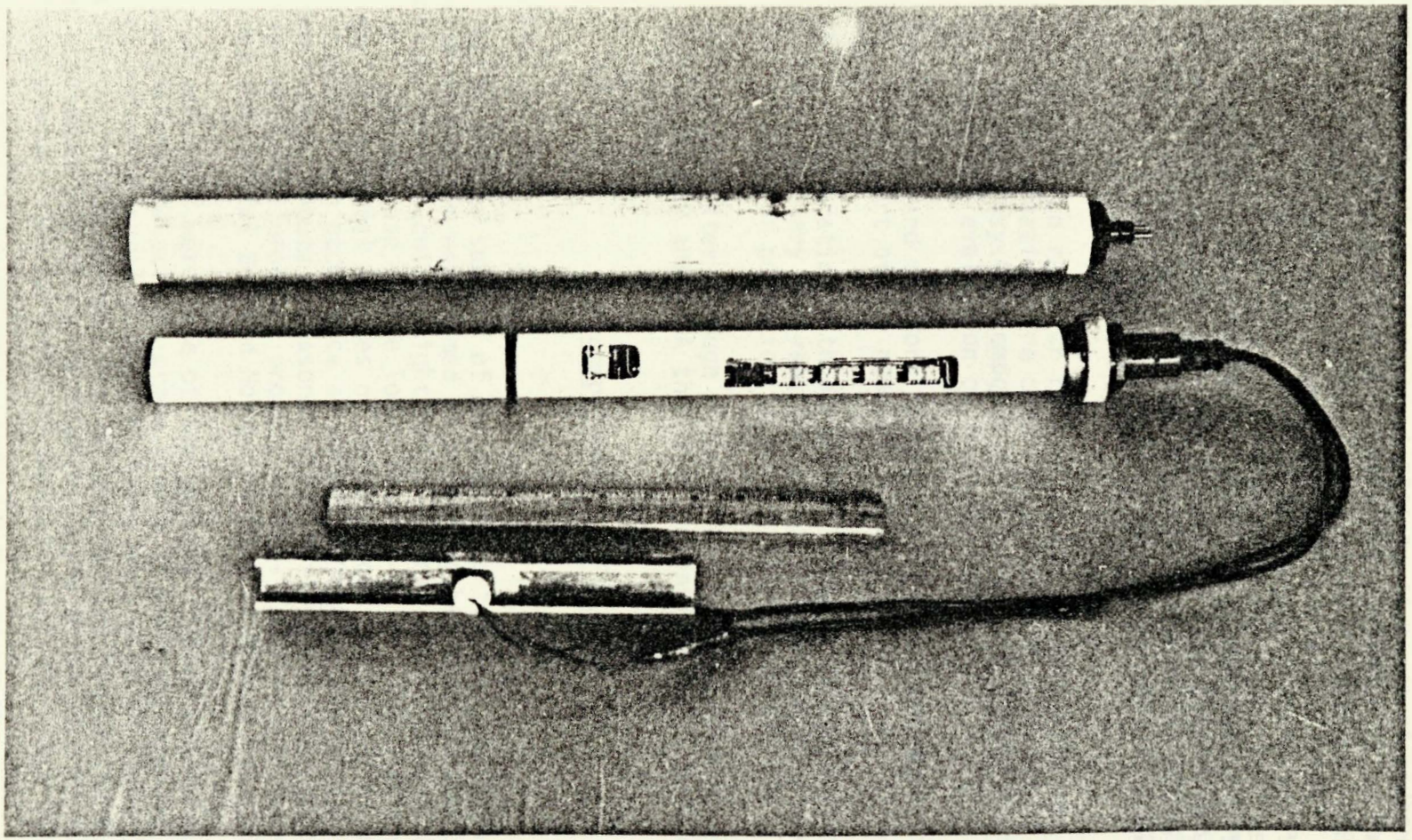

Figure 5. Deep-ocean timed release. From top to bottom are shown the release assembly mounted in its pressure case, the internal electronics package, and the explosive bolt release mechanism.

A cooperative observation program between the U.S.S.R. and U.S. will again be undertaken in the fall of 1977 in the Hokkaido-Kuril region. It will be similar in general plan to the experiment conducted during the fall of 1975; however, the time during which the instrumentation will be on the sea floor will be greatly increased. This will enhance the possibility of measuring a tsunami in the deep ocean. Work will be initiated on a new finite-element computational scheme for tsunami problems, and a start of a three-dimensional time-dependent marker-and-cell nonlinear hydrodynamic code will be initiated. This code will be suited to tsunamis wherein the length-to-height scale is very large. The consulting functions of JTRE will continue as in the past.

E. MARINE LIFE AND GEOCHEMICAL SYSTEMS (MARLAGS)

Jerry D. Larrance, Group Leader

Mission

The MARLAGS Group conducts basic and applied research in marine biological, chemical, and geochemical processes. The major purpose of these investigations is to determine short- and long-term effects of pollutants and other natural and man-induced changes on marine ecosystems. In fulfilling its responsibilities, MARLAGS:

1. Focuses on research related to marine environmental problems; (Investigations are concentrated on the transfer of contaminants among ecosystem components including the identification of pathways and evaluation of transfer rates.)

2. Surveys and monitors specific pollutants and ecosystem components in support of the research efforts;

3. In cooperation with other PMEL components, contributes to interdisciplinary analyses and prediction of the short- and long-term effects of pollution in oceans and estuaries; and

4. Participates through research and consultation in programs such as OCSEAP and MESA that address environmental problems of national concern.

Accomplishments, FY-76

Alaska

Activities in support of the Outer Continental Shelf Environmental Assessment Program were aimed at providing baseline information on zooplankton, low-molecular-weight hydrocarbons, and suspended particulate matter. The purpose of the low-molecular-weight hydrocarbon program is to identify regional sources of hydrocarbons (petroleum or biogenic) and to document their occurrence as potential indicators of petroleum seeps or man-induced inputs. Seasonal distributions for the components methane, ethane, ethylene, propane, propylene, iso- and n-butane have been described for Bristol Bay and Northeast Gulf of Alaska (fig. 6).

Observations were made of the autumnal distributions of zooplankton, phytoplankton, and primary productivity in the northeastern Gulf of Alaska and of seasonal changes of these variables in Lower Cook Inlet and Prince William Sound. Preliminary examination of the data indicates that suspended terrigenous particles play a major role in suppressing primary productivity in areas of copious river discharge (fig. 7).

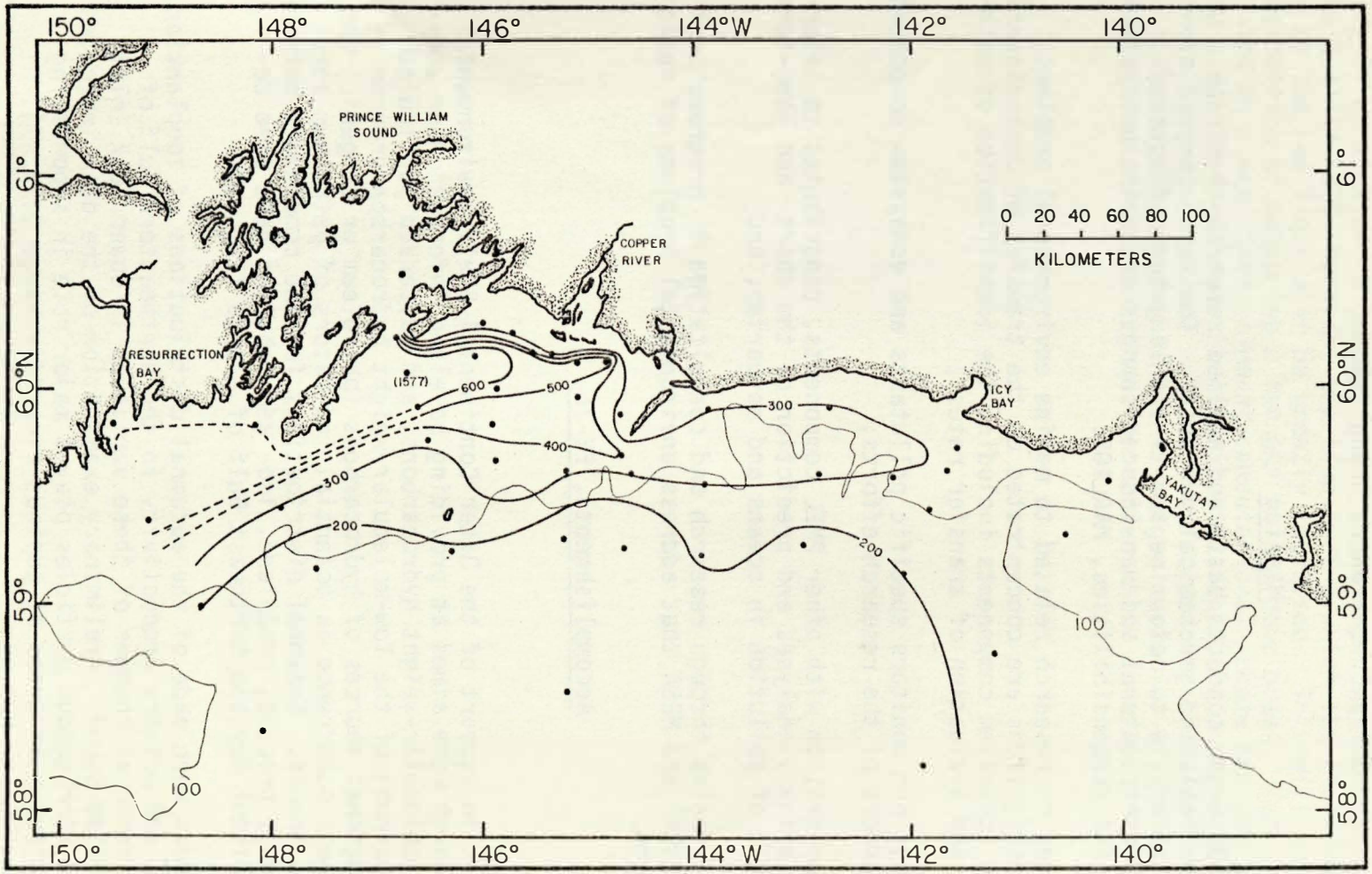

Figure 6. Distribution of nearbottom methane (in nℓ/ℓ) in the northern Gulf of Alaska in autumn 1975. The relatively high concentrations of methane observed with concomitantly low concentrations of ethane and propane (not shown) indicates the origin of the methane is biogenic. From these and subsequent measurements, the shape of the methane plume south of Prince William Sound suggests a weak nearbottom eastward flow.

PACIFIC SUBARCTIC REGION FOOD CHAIN

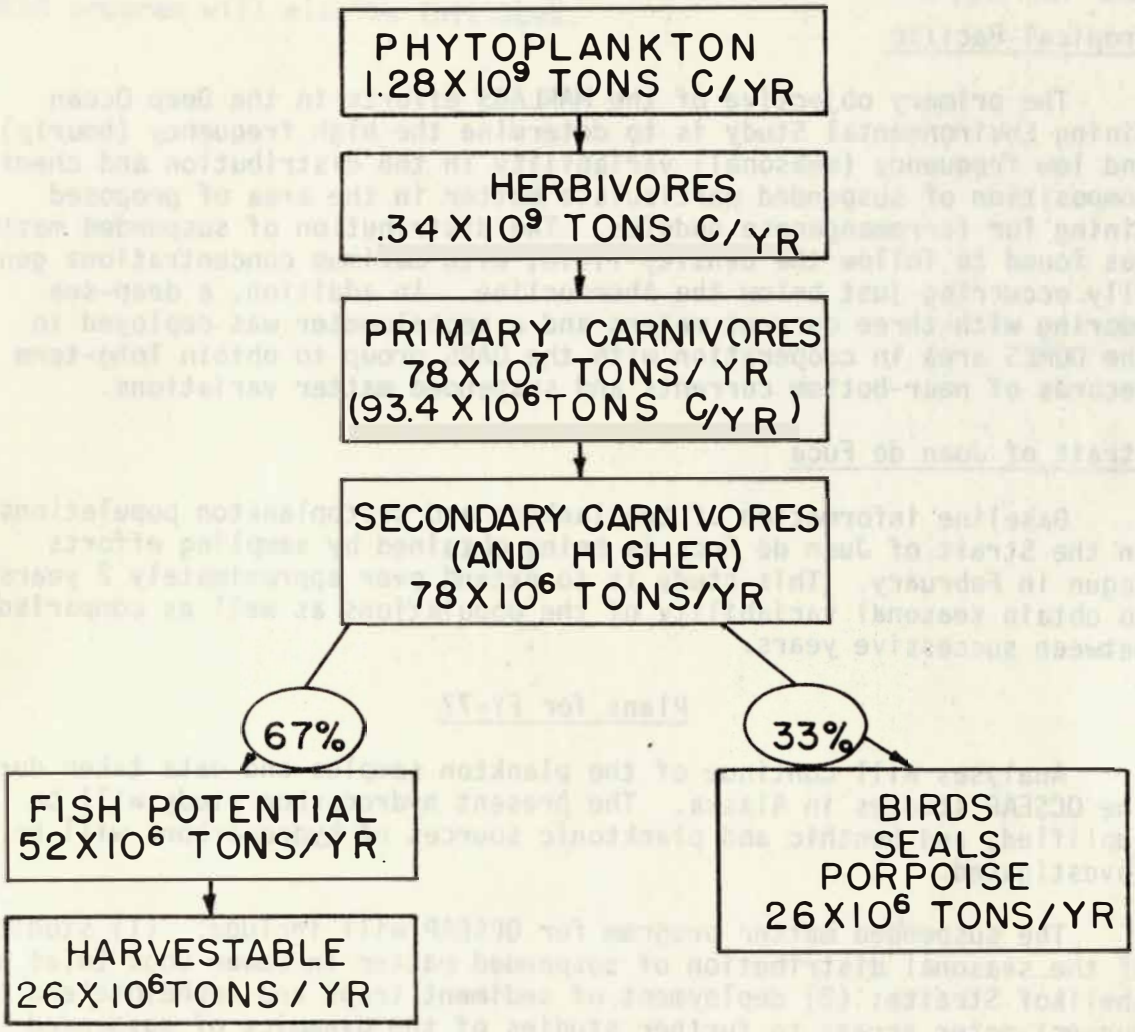

Figure 7. 1972 estimates of production of several trophic levels in the Pacific subarctic region. PMEL plans for investigating long-term ecological effects of man's activities, such as pollution, include considerations of qualitative and quantitative changes to generalized food chains similar to the one depicted.

Seasonal patterns of the distribution and composition of suspended particulate matter in the Gulf of Alaska and Southeastern Bering Sea shelf were determined. Simultaneous records were obtained of currents and suspended matter over several months by instrumentation deployed at the bottom near the edge of the continental shelf in the Gulf of Alaska. Preliminary analysis of the data affirms the hypothesis that tides and storms are major agents for the resuspension and redistribution of sediments in that area.

Tropical Pacific

The primary objective of the MARLAGS efforts in the Deep Ocean Mining Environmental Study is to determine the high frequency (hourly) and low frequency (seasonal) variability in the distribution and chemical composition of suspended particulate matter in the area of proposed mining for ferromanganese nodules. The distribution of suspended matter was found to follow the density field, with maximum concentrations generally occurring just below the thermocline. In addition, a deep-sea mooring with three current meters and a nephelometer was deployed in the DOMES area in cooperation with the OARS group to obtain long-term records of near-bottom currents and suspended matter variations.

Strait of Juan de Fuca

Baseline information of zooplankton and phytoplankton populations in the Strait of Juan de Fuca is being obtained by sampling efforts begun in February. This study is to extend over approximately 2 years to obtain seasonal variability of the populations as well as comparisons between successive years.

Plans for FY-77

Analyses will continue of the plankton samples and data taken during the OCSEAP studies in Alaska. The present hydrocarbon study will be amplified, and benthic and planktonic sources of hydrocarbons will be investigated.

The suspended matter program for OCSEAP will include: (1) studies of the seasonal distribution of suspended matter in Lower Cook Inlet and Shelikof Straits; (2) deployment of sediment traps and nephelometers on current meter arrays to further studies of the dynamics of suspended matter transport in the Northeast Gulf of Alaska; (3) studies of the adsorption of petroleum hydrocarbons onto particles in suspension; and (4) continuation of the development of x-ray fluorescence techniques for the determination of the chemical composition of suspended matter.

Work will continue on the DOMES project, beginning with real-time monitoring of discharge plumes from prototype mining ships.

Field and laboratory efforts will continue on the plankton baseline in the Strait of Juan de Fuca, which should provide the first comprehensive information on seasonal plankton distributions in this important transition zone between Puget Sound and the open ocean. Work will commence in November on the distributions of adsorbed hydrocarbons on suspended matter in northern Puget Sound. These studies will be supplemented with laboratory investigations concerning the adsorption characteristics of riverine sediments. Seasonal surveys of the distribution of suspended solids in the Strait of Juan de Fuca and the Strait of Georgia for the MESA program will also be initiated.

F. MODELING AND SIMULATION STUDIES (MASS)

Jerry A. Galt, Group Leader

Mission

The Modeling And Simulation Studies group uses numerical modeling and analysis techniques to enhance the understanding of basic physical, biological and chemical processes within the ocean. This work is carried out using analytic or numerical formulations to represent simplified components of the marine environment. These formulations are used to explore alternate modeling conceptualizations, extend the usefulness of sparse observational data, and aid in the analysis and communication of research results.

Accomplishments, FY-76

Numerical modeling and analysis of regional dynamic processes was carried out in support of the OCSEAP and MESA projects. During this period a number of subsystem or component models have been developed or refined. A diagnostic flow model to interface with observed temperature and salinity fields and represent flow in coastal regions has been documented and used in local studies of the Northeast Gulf of Alaska and around Kodiak Island (fig. 8). These modeling results have been presented to BLM representatives for incorporation into OCS gas and oil development planning. The model programs have also been given to researchers at AOML who are extending the studies to the New York Bight region. A second model under development functions as an automated tidal prediction routine; preliminary testing is being done using local observational studies from the Puget Sound region. A series of regional surface wind models has been used to infer small-scale (5-10 km) wind patterns in coastal regions. These models are driven by larger scale synoptic fields and include parameterizations of orographic effects and the exchange of mass and heat with the planetary boundary layer. Other component algorithms have been developed for the stochastic analysis of wind and current meter data with the results cast in a format that can be directly put into more complex mass transport models. The design of an oil spill trajectory model (fig. 9) that synthesizes the results of all of the above models has been completed and a supporting minicomputer has been purchased for delivery in early FY-77. An additional model study of the general circulation of the Bering Sea has been initiated, concentrating on the elucidation of exchange processes between the shelf and deep basin regions.

Plans for FY-77

During the coming year, modeling and simulation studies will continue in many of the areas initiated during the previous year. Major emphasis will be concentrated on the oil trajectory, or surface pollutant transport model. All the regional models will be upgraded as necessary and

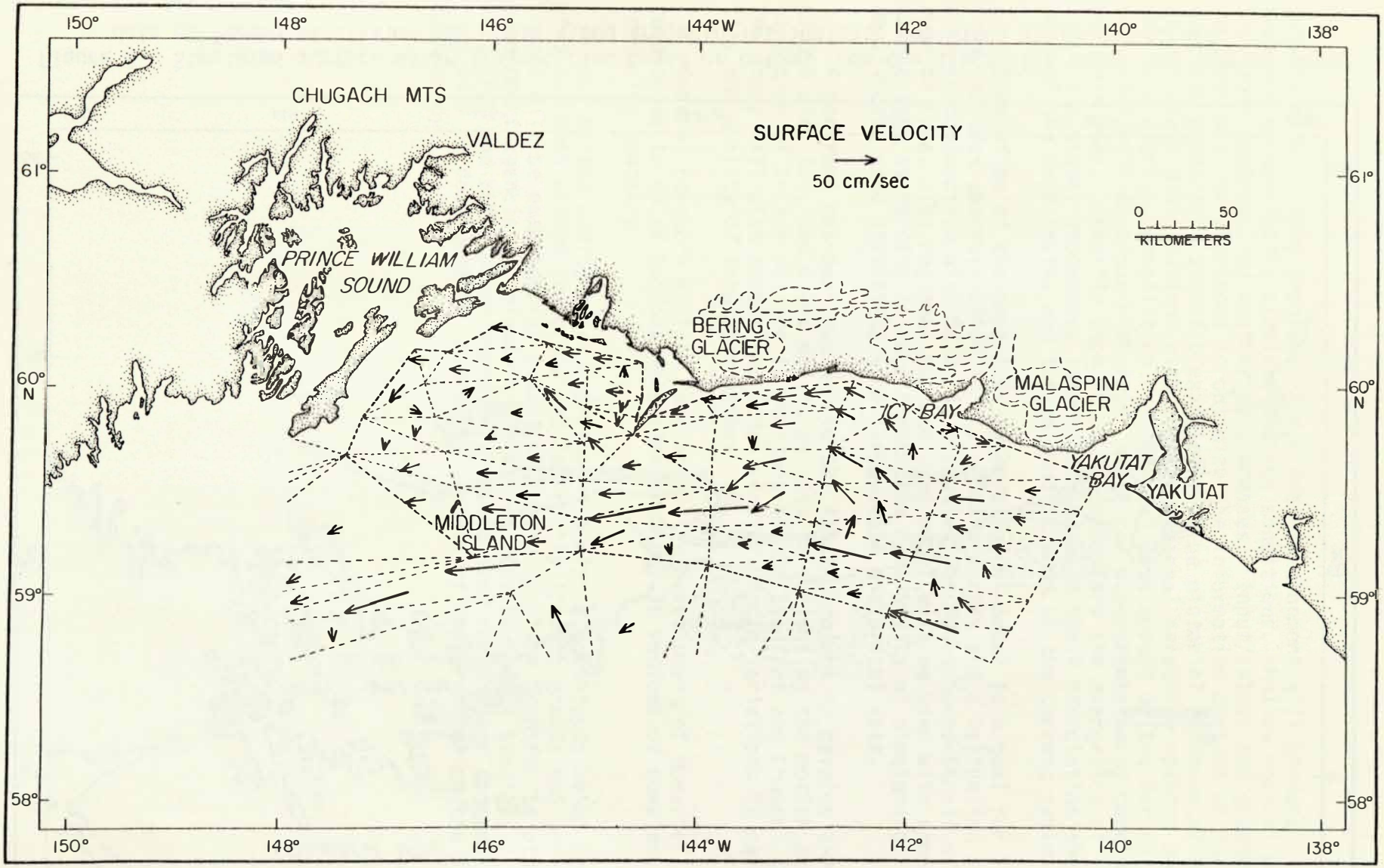

Figure 8. Surface currents predicted by the diagnostic circulation model for a study case run in the Gulf of Alaska.

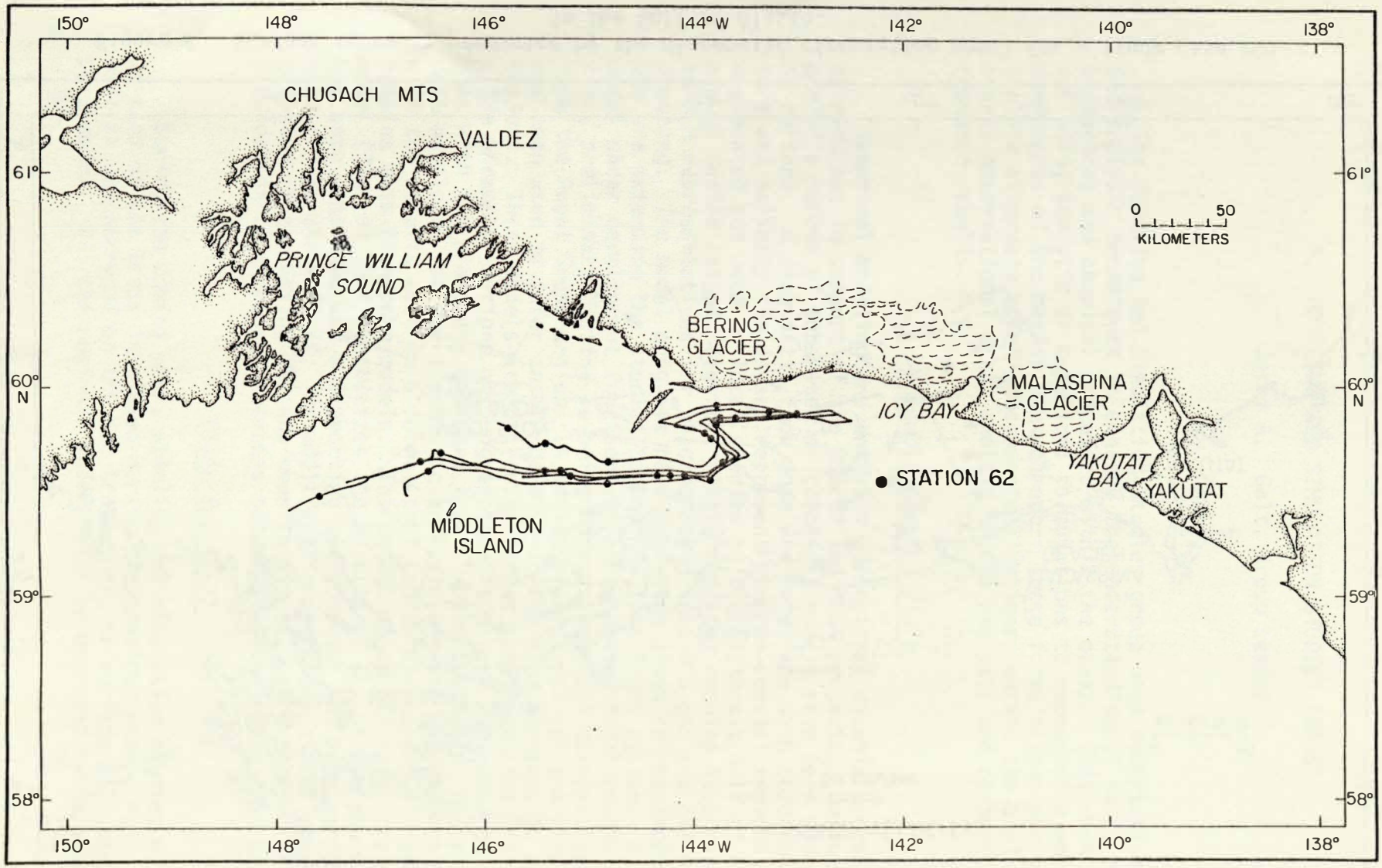

Figure 9. Simulated surface water trajectories based on output from the diagnostic model and current meter data collected at station 62. Dots along trajectories indicate positions at 1-wk intervals.

interfaced with this program. Additional development will produce branches to explicitly simulate sea ice conditions, shallow coastal or surf zone regions, and weathering processes. Input/output and graphics routines will be developed to optimize the information content of the modeling products. Specific examples will be pictorial representation of pollutant distributions with zoom or regional selection options and resource overlay capabilities. Additional development of the Bering Sea model will continue with major numerical experiments being carried out this year. Specific aspects of the study are the energetics of local and global processes, interaction between shelf circulation and that of the deep basin, and the seasonal change of the current system.

Completion of the mesoscale meteorological model is a goal for FY-77. This includes generalization of the model programs and a validation program in conjunction with MESA field studies for Puget Sound-Strait of Juan de Fuca. The regional surface wind model will be used with synoptic climatology as forcing to investigate the possibility of simulating small-scale wind statistics from large-scale historical data.

A contract has been awarded to the AIDJEX project to develop the AIDJEX air, ice, and ocean models as aids in estimating the motion and condition of Arctic sea ice in portions of the Beaufort and Chukchi Seas. The study will also assess the model sensitivity to variations in quantity and quality of input parameters.

General research will be carried out in development of numerical techniques to solve hydrodynamic flow problems in regions of complex, irregular geometry.

During the coming year, modeling or analysis techniques being carried out both within the group and indirectly through grants and contracts will be examined for potential application and transfer to other government agencies involved in operational environmental studies, e.g., NWS, EPA, and BLM. Where necessary, specialized routines or documentation will be developed to insure the success of the transfer of the technology.

G. OCEAN-ATMOSPHERE RESPONSE STUDIES (OARS)

David Halpern, Group Leader

Mission

The OARS group conducts research into the physical oceanic processes which result from variable atmospheric forcing. The group designs and implements experimental and theoretical studies whose primary objectives are the description and parameterization of the processes which contribute to the momentum and heat exchange between the coupled ocean-atmosphere system. In carrying out its research, the OARS group:

1. Studies upper ocean physical processes in regimes dominated by atmospheric scale forcing;

2. Develops and utilizes state-of-the-art technology for the measurement of a variety of physical parameters including upper ocean and near-surface velocity, pressure, temperature, conductivity, microstructure, and oceanic winds; and

3. Furnishes advisory and consultative services to government and nongovernment organizations on upper ocean circulation in relation to climate, pollution, and other environmental problems.

Accomplishments, FY-76

The OARS contribution to the Deep Ocean Mining Study concentrates on the upper 300 m and the bottom 50 m of the water column. Using moored arrays and shipboard profiling instruments, the velocity field, its temporal and spatial variability, and its response to wind forcing, has been measured at three sites in the proposed equatorial Pacific mining area. Additionally, the temperature and salinity microstructure and their relation to mixing processes are being characterized (fig. 10).

The Strait of Juan de Fuca experiment is concentrating on understanding the response of the currents in this channel to varying winds. In a pilot study, wind-generated currents were observed to alter significantly the flow regime produced by the tidal and estuary circulations.

The OCSEAP research has concentrated on the relations between the variations in sea surface slope and the barotropic velocity field on the continental shelf in the Gulf of Alaska. A process-oriented study is underway jointly with the COER group in order to describe the mesoscale response of the sea-surface slope and the velocity field to atmospheric and oceanic forcing. The basic instrument for the sea level measurements is a bottom moored, internally recording pressure-temperature gauge designed by the OARS project.

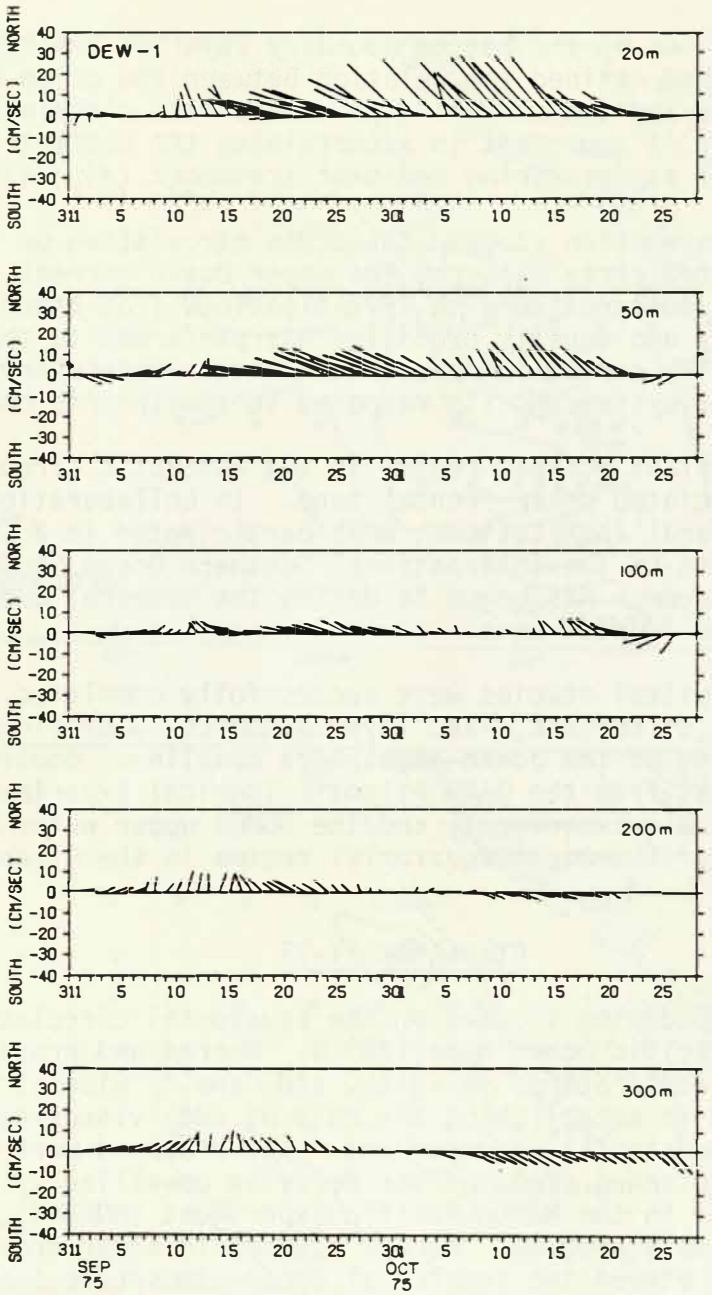

Figure 10. Time-variations of low-pass (f_c = 0.0167 cph) filtered time series of current vectors at 5 depths in the upper ocean at DOMES Site C. These data revealed a more complicated structure of the upper ocean circulation than suggested by *a priori* evidence. The vertical distribution of the 60-day mean currents indicated a subsurface countercurrent. The time-averaged vertical distribution was not representative of the low-frequency current variations, which were not in agreement with baroclinic geostrophic currents determined from hydrographic measurements (Halpern, 1976, Upper ocean studies).

An investigation of the bottom boundary layer on the continental shelf off Oregon has defined the relation between the ocean bottom velocity structure and the upwelling or downwelling circulation patterns. Bottom circulation is important in ascertaining the ultimate fate of many pollutants as well as describing sediment transport (fig. 11).

The EQUA-1 expedition studied the ocean circulation on the equator at 150° W. A moored array measured the upper ocean currents, temperature, and the wind. In cooperation with investigations from other institutions, shipboard velocity and density profiling was performed in the vicinity of the equator. The expedition provided a better understanding of the equatorial current system and its response to atmospheric changes.

Another important oceanic regime is the Antarctic Circumpolar Current and the associated polar frontal zone. In collaboration with investigators from several institutions, OARS participated in a study of the polar front as part of the International Southern Ocean Study (ISOS) program. This research has begun to define the temporal and spatial variability of the frontal zone.

Several analytical studies were successfully completed, including a numerical model of surface mixed layer dynamics, a problem fundamental to an understanding of the ocean-atmosphere coupling. Continued analysis of the OARS results from the GARP Atlantic Tropical Experiment (GATE), C-Scale Oceanographic Experiment, and the DOMES upper water experiment allow comparison of the north equatorial regime in the Atlantic and Pacific Ocean.

Plans for FY-77

An EQUA-2 expedition focused on the equatorial circulation is planned for the Eastern Pacific Ocean near 125° W. Moored and profiling velocity measurements and temperature, salinity, and density microstructure measurements will aid in establishing the role of eddy viscosity in the dynamics of the equatorial undercurrent. The proposed work will be coordinated with a planned study of the Peruvian upwelling system (CUEA), studies of El Niño in the North Pacific Experiment (NORPAX), and an evolving NOAA climate program. Recent studies in other areas have indicated a coupling between the equatorial ocean-atmosphere system and the coastal circulation off Peru.

OARS will also participate in a process-oriented study of the response of the upper layers of the North Pacific to an early autumn storm, in which we will measure the wind, current, and temperature fields to determine the temporal changes related to advection and vertical mixing. This experiment will lead to improved parameterization of the heat and momentum transports at the ocean-atmosphere interface.

Research into environmental processes will continue with contributions to the OCSEAP, MESA, and DOMES studies. Efforts conducted jointly

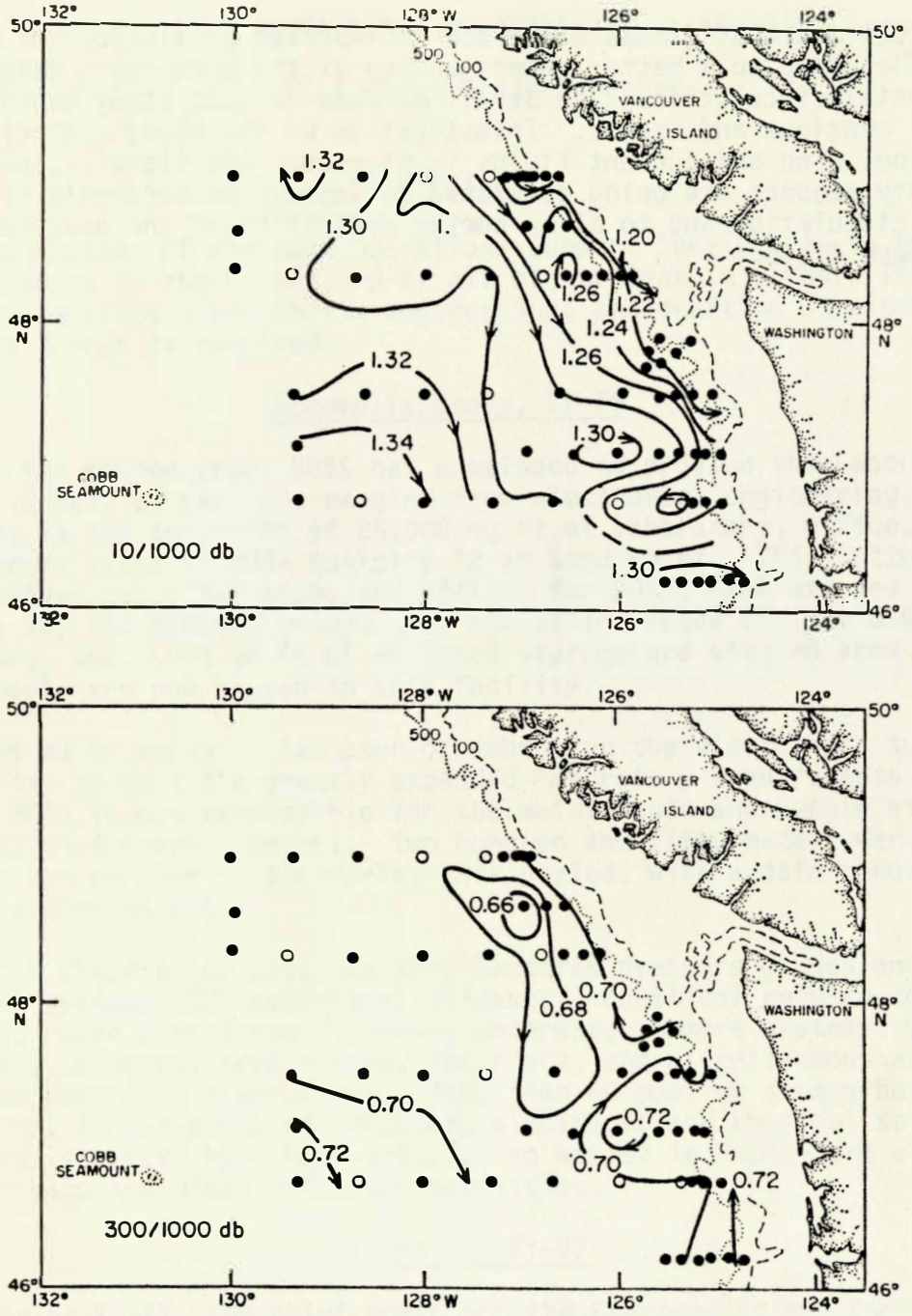

Figure 11. The 300/1000-db topography indicates a northward flow from the south along the continental slope. Discontinuities in the flow or eddies are evident. Similar features were observed at 150 db (referred to 1000 db), but not at the surface where the flow relative to 1000 db was generally southward. The northward flow at intermediate depths along the continental slope appears to be an extension of the California Undercurrent (Reed and Halpern, 1976).

with the COER and MASS groups will lead to improved predictions of the velocity field and to a better understanding of the barotropic response of the coastal circulation. The Strait of Juan de Fuca study begun in FY-76 will continue and expand. Investigation of the along-channel and cross-channel wind and current fields is planned. Additionally, moored conductivity sensors are being developed to improve measurements of estuarine circulation and to allow better definition of the near-surface internal wave field.

H. BASE OPERATIONS SUPPORT SERVICES (BOSS)

Leal W. Kimrey, Project Leader

Mission

The mission of the Base Operations Support Services is to provide plant support to the Laboratory at all of its Seattle sites. In addition, it provides electronics, engineering, and drafting services to the research groups as required.

Accomplishments, FY-76

In its second year, BOSS has continued to provide the Laboratory with a variety of services ranging from electronic, engineering, and drafting to the designing of 26,000 sq ft of laboratory, office, shop, and storage space in NOAA Building 32 at Sand Point. This latter effort has provided space for shops and offices for BOSS, laboratories and offices for the MARLAGS group, shop and office space for the OARS group, a library, and 8,000 sq ft of enclosed storage and staging area. Thirty-five people are now housed in this facility.

The major emphasis has been on improving the electronics support capability to meet the greatly expanded laboratory requirements in this area. BOSS is now responsible for the maintenance and repair of 110 Aanderaa CM-4 current meters. Two hundred and fifty meters were cycled through the service system during this period, with a data recovery record exceeding 90%.

BOSS Electronics also services Aanderaa pressure gauges and meteorological systems, AMF acoustical releases, acoustical release command systems, radar Mini-Ranger systems, underwater camera systems, STD's and CTD's, pingers, transducers, recorders, and miscellaneous electronic test and recording instruments. More than 60 mooring arrays have been assembled; 45 man-weeks of shipboard electronic and physical science technical services have been provided to assist in deployment of current meter arrays and other shipboard activities.

Plans for FY-77

During FY-77, the chief goals for the Electronics and Engineering Sections will be upgrading of obsolete equipment, implementation of management control of spare parts, hardware, and supplies necessary to support activities, and refinement of servicing techniques.

Establishment of a graphics section will be undertaken. This section will provide professional drafting, illustrations, photography, and reproduction services for the Laboratory.

All capitalized property will be inventoried and accounted for early in the year. Standardized procedures will be implemented to assure that proper accountability of all PMEL property is maintained.

IV. PMEL PERSONNEL, OCTOBER 1976

DIRECTOR

Apel, John R., Supervisory Oceanographer

COER (Robert L. Charnell, Group Leader)

Cannon, Glenn, Oceanographer
Charnell, Robert L., Oceanographer
Grigsby, Michael W., Physical Science Technician
Haslett, James C., Physicist
Hirst, Susan K., Clerk-Typist
Laird, Norman P., Oceanographer
Mofjeld, Harold O., Oceanographer
Muench, Robin D., Oceanographer
Pashinski, David J., Oceanographer
Reed, Ronald K., Oceanographer
Reynolds, R. Michael, Oceanographer
Schumacher, James D., Oceanographer
Walter, Bernard A., Physical Scientist
Wright, Sharon L., Physical Science Aide

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Erickson, Barrett H., Oceanographer
Padan, John W., Physical Scientist
Rhyneer, Margaret M., Clerk-Steno
Wilson, Cynthia M., Clerk-Typist
Wing, Robert H., Mechanical Engineer

ERSS (John R. Apel, Acting Group Leader)

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Rufenach, Clifford L., Physicist
Sawyer, Constance B., Physical Scientist

MARLAGS (Jerry D. Larrance, Group Leader)

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Chester, Alexander J., Oceanographer
Cline, Joel D., Oceanographer
Damkaer, David M., Oceanographer
Dey, Douglas B., Oceanographer

Feely, Richard A., Oceanographer
Fisher, Jane A., Oceanographer
Heron, Gayle A., Oceanographer
Larrance, Jerry D., Oceanographer
Massoth, Gary J., Oceanographer
Quan, Joyce, Physical Science Technician
Ruffio, Patricia A., Biological Technician
Tennant, David A., Oceanographer
Young, Anthony W., Oceanographer

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Fridlind, Clifford M., Oceanographer
Han, Young-June, Oceanographer
Kimura, Gary D., Math-Science Student Trainee
Overland, James E., Oceanographer
Pease, Carol H., Oceanographer
Smyth, C. Stephen, Oceanographer

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Freitag, Howard P., Oceanographer
Glenn, John W., Electronics Technician
Halpern, David, Supervisory Oceanographer
Hayes, Stanley P., Oceanographer
Holbrook, James R., Oceanographer
Osland, Roger, Physical Science Aide
Shepherd, Andrew J., Physical Science Technician
Soreide, Nancy N., Computer Programer
Wilson, Willie-Belle, Clerk-Typist

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Lembeck, Louise B., Editorial Clerk
Loomis, Harold G., Mathematician
Miller, Gaylord R., Supervisory Oceanographer
Nakamura, Alex I., Electronics Technician
Newcombe, Jean, Clerk-Steno
Preisendorfer, Rudolph W., Mathematician
Spielvogel, Lester Q., Physicist

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(Ralph F. Cunningham, Group Leader)

Calvert, Joyce, Clerk-Typist
Cooke, Florence, Travel Clerk
Cunningham, Ralph F., Administrative Officer
Jensen, Mary F., Secretary
Johnson, L. Louise, Administrative Aide
Johnson, Virginia, Procurement Clerk
Kisser, John, Procurement Clerk
Martinez, Sheila M., Procurement Clerk
Miller, Marian, Clerk-Typist
Schapiro, Sandra L., Procurement Clerk
Thomasson, Norma, Clerk-Steno

BOSS (Leal W. Kimrey, Project Leader)

Carlone, Richard A., Electronics Technician
Gable, James A., Warehouseman
Jackson, Thomas G., Electronics Technician
Kimrey, Leal W., Geologist
Newman, Roy, Electronics Technician
Parker, William J., Electronics Technician
Pizzello, Marilyn F., Physical Science Aide
Spell, Benjamin D., Electronics Technician
Stephens, James L., Physical Science Technician
Stevens, Hiram R., Physical Science Technician

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Allen, Michael H.
Bernard, Eddie N.
Dreves, Donald A.
Keister, Lawrence E.
Milburn, Hugh B.
Parsons, Lawrence D.
Poor, George M.
Tracy, Dan E.

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