JOINT INSTITUTE FOR THE STUDY OF
THE ATMOSPHERE AND OCEAN

2003 Annual Report

July 1, 2002 – June 30, 2003

a technical report

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An overview of JISAO

Since 1977, the Joint Institute for the Study of the Atmosphere and Ocean (JISAO) has fostered research collaboration between the National Oceanographic and Atmospheric Administration (NOAA) and the University of Washington. On the NOAA side the principal connection is the Pacific Marine Environmental Laboratory. JISAO is governed by 30 Senior Fellows. They are divided between University faculty and NOAA/PMEL staff who hold affiliate faculty appointments at the University. The Director of JISAO reports to the University's Vice Provost for Research.

JISAO has four core research themes: Climate and Global Changes, Environmental Chemistry, Estuaries, and Fisheries Recruitment. Of these four themes, only the first two have enjoyed the benefit of ongoing block funding for a visiting scientist and postdoc program.

The Institute's "core" Task I visiting scientist and postdoc program, to which the University contributes by waiving indirect costs, supports on average two postdoctoral fellows on annual appointments, renewable for a second year and, (with lower priority with regard to funding), more senior visitors on leave from their home institutions. JISAO provides space, computer time, administrative support, and other services for these individuals. It also provides travel expenses and honoraria for a number of short-term visitors and it organizes workshops and seminars. JISAO's Task II and Task III programs serve as vehicles for funding research scientists (UW professional staff), post-doctoral research associates and graduate students through the JISAO cooperative agreement grant. The Task II program supports directed collaborative research efforts between NOAA and University scientists and the Task III program supports University of Washington research in areas compatible with the Institute's major research themes.

Over its 25-year history, most of the cooperative research in JISAO has involved faculty, staff, and graduate students in the University of Washington's School of Oceanography and the Department of Atmospheric Sciences and NOAA scientists at the NOAA Pacific Marine Environmental Laboratory (PMEL). The present makeup of the Senior Fellows of JISAO (Table 1) is heavily weighted toward these units.

Table 1. JISAO Senior Fellows

Knut Aagaard, UW Applied Physics Lab
Tim Bates, NOAA/PMEL
David Battisti, UW Departments of Atmospheric sciences, JISAO
Glenn Cannon, NOAA/PMEL (Emeritus)
Robert J. Charlson, UW Departments of Atmospheric Sciences, Chemistry (Emeritus)
David S. Covert, UW Department of Atmospheric Sciences
Steven R. Emerson, UW School of Oceanography
Charles C. Eriksen, UW School of Oceanography
Richard Feely, NOAA/PMEL
Robert G. Fleagle, UW Department of Atmospheric Sciences (Emeritus)
Richard H. Gammon, UW Department of Chemistry, School of Oceanography
D.E. Harrison, NOAA/PMEL
Dennis Hartmann, UW Department of Atmospheric Sciences
James R. Holton, UW Department of Atmospheric Sciences
Gregory Johnson, NOAA/PMEL
Billy Kessler, NOAA/PMEL
Jimmy C. Larsen, NOAA/PMEL (Emeritus)
Michael McPhaden, NOAA/PMEL
Ed Miles, UW School of Marine Affairs
Harold Mofjeld, NOAA/PMEL
Dennis Moore, NOAA/PMEL
James Murray, UW School of Oceanography
James E. Overland, NOAA/PMEL
Paul D. Quay, UW School of Oceanography
Patricia Quinn, NOAA/PMEL
Peter Rhines, UW School of Oceanography
Minze Stuiver, UW Department of Geological Sciences (Emeritus)
Norbert Untersteiner, UW Department of Atmospheric Sciences (Emeritus)
John M. Wallace, UW Department of Atmospheric Sciences

JISAO Fellow

John Bullister, NOAA/PMEL

Recent changes in JISAO

In recent years JISAO's research programs have broadened to encompass collaborative projects with NOAA scientists at the National Marine Fisheries Service (NMFS) housed at the Alaska Fisheries Science Center (AFSC), the Northwest Fisheries Science Center (NWFSC), and the National Marine Mammal Laboratory (NMML). On the University side, increasing numbers of faculty in the newly renamed School of Aquatic and Fisheries Science (SAFS), the Applied Physics Laboratory (APL), the School of Marine Affairs (SMA), and the Department of Civil Engineering have become involved in research funded by NOAA grants administered as part of JISAO's Task III program.

A recent development within JISAO is the establishment of the Center for Science in the Earth System (CSES), which grew out of two previous JISAO components: (1) The Hayes Center, which concentrated on climate variability and climate processes connected with the Pacific Ocean, especially El Niño and (2) The Climate Impacts Group (CIG) which concentrated on the integrated impacts of climate variability and long-term climate change in the Pacific Northwest. The Hayes Center was funded as an Applied Research Center of the Climate Diagnostics and Experimental Prediction Program of the NOAA Office of Global Programs (OGP). The Climate Impacts Group was funded as a Regional Integrated Science Assessment (RISA) of the Climate and Societal Interactions Division of the same NOAA Office of Global Programs.

On the initiative of Edward Miles (the Director of CIG) and Edward Sarachik (the Director of the Hayes Center), and with the agreement of J. Michael Hall, the head of NOAA OGP, the two groups were merged into a single group: the Center for Science in the Earth System. Unique among all funded programs within NOAA, the CSES is funded from the same sources as before but proposes with a single unified proposal and reports with a single unified annual report. It is managed jointly by the two program managers of the two NOAA programs involved. The groups meet in common and undertake common programmatic efforts.

Task I Program

The Institute's "core" program, to which the University contributes, supports on average two postdoctoral fellows on annual appointments, which are renewable for a second year and also senior visitors on leave from their home institutions. JISAO provides space, computer time, administrative support, and other services for these individuals. It also provides travel expenses and honoraria for a number of short-term visitors.

Task I Postdoctoral Program (2002-03)

Andrew Rice, Research Associate
Rice's research is in the field of atmospheric chemistry, focusing on the study of budgets of trace gases. Specifically, his proposal is to study the isotopic composition of atmospheric formaldehyde. Research is being done in collaboration with Paul Quay and Richard Gammon and includes isotopic studies of methane, carbon monoxide, and molecular hydrogen. These radiatively and chemically important trace gases are tied to formaldehyde through oxidative pathways in the atmosphere and isotopic information on formaldehyde will ultimately provide information with which to better constrain their budgets. In addition, isotopic study of formaldehyde will improve our understanding of the oxidative capacity of the atmosphere as a whole. At this point, Rice's research is in the preliminary stages and he is developing new analytical methods that will be applied to the measurement of gaseous formaldehyde. Additionally, he is working with Quay and Gammon developing novel methods for measurement of isotope ratios of molecular hydrogen in small volume air samples.

Visiting Scientists (2002-03)

John Chiang, UCAR Fellow, resident at JISAO
Research activities funded by the Task 1 program

Mechanisms of the tropical ENSO teleconnection: Chiang and Adam Sobel worked on a mechanistic framework for investigating how the El Niño-Southern Oscillation spreads its influence over the rest of the tropics.

The Paleo Intertropical Convergence Zone (ITCZ): Chiang, with David Battisti and Michela Biasutti, investigated controls of the Atlantic and Pacific ITCZ's during the Last Glacial Maximum, using general circulation models and paleorecords.

ITCZ variability in the Pacific and Atlantic: Chiang, with Daniel Vimont, identified a mode of variability, from observational data, that is common to both tropical basins, characterized by a meridional displacement of the ITCZ and a meridional gradient in sea surface temperature and associated cross-equatorial flow.

Wei Cheng, Visiting Research Associate
Research activities funded by a grant from the Vetlesen Foundation

Cheng's research has been focused on understanding the effects of high-latitude fresh-water flux on the meridional overturning circulation (MOC). The fresh-water input to the North Atlantic takes place along pathways on either side of Greenland, and subsequently perturbs different branches of the North Atlantic deep water, namely, the Greenland-Iceland-Norway (GIN) sea overflow water and the Labrador Sea Water. The particular goal of her study was to understand the relative importance of the two major deep-water sources on the MOC and the possible interactions between them.

Task I Program Workshops and Special Events

2002

August

6: *Johnny Wei-Bing Lin*, Research Associate, CIRES, University of Colorado, "Influence of a stochastic moist convective parameterization on tropical climate variability and intermediate-level modeling of the Arctic."

7: *Benjamin Lintner*, Research Associate, Berkeley Atmospheric Sciences Center, Berkeley, CA, "Interannual Variability of Passive Tracer Interhemispheric Transport in the GISS-UCB AGCM."

8: "Live Access Server" meeting, Sarachik, Callahan, Mitchell, Warren, Hamlet, and Snover.

9: *Anand Gnanadesikan*, Oceanographer, NOAA's Geophysical Fluid Dynamics Laboratory, "Ocean heat transport: What are the key drivers?"

14: *Christoph Schär*, Institute for Climate Research, Swiss Federal Institute of Technology (ETH), Zürich, "Numerical and Predictability Aspects of High Resolution Numerical Weather Forecasting."

20*:* *Andrew Rice*, Graduate Researcher, Dept. of Chemistry and Earth System Science, University of CA, Irvine (Post-doc applicant), "Countinuous flow measurement of stable carbon and hydrogen isotopic abundance in atmospheric methane."

23: *Gabriel Lau*, Professor in Atmospheric and Oceanic Sciences, the Dept of Geosciences, at Princeton University; Scientist at NOAA/GFDL, "The 'Atmospheric Bridge' linking ENSO events to variability of the world oceans."

October

3-4: *Matt Newman,* Research Scientist III, CIRES, University of Colorado:
"A null hypothesis for the Pacific Decadal Oscillation."
"A linear model of low frequency variability: formulation, forecast skill, and associated predictability limits."

10: *Gabriele Hegerl*, Associate Research Professor, Earth and Ocean Sciences Division, Duke University, NC, "Beyond detection of anthropogenic climate change in surface temperature data."

14: *Geoffrey K. Vallis*, Faculty member in the Program in Atmospheric & Oceanic Sciences and in Applied & Computational Mathematics; Scientist at the Geophysical Fluid Dynamics Laboratory at Princeton University, "The NAO and all that: a simple dynamical model."

22: *Lara Whitely-Binder*, Climate Impacts Group Seminar. "Vulnerability Assessment of Washington Watersheds."

29: *Don McKenzie*, Climate Impacts Group Seminar, "Predicting Conifer Species Responses to Climatic and other Biophysical Parameters."

November

5: *Ed Miles*, Climate Impacts Group Seminar, "Designing a Distributed regional Climate Impacts Model for the PNW (I): Assembling a Target List of Policy Relevant Questions."

14-15: *Sergey Kravtsov,* UCLA
"Phenomenology of interdecadal variability in a hybrid ocean-atmosphere-sea-ice model."
"Multivariate regression modeling of nonlinear datasets."

14: *Mike Dalton*, Climate Impacts Group Seminar, "The California Rockfish Conservation Area: Climate Fluctuations and Groundfish Trawlers at Moss Landing Harbor."

19: *Ed Sarachik*, Climate Impacts Group Seminar, "Book Review: Diffusion of Innovations (Rogers 1995, New York: Free Press)."

26: *Ed Miles*, Climate Impacts Group Seminar, CIG and School of Marine Affairs, "Designing a distributed regional climate impacts model for the PNW (III): Assembling a target list of policy relevant questions."

December

3: *Pete Lawson*, NOAA, Climate Impacts Group Seminar, "Closing the Loop: Environmental Variability Throughout the Life-Cycle of Oregon Coastal Matural Coho Salmon."

10: *Craig Brown* and *Nathan Mantua*, Climate Impacts Group Seminar, "Predicting Extreme Weather Events."

2003

February

7: *Amir Shabbar*, Environment Canada, "An overview of Canadian climate activity and low frequency climate modes and winter climatic extremes in Canada."

18: *Nicholas Bond* and *Gabriel Vecchi*, "The Madden-Julian Oscillation (MJO) and Precipitation in the Pacific Northwest: Composites and a Case Study."

March

3: *Shoshiro Minobe*, Hokkaido University, Japan, "A detection of internannual air-sea coupled signal along the subtropical front in the North Pacific."

4: *Joel Thornton*, Univ. of Toronto, Climate Impacts Group Seminar, "Weaving New Destinies for Atmospheric HOx and NOx Radicals from Field and Laboratory Observations."

11: *Alan Trimble*, Climate Impacts Group Seminar, "Climate-related trends and variability in PNW oyster recruitment and condition."

April

8: *Ed Sarachik and David Battisti*, Climate Impacts Group Seminar, "The role of the tropical Pacific in global climate variability: what sort of climate variability might we expect with global warming?"

15: *Ed Sarachik, Richard Slaughter and Assoc*., Climate Impacts Group Seminar, "Addressing criticisms of the 2001 IPCC SRES scenarios."

22: *Clara Deser*, NCAR/Climate and Global Dynamic Division, "Pacific decadal climate variability: What the instrumental record tells us."

24: *Bin Wang*, Dept. of Meteorology, University of Hawaii, 10:30 am, JISAO conference room: "New perspective of the Asian-Australian monsoon variability and predictability."

May

1: *Martyn Clark*, UC, Climate Impacts Group Seminar, "The Western Water Assessment."

20: *Daniel Kirk-Davidoff*, University of Maryland, "Polar stratospheric clouds, stratospheric overturning and the tropical tropopause: a feedback on Earth's meridional temperature gradient?"

23: *Alexey Fedorov*, GRDL, Princeton University, "The impact of salinity on the large-scale structure of the ocean thermocline, or can global warming induce a permanent El Niño?"

27: *Piers Forster*, Univ. of Reading, Climate Impacts Group Seminar, "Understanding Temperature trends in the lower troposphere."

June

3: *John Field*, UW, Climate Impacts Groups Seminar, "Modeling northeast Pacific Ecosystems."

Task II Program

Task II supports collaborative research efforts between NOAA and University of Washington scientists at the Pacific Marine Environmental Laboratory (PMEL) and the Alaska Fisheries Science Center (AFSC) in Seattle, Washington.

Overview of Task II Research Accomplishments

Cycling of carbon and other elements in the atmosphere and oceans
The PMEL/JISAO Global Carbon Cycle Program (GCCP) conducts research on the sources and sinks of carbon dioxide in the oceans. Atmospheric and oceanic carbon dioxide data are collected on cruises on board NOAA vessels and from the TAO moorings. Modeling studies employing these data enhance our understanding of the ocean's role in the global carbon cycle and the important feedback mechanisms that will affect future climate changes. The following summarizes several of the GCCP successes, including promising developments in new research.

***Goal**: To contribute to our scientific understanding of carbon sources and sinks in the oceans.*

✦ *Determined Anthropogenic CO_2 in the Pacific Ocean*. The GCCP provided an estimate of the amount of anthropogenic CO_2 in the North Pacific Ocean based on observations from the WOCE/JGOFS/OACES Global CO_2 survey. The integrated amount of anthropogenic CO_2 in the Pacific Ocean through 1994 is approximately 44.5 ± 5 Pg C, with 63% in the South Pacific and 37% in the North Pacific. The highest inventories and relatively deep penetrations are associated with the Subtropical Convergence zones. Low inventories are observed in the equatorial and high latitude Southern ocean region. The deepest penetration of anthropogenic CO_2 occurs in the areas of deep and bottom water formation in the Southern Ocean.

✦ *Estimated the mass of carbonate dissolved in the Pacific and Indian oceans*. The GCCP used total alkalinity and CFC data to estimate CaCO3 dissolution rates in the Pacific and Indian oceans. These rates are important for predicting how fast the oceans can neutralize the anthropogenic CO_2. The integrated rate of dissolution for the global ocean is approximately 0.5 Pg C yr^{-1}. The penetration of anthropogenic CO_2 into the ocean interior has caused an upward migration of the calcite and aragonite saturation horizons by about 40-200 m over large regions of the Pacific and Indian oceans. Over time, these changes in the aragonite saturation state will have profound impacts on the health of our coral reefs and their associated ecosystems.

✦ *Determined the effects of El Niño on the air-sea exchange of CO_2*. Determining the effects of El Niño on the sea-air flux of CO_2 in the equatorial Pacific is critical for understanding the phasing of CO_2 sources to the atmosphere. Our results from 90+ cruises over the past 12 years provided the first detailed observations of the regional variability of pCO_2 during the 1997-98 and 2002-03 ENSO events. The data show the large interannual effects of El-Niño on CO_2 exchange in the equatorial Pacific during

weak and strong El Niño events. For example, from the time of the strong El Niño event of 1997-98, the average CO_2 flux from 10°S to 10°N and 90°W to 160°E increased from approximately 0.2 to 1.4 mol C $m^{-2}yr^{-1}$. The high CO_2 fluxes in 1996 and 2000 were due to increased surface water pCO_2 values and higher winds. The Equatorial Undercurrent was much closer to the surface in 1995-96, and supplied the higher p CO_2 found in surface waters. The lower fluxes during the 1997-98 El Niño were primarily the result of the weaker winds and the transport of the CO_2-depleted warm pool into the central and eastern equatorial Pacific. We estimate that for the 1-year period of 1996 approximately 0.9±0.6 Pg C as CO_2 was released to the atmosphere. In sharp contrast, for the 1-year period from the spring of 1997 to the spring of 1998, the CO_2 flux to the atmosphere was approximately 0.2±0.14 PgC over the same region. Thus, the amount of CO_2 retained in the equatorial oceans during the 1997-98 El Niño period (i.e., 0.7±0.4 PgC yr^{-1}) was slightly higher than during the severe El Niño of 1982-83 (~0.6 PgC yr^{-1}). In contrast, the weak El Niño of 2002-03 showed weak CO_2 fluxes in the western Pacific and near-normal CO_2 fluxes in the eastern Pacific. This remarkable contrast between the western and eastern Pacific is attributed to a deeper thermocline and a weaker wind in the western Pacific which causes seawater pCO_2 values to be nearly in equilibrium with respect to the atmosphere and, hence, the lower sea-to-air CO_2 fluxes. Whereas, the eastern Pacific had much higher CO_2 fluxes because the thermocline was almost as shallow as during non-El Niño periods, resulting in very high p CO_2 values due to upwelling of relatively cold CO_2-enriched waters from the Equatorial Undercurrent. Coupled with strong southeasterly winds, the resulting CO_2 fluxes during the 2002-03 El Niño in the eastern equatorial Pacific were very similar to the fluxes observed during non-El Niño periods. These results suggest that the recent PDO phase shift of the late 1990s may have resulted in a net increase in the outgassing of CO_2 at the equator, causing an enhancement of the global warming impacts of CO_2 on the atmosphere.

***Goal**: To foster the use of chemical and hydrographic data information for modeling efforts.*

✦ *Ocean carbon data distributed to the oceanographic community*. The GCCP group has developed a web-based access for hydrographic and carbon data that has been used by the modeling community to verify their models of carbon system biogeochemical processes in the oceans. The website is supported by a live access server that provides both data access and graphical outputs. All the data and graphics can be found at www.pmel.noaa.gov/co2/co2-home.html.

✦ *Historical PMEL carbon data integrated with other data sets*. The GCCP group has formed a partnership with CDIAC to provide data products from the Repeat Hydrography CO_2/Tracer Program and the WOCE/JGOFS/OACES Global CO_2 Survey. These products can be found at cdiac.ornl.gov/oceans/glodap/Glodap_home.htm.

Goal: *To contribute to education at the University of Washington*

✦ *Hosted North Pacific Climate Variability Workshop*. The GCCP Group has received funds to conduct a workshop on the variability of the carbon system of the North Pacific. The focus will be on an overall picture of North Pacific variability that draws together all of these individual lines of evidence and looks for coherent patterns that may help us understand the regional significance of this variability and the possible mechanisms controlling the observed spatial and temporal patterns into a basin-scale picture of the North Pacific carbon cycle. The workshop will not simply recount published studies, but will enhance these studies by gathering the relevant data sets together and re-analyzing them with a view toward the larger picture. This data synthesis will be further enhanced by a simultaneous examination of North Pacific variability in a variety of climate model runs. It is proposed that the workshop will become a component of the University of Washington Program on Climate Change so that both students and faculty members can benefit from the workshop results.

Sources, sinks, long range transport, and optical properties of marine aerosols
The PMEL-JISAO Atmospheric Chemistry-Aerosol Program is designed to quantify the spatial and temporal distribution of natural and anthropogenic atmospheric aerosol particles and to determine the physical, meteorological, and biogeochemical processes controlling their formation, evolution, and properties. Recent efforts are grouped under three objectives:

Goal*: To reduce uncertainties in radiative forcing by aerosols*

✦ Measurements of aerosol properties during integrated field campaigns provided data for the validation of regional models that are used to estimate aerosol direct radiative forcing and the validation of algorithms used to retrieve aerosol optical depth from satellite observations. In addition, the measurement of regional aerosol plumes allowed for the linking of aerosol sources to climate impacts. The overall payoff is a reduction in the uncertainty associated with estimates of aerosol direct radiative forcing. Recent field programs have measured aerosol particles transported out of Asia (ACE-Asia, spring 2001), particles along the west coast of North America (ITCT - Intercontinental transport and chemical transformation, spring 2002), and particles transported out of North America (NEAQS- New England Air Quality Study, summer 2002). Data analysis from these field programs in 2003 are posted at: *ACE Asia (saga.pmel.noaa.gov/aceasia/), ITCT (www.al.noaa.gov/ITCT/),* and, *NEAQS 2002 (www.al.noaa.gov/NEAQS/).*

Goal*: To determine the oceanic source of atmospheric sulfate particles*

✦ A database of seawater DMS concentrations is essential for global chemical transport and climate models to accurately predict climate change scenarios. PMEL-JISAO scientists are developing a web-based interactive database containing the thousands of global observations of surface seawater DMS concentrations that have been collected by various institutions in the national and international community since the early

1980's.Additional measurements of surface seawater DMS concentrations are needed to assess the temporal and spatial variability, particularly in higher latitudes. The Automated PMEL Underway-DMS system has been operating onboard the NOAA Ship Miller Freeman since April 2002. The DMS data collected with the underway automated system can be viewed in near real time at saga.pmel.noaa.gov/underwaydms/. This web site also allows users to plot the DMS and auxiliary data collected during various time periods in 2002 and 2003.

Goal: *To improve our capability to observe, understand, predict, and protect the quality of the atmosphere through national and international partnerships*

✦ PMEL/JISAO is now hosting the International Global Atmospheric Chemistry (IGAC) Core Project Office with funding from NOAA, NSF, and NASA. The goal of IGAC is to promote and facilitate international atmospheric chemistry research that will lead to a better understanding of the Earth System. Sarah Masonis, JISAO Research Scientist, has been hired as Executive Officer of the Seattle Project Office (www.igac.noaa.gov/). Tim Bates, PMEL Research Chemist, is a co-chair of the IGAC Scientific Steering Committee.

Hydrothermal vents

Scientists at the University of Washington and the Pacific Marine Environmental Laboratory share an interest in submarine hydrothermal venting, its impact on regional and global ocean chemical and heat balance, and its importance as a habitat for microbes and vent fauna. Vents Program research is interdisciplinary in nature and involves studies of the geology, geophysics, acoustics, physical oceanography, chemicaloceanography, geochemistry, and microbiology of submarine hydrothermal systems.

Goals: *To relate the chemical composition and output of hydrothermal systems to the geophysical environment and perturbations in that environment, to determine the magnitude of the chemical exchange between the ocean crust and the ocean, to determine how the chemical environment affects animal and microbial communities within and around hydrothermal systems.*

New Millennium Observatory (NeMO) at Axial Volcano on the Juan de Fuca Ridge is a unique deep-sea observatory that has established for the first time a real-time, two-way communication link between seafloor instruments and shore-based laboratories. Data from this observatory can be accessed by the public on the internet. This observatory allows us to follow the evolution of submarine hydrothermal and volcanic systems by monitoring hydrothermal flow and composition, hydrothermal plumes above the volcano, and geophysical properties of the volcano itself. The prototype real-time observatory/mooring system has been in place each year since 1998 and is leading the way into a future of oceanography where entire systems will be observed continuously. Currently NeMO includes instruments that measure volcanic deformation, collect fluids, determine fluid compositions, and evaluate the properties of the outlying hydrothermal

plume. Select instruments are linked to shore via an acoustic modem/satellite data transmission system. If a volcanic or tectonic event causes a change in the hydrothermal system, the fluid sampling instruments have the capability to respond rapidly by changing their sampling interval and thus determine the immediate effects on fluid composition and temperature. NeMO instruments are designed to conduct in-situ monitoring and sampling for year-long intervals, providing for critical deep-ocean environmental observations and tailored sampling via the internet. It is believed that volcanic eruptions and tectonic perturbations result in significant changes in hydrothermal output. The magnitude and timing of these changes, and thus their impact on the geochemical mass balance of the oceans is still unknown. Microbial activity is dependent on the chemical energy supplied by hydrothermal fluids, and work at NeMO has included a strong component relating microbiology to the chemical environment of hydrothermal vents. The NeMO observatory will help us to understand these processes. JISAO scientists are also involved in prototype experiments aimed at establishing a cabled observatory in the NE Pacific (the NEPTUNE project).

The interests of this group extend beyond the NeMO. Some 20,000 km of volcanic arcs, roughly one-third the total length of the global mid-ocean ridge (MOR) system, rim the western Pacific Ocean. But compared to 25 years of hydrothermal investigations along MORs, exploration of similar activity on the estimated 600 submarine arc volcanoes is only beginning. Arc and back arc hydrothermal systems are directly responsible for forming massive ore deposits, and it is believed that the richest ore deposits on land arose from these types of hydrothermal systems in the geological past.

Accomplishments

✦ JISAO scientists visited the Mariana volcanic arc and back-arc basin in the western Pacific. During the Marianas expedition we mapped 70 different submarine volcanoes and found that ten of them were currently active. Of those ten, eight were found to exhibit intense activity with extraordinarily large chemical anomalies. The intensity of this activity was reflected by extremely elevated levels of iron in the water plumes above the volcanoes. The effects of this flux on the oceans may be much different due to its emission into the shallow ocean. Our continued study of these systems will be very important.

✦ JISAO scientists and others also investigated a new type of hydrothermal system where deep mantle rocks (peridotites) are exposed on the ocean floor near the Mid-Atlantic Ridge. In April and May JISAO scientists mapped and sampled this area in detail, finding a very unique style of venting brought about by a fundamentally different geological and geophysical regime. It is hypothesized that heat derived from the chemical alteration of peridotite by seawater drives the circulation of fluids where cold mantle rocks are exposed to seawater. This site is different from other volcanically-driven hydrothermal systems studied to date, challenging our ideas on hydrothermal flux and microbial environments.

Atmosphere-ocean interaction in the equatorial Pacific

JISAO air-sea interaction research seeks to improve understanding and prediction of El Niño and the Southern Oscillation (ENSO). The centerpiece of the ENSO observing system is the Tropical Atmosphere Ocean (TAO) mooring array, designed to monitor variability in the tropical upper ocean and at the surface. The TAO array is maintained by NOAA and JISAO scientists at PMEL. Together with the TRITON array maintained by Japanese scientists in the western Pacific, the combined TAO/TRITON array is comprised of 70 moorings at 11 different longitudes, spanning the equator from 8°S to 8°N. In addition to monitoring ENSO, data from the array are used for a variety of oceanographic and climate research studies. One such study is the Eastern Pacific Investigation of Climate (EPIC), described below.

Goal: *To improve understanding and prediction of ENSO*

✦ *Real time monitoring and diagnostic of El Niño events.* In contrast to the 1982-83 El Niño, which was not predicted and remained undetected until nearly at its peak, ENSO events are now routinely monitored in real-time and predicted with some skill. This is evidenced by several papers by members of the group documenting the onset, evolution, and termination of the 2002-03 El Niño. JISAO research has also focused on detailed analyses of the extraordinarily strong 1997-1998 El Niño, including analyses of heat, salt, momentum, and carbon cycle variations.

✦ *Decadal variability.* The increased frequency of El Niños during the 1990s and the occurrence of two extremely strong El Niños within 15 years of each other has led to several JISAO studies on decadal modulation of ENSO, tropical-subtropical interactions, and linkages between the Pacific Decadal Oscillation (PDO) and ENSO. Some of the past year's efforts in JISAO focused on describing these decadal variations and on the debate as to whether PDO is the cause or the consequence of the decadal modulation of ENSO.

✦ *Short term fluctuations.* An analyses of the diurnal cycle of rainfall has shed light on some of the physical processes operating on that time scale in the coupled ocean-atmosphere system. Similarly, equatorial Kelvin and Rossby waves are the vehicle by which the ocean and atmosphere adjusts to large-scale changes in forcing. Thus there is ongoing JISAO research towards understanding and characterizing the intraseasonal oscillation in convection and wind forcing, how this communicates with the ocean and forces equatorial waves in the ocean and atmosphere, and how these waves rectify into the ENSO signal.

Goal: *To improve monitoring, understanding, and prediction of ITCZ/cold tongue/stratus deck complex in the eastern Pacific*

✦ Expansion and enhancement of the TAO array have fueled concentrated research into the processes governing climate variability. The past year marks the final year of enhanced monitoring for the Eastern Pacific Investigation of Climate Studies (EPIC) that began in late 1999. EPIC enhancements to the easternmost TAO line at 95°W included

extra sensors and moorings to monitor the air-sea heat, moisture, momentum fluxes, and upper ocean temperature, salinity, and currents from 12°N to 8°S across the ITCZ/cold tongue/stratus deck complex. JISAO scientists have also been involved in biannual cruises along 95°W that monitored the oceanic and atmospheric boundary layer. The intensive field study (EPIC 2001) took place in September 2001, with 2 aircraft, 2 ships, and scientists from 5 countries, including a contingent of more than 10 oceanographers and atmospheric scientists from UW and PMEL. These coordinated data are providing valuable clues as to how the oceanic and atmospheric boundary layers couple and vary to form a seasonally evolving stratus deck/cold tongue/ITCZ complex in the far eastern Pacific. It is expected that this will lead to reduced biases in coupled general circulation models of the tropical Pacific.

Climate variations over the North Pacific and North America

Research scientists as JISAO, in collaboration with NOAA/PMEL scientists with the Ocean Environment Research Division (OERD), are carrying out a set of studies on the climate variability of the North Pacific and North America. The North Pacific work focuses on the pathways by which climate fluctuations impact the marine ecosystems of the Bering Sea and Gulf of Alaska. The North American component involves analysis of the principal modes of climate variability, especially in terms of how they influence the weather of the Arctic, Alaska, and the Pacific Northwest. The objectives of this research are:

Goals: *To learn more about how the interactions between atmosphere and ocean impact the marine ecosystem of the Bering Sea: specifically to better understand how climate variations ultimately influence marine populations over the eastern Bering Sea shelf, and to determine whether climate changes represent an important causal factor related to the decline of Steller sea lions in the Aleutian Islands.*

✦ Moored buoy and shipboard measurements in the Bering Sea and the vicinity of the Aleutian Islands have been used to directly assess how physical factors determine the chemical and biological properties of the upper ocean of the region.

✦ Time series of the primary components of the atmospheric forcing of the eastern Bering Sea since the mid-20th century have been described and related to the large-scale modes of climate variability.

✦ Innovative techniques have been developed to classify the variability of the Aleutian low (the principal feature of the wintertime atmospheric circulation of the North Pacific), and to diagnose abrupt shifts in the North Pacific climate system.

Goals: *To investigate the dynamics of the Alaska Coastal Current*

✦ A series of studies was undertaken under the auspices of the Global Ocean Ecosystem Dynamics Project (GLOBEC). An organizing theme relates to factors hypothesized to influence salmon populations in the Gulf of Alaska.

✦ High-resolution ocean model simulations have been carried out using the Regional Ocean Modeling System (ROMS); this output has been found to compare favorably with observations from moored buoys.

✦ The observations and ROMS simulations have shown that the flow over the shelf is sensitive to local atmospheric forcing, and that this forcing can be specified using output from a high-resolution numerical weather prediction model.

✦ Enhanced nutrient and phytoplankton concentrations have been found to be sustained into summer over relatively shallow regions of the shelf of the Gulf of Alaska; these regions may represent preferred nursery grounds for juvenile salmon and other important fish stocks.

Goal: *To document some previously unrecognized aspects of the recent warming of the Arctic*

✦ The springtime warming trend from the 1980s to the 1990s in northern Alaska and the Beaufort Sea has been shown to be associated with an increasing frequency of storms pumping mild, maritime air poleward.

✦ The land areas of the Arctic have experienced a net loss of tundra due to an increase in summer temperatures; the replacement of tundra by shrubs and trees may be providing a positive feedback for Arctic warming.

Goal: *To contribute towards further knowledge of how the tropics influence the weather of North America*

✦ JISAO investigators have shown that wintertime precipitation in the Pacific Northwest and temperature in Alaska are influenced by the so called "Madden-Julian Oscillation," the principal source of sub-seasonal variability on the tropics.

Impacts of climate variations on marine fish recruitment and marine ecosystems

JISAO fishery and climate scientists have a relatively long history of collaboration on studies aimed at better understanding, and in some cases predicting, climatic impacts on marine fish stocks and marine ecosystems. These studies are typically aimed at providing fishery managers with improved information about the causes for interannual-to-interdecadal variations in marine fisheries. Applications of this research fall into two general categories: (1) (short-term) annual stock assessments and harvest management for commercially valuable fish stocks and (2) (long-term) recovery planning for depleted species, and in some cases Federally protected Endangered Species.

Typically, these two categories are distinct, though in the case of Pacific salmon there is a great deal of overlap as harvest managers attempt to offer sport, tribal, and commercial fisheries while at the same time protecting Endangered species in mixed-stock fisheries.

Goal: *To provide improved understanding of the factors that cause salmon recruitment to vary from year to year and from decade to decade.*

✦ Empirical models have been developed that link regional changes in coastal ocean temperatures, sea level, and the timing of springtime upwelling events to year-to-year changes in Oregon coho marine survival. Hatchery reared Oregon coho now support valuable commercial, sport, and tribal fisheries, while natural Oregon coho stocks are listed as threatened under the Federal Endangered Species Act. It has been well documented that over the past 30 years, Oregon coho have experienced order-of-magnitude changes in marine survival rates. We have demonstrated that the nearly 75% of the observed variations in Oregon coho marine survival can be explained with a relatively simple "general additive model" that captures key features of the interannual variability in coastal ocean upwelling habitat.

✦ Empirical models have been developed that link regional changes in seasonal stream flow extremes, surface air temperature (as a proxy for stream temperature), and the timing of the fall year-to-year changes in natural Oregon coho freshwater productivity. This work also documents and describes the coherence between climate impacts on marine and freshwater coho productivity, providing insights into the climatic processes that are especially effective in causing large year-to-year to decade-to-decade changes in coho productivity, and lays the necessary foundation for translating anthropogenic climate change scenarios into Oregon coho salmon impacts scenarios.

✦ JISAO staff at PMEL have contributed climate and data analysis expertise to the new "Ecosystems Indicators" effort led by Patricia Livingston at the Alaska Fisheries Science Center. A particularly important issue in this work is the evidence for or against North Pacific climatic and/or marine ecosystem regime shifts.

✦ JISAO research has contributed to the development of climatically resilient policy response strategies for sustainable fisheries for Pacific salmon. Because of inherent limits in the predictability for environmental changes that influence salmon production in freshwater and marine environments, policies are advocated that de-emphasize prediction while emphasizing environmental and fish stock monitoring. Strategies for increasing the resilience of target fish populations are also promoted.

Tsunami preparedness

The Tsunami Research Program conducts research to improve our understanding of tsunami dynamics and develop applications that will reduce the loss of life and property. Summarized below are research accomplishments in support of two major goals of the U.S. National Tsunami Hazard Mitigation Program.

Goal: *To improve hazard assessment*

✦ *Identification of potential tsunami sources in Puget Sound*. The best available information regarding Puget Sound earthquakes, landslides, and delta failures was

reviewed, and the most probable sources of future tsunamis were identified. This was the first systematic inventory of such hazards, and is recognized as an important baseline study that provides recommendations and a framework for further research to improve our understanding of these hazards. This work also provides the scientific basis for numerical simulation studies to assess the tsunami hazard to Puget Sound communities.

✦ *Assessment of community-specific tsunami hazards*. Tsunami inundation modeling studies were conducted to assess the tsunami hazard to selected coastal communities in Puget Sound and in the Straits of Juan de Fuca. The results have been provided to State officials, as guidance for the development of emergency management products and programs. The program made significant contributions to similar efforts in Alaska, California, Hawaii, and Oregon, including the development of methods for integrating bathymetric and topographic data to create computational grids suitable for tsunami numerical modeling.

Goal: *Improve tsunami warnings*

✦ *Deep-ocean, real-time reporting tsunami monitoring network*. A tsunameter (soo-NAH-metter) network was established in the Pacific, with stations sited seaward of known tsunamigenic seismic zones, to monitor tsunami generation and provide real-time measurements of tsunamis as they propagate from the source to coastal communities. The transition from research-to-operational status has been completed, and NOAA's National Data Buoy Center has now assumed responsibility for the continued operation of the network.

✦ *Tsunami Forecasting*. A model-based methodology for optimal interpretation of real-time deep-ocean tsunameter and coastal tide gage data was developed. Implementation of this tsunami forecasting system at NOAA's Tsunami Warning Center is now underway, and is key to improving the speed, accuracy, and reliability of tsunami warnings.

Applications of information technology to the display and analysis of climate data
The PMEL/JISAO information technology (IT) groups are instrumental in providing support to and developing critical infrastructure for research efforts in climate dynamics, environmental chemistry, and fisheries recruitment.

Goal: *To provide information technology support for research in climate dynamics, environmental chemistry, and fisheries recruitment*

✦ *The group has provided IT support to local researchers*. Support has included the development of project specific web sites. These include the Arctic Science Laboratory (asl.arctic.noaa.gov), Delayed-Mode Salinity Calibration for US Argo Floats (floats.pmel.noaa.gov/argo), NOAA ShipTracker (shiptracker.pmel.noaa.gov), Bering Climate (www.beringclimate.noaa.gov), the Unaami data collection (www.unaami.noaa.gov), Ocean Surface Current Analyses Real Time (www.oscar.noaa.gov), and the Facility for the Analysis and Comparison of Tsunami

Simulations (ferret.pmel.noaa.gov/FACTS). Support has also included the development of scripts and software display and analysis of observational data.

***Goal**: To develop critical infrastructure for the dissemination, visualization, and analysis of observational and model data*

✦ *The group has developed servers for the dissemination of observational and model data*. The Live Access Server (LAS) and the Climate Data Portal (CDP) web sites provide easy access to data for both local and off-site researchers. Access to many of these datasets would be difficult because of the large variety of formats in which the original data is made available. These servers provide access to these data products through a single interface and make the data available in several formats to the researcher.

✦ *The group has developed visualization and analysis tools.* Development continues on Ferret, a desktop visualization and analysis tool, the Scientific Graphics Toolkit, a Java graphics toolkit, and ncBrowse, an application for the browsing and visualization of netCDF and OPeNDAP formatted data. These tools provide researchers with easy-to-use and extensible tools for visualization and analysis.

Task II Funded Research Programs

Climate

Eastern Pacific Investigations of Climate Process (EPIC), PMEL
Graduate Student: Rachel Wade, Research Associate

Intraseasonal Ocean Response to Atmospheric Forcing, PMEL Program
Research Staff: Dongxiao Zhang
Graduate Student: Xeubin Zhang

Dongxiao Zhang, Research Scientist
Shallow subtropical overturning cells (STCs) transfer mass, heat, salt, and tracers between the subtropical and tropical oceans. Using historical oceanic and atmospheric data, Zhang has conducted empirical studies of the STCs in both the Atlantic and the Pacific. The purpose is to better understand the STC's potential role in tropical sea surface temperature (SST) and climate variability, and to validate and improve numerical simulations that have produced different results of the mean state and changes of the STC.

Atlantic
Zhang kept the historical hydrographic data in the Atlantic basin up-to-date, compiling and providing quality control from the World Ocean Database (2001), WOCE hydrographic sections, and real-time float profiles. He has used this data set to document the mean pathways and transports of the Atlantic subtropical cells, and the structure and variations of Atlantic Equatorial Deep Jets.

Zhang's on-going research was focused on the temperature and salinity anomalies of the STCs. The results show that decadal temperature and salinity anomalies in the surface of subtropical Atlantic oceans were subducted into the pycnocline. This results in a long-term change in temperature and salinity in the tropical Atlantic pycnocline from the pre-1970s to after the 1970s. Superimposed on these multi-decadal trends is hemispherically anticorrelated water mass variation on decadal time scales. These anomalies were upwelled near the equator to produce anomalous SST gradients that can be linked to cross equatorial wind changes, and enhanced the coherence of the North and South Tropical SST anomalies in the period band of 8-12 years.

Pacific
Zhang has also updated our Pacific hydrographic data set during the past year (up to June 2003). Using the earlier part of this data set (till 1999), Zhang shows that the STCs in the Pacific have been slowing down since the 1970s. Our new calculation shows that the STC has been spinning up from 1992-1998 to 1998-2003. The implications of this dramatic change on Pacific Decadal Oscillation are under investigation.

He is also looking into the structure and variability of the STC in a coupled ocean atmosphere model—the MICOM (Miami Isopycnal Ocean Model)-NCAR CCM3 model. He and colleagues found the variability of the STC transport is correlated with the modeled decadal variability in SST. Being funded by NOAA/OGP, we are investigating the relationship between the STC transport, the tropical SST, and the atmospheric circulation in the coupled simulation on decadal time scales.

Moored Tropical Rainfall Analysis Program, PMEL

Research Staff: Serra

Yolande Serra, Research Scientist

In the past year Serra has focused on three research areas, all of which involve analysis of tropical Pacific and Atlantic rainfall. The first project was to complete comparisons of the Tropical Atmosphere Ocean/Triangle Trans-Ocean Buoy Network (TAO/TRITON) and Pilot Research Moored Array in the Tropical Atlantic (PIRATA) moored buoy rainfall measurements with the NASA Tropical Rainfall Measuring Mission (TRMM) microwave imager (TMI) and precipitation radar (PR) rainfall measurements. The goal of the TRMM program was to provide rainfall measurements with a long-term accuracy of 10% across the global tropics. The publication that resulted from this work was part of the overall ground validation of the TRMM satellite data, providing the only open ocean data comparisons for the program.

In another project Serra has analyzed the diurnal cycle in tropical rainfall over open ocean regions using the buoy self-siphoning rain gauge data. The goal of this research is to gain insight into convective processes and to compare the buoy results with previous studies of tropical rainfall variability. Her analysis indicates that the diurnal cycle in rainfall at the buoys has an early morning maximum, followed by a secondary maximum in the afternoon. Although these results describe the overall pattern in the diurnal cycle that emerges from the data, there is significant regional and seasonal variability. The publication from this study discusses the relative agreement of our results with previous studies of short-term tropical rainfall variability, pointing out some significant discrepancies with recent satellite studies and possible reasons for these discrepancies.

She is also exploring the effect of the diurnal cycle in fresh water forcing on surface salinity variability and upper-ocean mixing processes on short time scales. The surface buoyancy flux, corresponding to the heat and fresh water fluxes measured at the buoys, indicates negative (stable) values during the day and positive (unstable) values at night. Thus, cooling overwhelms any negative stability related to the early morning maximum in rainfall, also observed at the buoys. The corresponding diurnal cycle in surface salinity at the buoys has a maximum in the early morning and a minimum in the afternoon. This variability is primarily a function of wind speed, with a tendency for the largest diurnal amplitudes to occur during low wind conditions when turbulent mixing is a minimum. Afternoon rainfall establishes a vertical gradient in upper-ocean salinity and is, therefore, also necessary for observing a diurnal cycle in surface salinity.

Observing System Research Studies Program, PMEL

Research Staff: Callahan, McLean, McHugh, O'Brien, Vecchi

Jonathan Callahan, Research Consultant

Callahan has continued his work on the Live Access Server (LAS), developing enhanced functionality and supporting the increasing base of users that have installed LAS. Important collaborative efforts have included work with the National Oceanic and Atmospheric Administration (NOAA) Hazardous Materials group (HAZMAT), the Global Ocean Data Assimilation Experiment (GODAE), the Joint Global Ocean Flux Study (JGOFS), and Tsunami modelers at the Pacific Marine Environmental Institute (PMEL).

Joseph McLean, Research Consultant

McLean's primary work over the year was the development of Live Access Server (LAS) access to the National Oceanographic Data Center's World Ocean Database. This work will increase the availability and exposure of a large collection of in-situ ocean data to the Oceanographic and Atmospheric community by including the data in the National Virtual Ocean Data Hub (NVODHub).

McLean's continuing responsibilities involve configuring oceanic and atmospheric data for inclusion in the NVODHub. The data sets are in a variety of formats and his work consists of finding and developing efficient ways to make the data accessible through the Live Access Server, the NVODHub's Web previewing interface. Working with the developers of the Open-Source Project for a Network Data Access Protocol (OPeNDAP), he implements solutions for a variety of visualization techniques, user interface customizations, and aggregation of large data collections.

Kevin McHugh, Research Scientist

McHugh's work was mainly in support of data integration, access, and visualization of global in-situ data. Working with first-order statistics, he has developed a working "score" of how well the ocean is being monitored. He has also worked with developing multiple data sets to allow easy analysis of global satellite observations, ranging from TRMM's TMI satellite to AVHRR's high resolution SST.

McHugh has also developed multiple websites allowing easy access to Indian Ocean monsoon forecasts from in-house analysis.

Kevin O'Brien, Research Scientist

Over the past year O'Brien has functioned as co-manager of the Ferret project. The Ferret project is one of PMEL's significant in-house graphical visualization and analysis programs. He continues to be responsible for Ferret ports to Compaq Unix, Solaris, Linux, SGI Irix, and Win32 machines

As co-manager of the Ferret project, O'Brien has maintained environments for both source code control [using the Concurrent Version System (CVS)] and testing and quality control to ensure integrity of the Ferret program and its public releases. The Ferret

program is approximately 250,000 lines of code in FORTRAN 77, FORTRAN 90, and C. It is crucial to ensure that all of the new features, bug fixes, etc. are integrated correctly and completely into the source code control system. The Ferret program is employed widely throughout the scientific community.

O'Brien continues to be responsible for integrating Ferret with the Distributed Ocean Data System (DODS). The inclusion of the DODS code into Ferret allows seamless access to remotely served datasets, anywhere in the world. This capability forms the heart of the distributed data access capabilities of the Live Access Server (LAS). He continues to assist the DODS group as beta tester and provides important feedback for the improvement of the DODS software.

O'Brien continues to be responsible for supporting and maintaining the TMAP group's local computing environment. This environment consists of high-performance Unix workstations, with differing operating systems, as well as a number of PCs running Windows NT/2000/XP. This support includes installing hardware (tape Jukeboxes, hard disk drives, internal cards, and memory), basic troubleshooting, and taking control in emergency situations. O'Brien is responsible for acting as liaison between the TMAP Group and the Computing and Network Services Division (CNSD) to ensure efficient operation of computer systems and scheduling of system tasks. As he has responsibility for the evaluating, testing, and purchasing of software, hardware, and networking equipment, it is crucial that O'Brien stay abreast of current trends in technology such as computers, processors, high-speed disks, and other peripherals.

Gabriel Vecchi, Research Scientist
Vecchi's principal responsibilities are the analysis of satellite and in situ datasets, and ocean general circulation modeling of the tropical Indo-Pacific, with a focus on sub-seasonal-to-interannual variability.

Vecchi has focused on ocean climate observing system evaluation and analysis, on the mechanisms of interannual variability in the tropical Pacific, on mesoscale interactions between the ocean and the atmosphere, and on links between tropical atmospheric variability and weather variability in mid/high-latitudes. He has also been refining the TMAP (Thermal Modeling and Analysis Project) version of the MOM-2 (Modular Ocean Model Version 2) ocean general circulation model (GCM), in the tropical Indian and Pacific basins, in hindcast, climatology and idealized experiment modes, and using the GCM results to understand relationships between atmospheric variability and subseasonal to interannual oceanic variability.

Vecchi continued an exploration of surface and subsurface temperature, and wind data over the global oceans from a variety of in situ and satellite sources. He also continued exploration of the coupling between wind, convection, and SST (sea surface temperature) over a variety of timescales. He has continued his collaboration with Shang-Ping Xie at the IPRC, U. Hawaii and Albert Fischer at LODYC, Paris, exploring interactions between the ocean and atmosphere in the western Arabian Sea.

Submarine Cable Observation Program, PMEL

Research Staff: Flosadottir

Agusta Flosadottir, Research Scientist

Flosadottir's work continues with transport observations in the Straits of Florida, using cross-stream voltage on the retired submarine cable 'Florida-Bahama'.

Observations on the ECFS (Eastern Caribbean Fibre System) cable across the Grenada Passage between the islands of Trinidad and Grenada have now been in place for over a year. Analysis of early data indicated an undesirable level of variation due to temperature-sensitive resistors in the power feed equipment at the cable stations. Toward the end of the year we were able to replace it with a more accurate model at the Trinidad station. Efforts are under way to replace a similar resistor at the Grenada end, and to get separate observations of a sea-earth ground in the Bay of Paria on line.

Work is in progress to apply the 'ISIS' (Induction Sources In the Sea) numerical model to magnetometric resistance observations from the East Pacific Rise, funded by a supplementary grant to R. Evans' NSF project.

The North Pacific submarine cable observations are presently unfunded, but efforts continued to maintain a presence at the cable stations and seek opportunities to restart observations.

Tropical Ocean Atmosphere (TAO) Program, PMEL

Research Staff: A'Hearn, Dougherty, McCarty, McClurg, Noor, Ruiz, Stratton, Zimmerman

Patrick A'Hearn, Research Consultant

A'Hearn was Chief Scientist on board three research cruises for the TAO program to service buoys and collect data in the tropical Pacific. He wrote software to load high accuracy TAO Next-Generation buoy data into a database to permit fast and simple access and comparison with other datasets. He wrote software to display and compare various TAO data sources before the data are released to the public, and made alterations to a number of software packages used to process TAO data. He also helped diagnose and develop solutions for a lightning susceptibility problem with TAO rain gauges.

Daniel Dougherty, Research Scientist

Dougherty is responsible for the maintenance and continual operation of computer resources used to acquire, process, monitor, and archive real-time oceanographic and meteorological data for the Tropical Amosphere-Ocean (TAO) Project. This work includes the scheduling and coordination of computing processes, software troubleshooting and repair, and new software development. Other recurring duties are preparation of TAO project data summaries, assistance in TAO data monitoring operations, and providing direction and review for collaborative projects involving software development and database management.

Marguerite McCarty, Research Scientist
McCarty has continued her involvement with the TAO project during the past year. Emphasis has been on the quality control of salinity time series from TAO moorings. She has continued her involvement with the calibration, archiving, and dissemination of recorded time series data from instrumented moorings. She has also served as the substitute monitor for incoming real-time data. In the last year she has continued to extend and refine the capabilities of the salinity quality control software. She has also continued training another individual in quality control procedures; 150 quality controlled salinity data sets were added to the TAO public data server as a result of their joint efforts. (Each data set represents 6 to 18 months of data collected by one to seven instruments from a single mooring.) She served as Chief Scientist on the GOALS/PACS cruise GP3-02-KA, aboard the NOAA Ship Ka'imimoana. The major tasks performed during the cruise were the recovery and redeployment, or repair of 16 current meter and ATLAS moorings, and completion of CTD (conductivity - temperature - depth profiler) sections along 155°W and 170°W.

Dai McClurg, Research Scientist
McClurg acquired various oceanographic data sets and converted them to compact three-dimensional netcdf files including a TOPEX/Poseidon/Jason sea-surface height analysis, a TOPEX/Poseidon/Jason sea-surface height analysis, the Center for Space Research European Remote Sensing weekly and monthly wind analyses, the NASA QuikScat weekly and monthly wind analyses, and Ocean Surface Current Analysis Realtime (OSCAR) data. He performed various analyses including the creation of smoothed annual cycles for the TAO 20°C isotherm depths and TOPEX/Poseidon/Jason sea surface heights. McClurg also performed a contracted major upgrade of the JAMSTEC TRITON web pages www.jamstec.go.jp/triton/data_deliv/ and www.jamstec.go.jp/triton/jsdisplay/, applying technology he developed at PMEL for TAO/TRITON pages and using the Apache web server for improved performance. He provided Pentad analyses of TAO sea surface temperature, air temperature, and surface winds for external users and web sites. He designed an algorithm for estimating monthly-mean precipitation accumulations from hourly rain rates recorded in the TAO array. He also created database files for two new data sets, i.e., the TAO Longwave Radiation and Sontek Current data, and added them to the TAO/TRITON delivery page.

McClurg continued to develop and refine the combined display and delivery web page www.pmel.noaa.gov/tao/data_deliv/local/disdel.html including the addition of various gridded fields of salinity and sigma-theta, longwave and shortwave radiation, precipitation, and acoustic doppler current profiler data. He modified various software and daily data files to include previously unavailable temperatures at non-standard depths from ATLAS Next Generation Buoys. He also modified and enhanced various programs to use the new format daily average TAO files which include recovered RAM data wherever available, in various data streams for the TAO/TRITON display and delivery pages. He extensively modified TAO/TRITON delivery page software to add source metadata to all ATLAS Next Generation high-resolution files, as well as instrument metadata for hourly salinity and sigma-theta.

McClurg upgraded various database programs to store availability data as 1-bit data rather than byte data, reducing disk storage requirements on our web server by a factor of 8. He ported 14-years worth of software developed for processing and analysis of TAO data from an aging Sun workstation to a new Dell/Linux machine. He also maintained and upgraded various TAO and TRITON web pages, primarily upgrading JAVAScript and JAVA software to maintain functionality after browser and JAVA plug-in version changes.

Sonya Noor, Research Consultant
Noor processed and provided preliminary quality analysis of delay-mode, high-resolution TAO and PIRATA data and reported instrument performance to technicians and TAO management. She flagged or replaced data after consultation with her supervisor. She provided quality-controlled data to the web data delivery page manager and maintained and upgraded processing software as needed. She also designed, implemented, and executed software and web-based interfaces for other data analysis projects such as laboratory calibrations and/or intercomparisons.

Noor has been primarily involved in processing high-resolution, delayed-mode, ATLAS Next Generation data collected from the TAO and PIRATA arrays of buoys in the Pacific and Atlantic oceans. This has included both the operation and maintenance of processing software in Unix and Windows environments, as well as the creation of new Perl and Matlab processing software (including routines for flagging and for rain processing), and the documentation of the processing procedures. She has analyzed the different components of the observational data, such as wind velocity, relative humidity, rainfall, radiation, temperature, and salinity. In doing so, she makes use of various forms of metadata, such as reports from real-time data analysts, automated computer programs, and records of sensor calibration and mooring deployment histories. She establishes a preliminary estimate of data validity and quality, implements quality control measures, and reports summaries to senior TAO personnel. She reports instrumentation performance to electronics and mooring technicians and consults with data systems analysts and managers on the design and operation of the TAO database.

Another project involved the processing of data collected from laboratory evaluations of various sensors. These intercomparisons confirm the proper operation of instrumentation, provide an independent check on sensor calibrations, and identify and quantify sensor or environmental problems that may not have been evident during calibration. She maintained and enhanced the Perl and Matlab computer programs which process and display this data.

She also processed, compared, and reported the results of various sensors that underwent testing in the lab and elsewhere (such as the EDD buoy data or the tubes at NDBC), and aided in locating the source of numerous spikes in rain and radiation data.

Nuria Ruiz, Research Consultant
Ruiz's primary duties include the architecture and design of the laboratory's calibration, inventory, and instrumentation database as well as the development and design of a web

accessible user interface that allows users to access the database through the intranet. Ruiz's additional tasks include the following: data processing, data analysis, assistance with the lab's research programming, and participation on TAO cruises as part of the TAO scientific party.

On December 2002, the full automation of the TAO_lab calibration system was completed; i.e., the process through which calibration data is stored and retrieved to be used in mooring data processing is now automated. Also, a system to keep track of lost instrumentation has been designed, developed, and completed.

The database work was accomplished by physical design of the relational database, SQL development, supervision of data migration from legacy systems, and object-oriented programming for the development of the graphical user interface in PHP and Perl-CGI.

Linda Stratton, Research Scientist
Stratton's responsibilities include daily monitoring and assessment of the real-time TAO moorings, as well as weekly and monthly statistical and graphical analysis of the data; cruise planning and preparation, including evaluation of currently deployed moorings and instruments, and documentation of operational and logistical requirements for upcoming cruises. When cruises are in progress (approx 10 months of the year), she keeps at-sea ships advised of any changes to the array that could effect cruise plans. Stratton consults on design and needs for operational/calibration/real-time databases and makes recommendations based on project requirements. Maintains, coordinates, organizes, and designs the TAO Project home page and the NOAA Ship *Ka'imimoana* real-time pages. Other duties include continuing documentation of the ATLAS system, training new personnel, filling routine and special data requests, maintenance of high-resolution data files, and data submissions to institutions throughout the world. At-sea duties include acting as Chief Scientist (on American vessels) or TAO Project Leader on foreign vessels. Stratton supervises at-sea scientific operations and she deploys, recovers, and repairs TAO moorings. She also handles CTD deployment and processing at sea and reports shipboard scientific operations.

David K. Zimmerman, Research Scientist
Zimmerman was involved in the technical and operational support of the Tropical Atmosphere Ocean (TAO) Array Project, Ocean Climate Research Division, at the NOAA Pacific Marine Environmental Lab (PMEL).

Zimmerman has served as Chief Scientist on three TAO buoy cruises. All were on the NOAA Ship *Ka'imimoana* for a total of 86 days at sea. During these cruises he oversaw all aspects of buoy deployment, recovery, and repair operations. This included mooring instrumentation and hardware, logistics, supervision of PMEL personnel, and coordination of mooring operations with shipboard personnel. It also included coordination of onboard scientific data collection with shipboard personnel and participating cruise scientists.

While at the lab, his responsibilities continue to include the technical support of TAO mooring instrumentation, including fabrication, testing, maintenance, calibration, and repair. Specific systems that he was responsible for include these: rain gauges, short wave and long wave radiation sensors, Sontek current meters, RDI Acoustic Doppler Current Profilers (ADCP), Seabird Seacat and Microcat conductivity and temperature recorders, and Mini Temperature and Pressure Recorders (MTPRs).

Other duties included logistical support for cruises and procurement of supplies, including support and calibration equipment, sensors and instrumentation, hardware parts, and materials.

Environmental Chemistry

Atmospheric Chemistry Program, PMEL

Research Staff: Coffman, Hamilton, Johnson, Miller

Derek Coffman, Research Scientist

Coffman has continued his research of atmospheric aerosols with the Atmospheric Chemistry Group at the Pacific Marine Environmental Laboratory (PMEL). Specifically, Coffman participated in the New England Air Quality Study (NEAQS) research cruise from 12 July – 10 August 2002. The goal of the cruise was to increase the understanding of the processes that influence the air pollution levels in New England. As in the past, Coffman was responsible for various instruments during NEAQS, including a suite of particle-size distribution instruments (two differential mobility particle sizers, one aerodynamic particle sizer) and the group's optical instruments (nephelometer, particle soot absorption photometer).

Coffman continued to reduce and analyze aerosol data from NEAQS and the ACE-Asia cruise (2001). These analyses include calculating thermodynamic properties for the measured aerosol based on chemical composition and calculating optical properties using the previous calculations and the size distribution data.

Drew Hamilton, Research Scientist

Hamilton participated in the NEAQS (New England Air Quality Study) field Project (July 8 – Aug 10, 2002) and conducted radiosonde launches with data reduction, prepared carbon foils, filters and petri dishes for the OC/EC Analyzer, and conducted aerosol optical depth measurements. He also weighed and calibrated permeation tubes, weighed and extracted filters for NOAA monitoring stations, and tested aerosol mast inlet and instrumentation before the NEAQS project.

Hamilton coordinated design and building of the new Chemistry Lab and Aerosol Lab vans and designed the new Hyperbaric Chamber Van for the NOAA Dive Program. He coordinated ship loading and unloading for field projects and coordinated and set up the Aerosol and Chemistry Lab Van before the cruise. Hamilton also ensured the proper disposal of the group's hazardous materials and maintained the MSDS for all chemicals and compressed gases. As part of this responsibility, Drew participates in the PMEL Hazardous Material Response Team.

James Johnson, Research Scientist

NEAQS –2002 (New England Air Quality Experiment)

Johnson started the fiscal year by traveling to Charleston, SC to help set up equipment and take measurements on the NOAA Ship *Ronald H. Brown*. He was on the *Brown* for the first half of the project when he had to leave to travel to Alaska to work the automated underway DMS system (see below). After the project he was involved in reducing data and putting it on his group's web server.

DMS underway system
Johnson's group is funded by NASA to develop an automated underway system to measure DMS (Dimethyl Sulfide) in seawater for use on ships of opportunity. Last year he installed this on the NOAA Ship *Miller Freeman* and it ran in an automated, unattended mode for 5 weeks, before it had a critical malfunction. In December 2002 – and January 2003 he redesigned several critical parts and redeployed the system on the *Miller Freeman*. The ship left Alaska at the end of January, and the system has since logged 125 days of data collection. The ship emails the data back to PMEL each day. Johnson has developed a web page to give interactive displays of the current DMS data (saga.pmel.noaa.gov/underwaydms/).

DMS data server
Johnson has worked on a project to put the global database of oceanic surface seawater DMS measurements on a web-based interactive server. This database is now active and online at saga.pmel.noaa.gov/dms/. This data server allows users to select DMS data by time and/or region.

Data collection system
Johnson has continued to improve the hardware and software for his group's main underway data logging system. He has worked on adding a new capability for the system to write its data to a mySQL database running on a networked server. A second part of this project is to enable a web server to access that data on the database and display the data in real time. He has recently added the capability for the system to plot underway data as color-coded values on a two-dimensional map with coastlines so that measurements can be visualized as they are collected. His group intends to use this data-display capability on a research ship during their next major research cruise.

Theresa Miller, Research Scientist
Miller participated in the Northeast Air Quality Study (NEAQS) from July 12-August 11 while aboard the NOAA Ship *Ronald H. Brown*. It was a multi-institutional research project focusing on air quality prediction and monitoring, weather and climate-related issues in New England. Scientists aboard the ship were mainly focusing on tracking the transport and transformation of air pollution. To this end, she was again responsible for the shipboard ion chromatography (IC) analysis of sampled, filtered aerosol. She also assisted with the real-time chemical analysis of sub-micron aerosols using the new particle-into-liquid-sampler (PILS) – IC.

Back in Seattle, Miller's regular duties include maintaining and analyzing aerosol samples from our existing network of sampling sites. This past year a new site at Trinidad Head, CA was added to our sites at Bondville, IL; Barrow, AK; and a rural station in northern Oklahoma. She is also continuing to analyze aerosol samples from Denali National Park and Poker Flats Research Stations in Alaska as part of an on-going study monitoring the arctic haze episodes.

Chlorofluorocarbon Tracer Program, PMEL

Research Staff: Menzia, Spillane

Fred Menzia, Research Scientist

Menzia finalized CFC data from two previous cruises: the repeat of P15S and SR3. He helped with the preparation and distribution of CFC standards for use in the upcoming WOCE repeat cruises.

Menzia arranged for the shipment of sampling apparatus to the Black Sea for the collection and subsequent analysis of water samples for CFCs in the lab at PMEL.

He prepared the laboratory container for shipment to the NOAA Ship *Ron Brown* for the A16N repeat cruise. He arranged for that shipment when the van was prepared.

Menzia collaborated with the aerosol measurement program at PMEL. He worked on both ongoing station work and helped prepare samples for cruises and run samples returned from cruises.

He has begun to work on an analytical system for the measurement of the alkalinity of seawater in the lab and at sea. The group will also adapt this system to potentially measure pH in the future.

Michael Spillane, Research Scientist

Spillane collaborates with Jim Overland in the investigation of Arctic climate change, and is a member of the EPIC and Science Applications support groups at NOAA/PMEL. With a background in oceanographic data analysis and numerical modeling, his tasks include maintenance and upgrades to the EPIC data analysis program suite, user support for the Ferret and Plotplus packages, Fortran and Unix shell programming, and the development of systems to make available, visualize, and display various datasets locally and via the web.

Spillane is assisting Jim Overland of PMEL in the acquisition and analysis of indicator series of physical, chemical, and biological processes in the Arctic region where evidence of environmental change in recent decades is mounting.

Spillane continues to be involved in the numerical modeling of the physical environment of the Shelikof Strait region of the Gulf of Alaska. He is analyzing the results from 1978 to 2002 in support of fisheries studies to determine whether circulation variability can help explain the major fluctuations observed in fish stocks.

Spillane has contributed to the maintenance and update of various databases provided by the EPIC and Ferret groups at PMEL. He assists users in accessing information from these and remote databases and in disseminating their results via the web. Among the operational analysis and visualization tools provided by NOAA/PMEL are the EPIC program suite, Ferret, and Plotplus. As part of the SCIAPP (Science Applications)

support team, Spillane assists local and remote users in applying these tools in their research and addresses the day-to-day problems that arise.

Marine Carbon Program, PMEL

Research Staff: Cosca, Sabine, Sonnerup

Cathy Cosca, Research Scientist

Cosca's primary work is to measure and analyze CO_2 fluxes across the air-sea interface in the Pacific. This work involves maintaining and improving software and instrumentation on board NOAA research vessels to measure CO_2, writing software to quality assure the data which is transmitted on a weekly basis, analyzing the data, and writing technical reports and scientific articles pertaining to the data, and creating and maintaining web sites to distribute the data to the public. Her research interests involve predicting CO_2 distributions, particularly in the equatorial Pacific, utilizing measurements of temperature, salinity, and chlorophyll.

To accomplish her responsibilities as a research scientist, she maintained a CO_2 sensor on one of the NOAA vessels and visited the ship twice to implement improvements to the system. She continued to process and analyze the data which she received weekly, and created new maps of CO_2 distributions in the equatorial Pacific through April 2003. She provided programming and graphical support to the CO_2 group at NOAA

Cosca plans to continue improving and maintaining the CO_2 system on board the NOAA Ship *Ka'imimoana*. She will continue to process and analyze underway CO_2 data in the equatorial Pacific. She will create a new web site to manage and display real-time data gathered from two new buoy-mounted CO_2 systems and will assist in the development and deployment of two new underway systems to measure CO_2 distributions from ships of opportunity.

Christopher L. Sabine, Research Scientist

Sabine's research focuses on understanding the global carbon cycle. In particular, his work centers around interpreting inorganic carbon measurements in the oceans. This includes understanding the air-sea exchange of CO_2 at the ocean surface, examining the basin-scale distributions of both natural and anthropogenic carbon in the ocean's interior, understanding multiple tracer relationships (e.g. anthropogenic CO_2 and CFCs), evaluating ocean carbon cycle GCMs with data-based global carbon distributions, and examining carbonate and organic matter remineralization within the oceans. Sabine's responsibilities include helping to determine the research priorities of NOAA's marine CO_2 program and helping to supervise and direct the daily activities of the CO_2 group (including maintenance/development of sea-going measurement capabilities, and participating in national and international working groups and planning activities that affect his area of study.

Rolf Sonnerup, Research Scientist
Sonnerup computed recent changes in dissolved inorganic carbon (DIC) and its isotopic composition in the Pacific Ocean based on a multiparameter regression comparison of 1970s with 1990s data. He also took a multiparameter optimization approach to computing total anthropogenic CO_2 along the WOCE sections and modified it to yield smaller errors overall. He computed column burdens of CFC-11 and -12 in the Pacific basin based on the WOCE CFC data set, and he evaluated the constraint that CFC inventories place on anthropogenic CO_2 inventories in the oceans.

The above multiparameter approach was augmented to track the d13C of DIC and organic matter so that the oceanic Suess effect since pre-industrial time could be estimated from the modern-day OACES/WOCE data set. Modifications to the MIX approach afford more efficient computation of the most probable carbon isotopic (13C) change on a more objective basis, i.e., with less guesswork.

Sonnerup evaluated the constraint that oceanic 13C changes place on GCM simulations of oceanic uptake of anthropogenic CO_2. He implemented $13CO_2$ in the Princeton model's carbon cycling simulations, and adapted the code to run on workstations at PMEL. Presently both biotic and abiotic versions of $13CO_2$ cycling in a base rendition of the model's circulation field are running to attain equilibrium with the pre-industrial atmosphere, a process which takes several thousand model years. He constructed a reservoir model of the Sacramento/San Joaquin Delta and used it to estimate in-delta productivity of dissolved organic carbon.

Sonnerup used a diagnostic model of thermocline ventilation in the North Pacific Ocean to estimate the magnitude of mixing impacts on CFC ages.

Submarine Hydrothermal Venting Program, PMEL

Research Staff: Butterfield, Lebon, Martin, Resing, Roe

David Butterfield, Research Scientist
The primary goals in vent fluid chemistry are to understand sub-seafloor hydrothermal processes and the water-column signatures they generate. Hydrothermal vents represent outcrops on the seafloor of different portions of the thermal and chemical gradients in the sub-seafloor hydrothermal system. By measuring a suite of major, minor, and trace elements in vents with a range of temperatures and geological settings, we can infer what reactions are occurring in the sub-seafloor, and how different types of venting affect global ocean fluxes and budgets. Vent chemistry also provides an essential environmental background for studies of hydrothermal biology.

Butterfield's laboratory is involved in three major areas of inquiry: time-series studies to understand temporal variability on a range of scales in hydrothermal systems, studies of diffuse fluids to understand the processes that generate diffuse flow, how they vary in time and space, and how they contribute to hydrothermal fluxes and plume composition, and studies of the interaction of geochemistry and microbial activity below the seafloor to understand if and how microbial communities depend on the geochemical environment.

These three areas have dictated the direction of field and laboratory studies and will continue to do so in the next few years. These areas of study are firmly integrated into the growing observatory effort at Axial Volcano and the Endeavour segment of the Juan de Fuca ridge. Butterfield's lab is at the forefront of the study of diffuse hydrothermal fluids and in using innovative technology to monitor hydrothermal processes.

Butterfield's lab has been analyzing the large suite of samples collected in 2000 - 2002, and most measurements on those samples are complete. Many samples were collected in April/May at the recently discovered Lost City field near the Mid-Atlantic Ridge, and samples are being collected from June-September 2003 along the Juan de Fuca Ridge.

Research Expeditions and Project Summaries
Vents New Millenium Observatory (NeMO), Ocean Exploration Expedition
The NeMO satellite/acoustic link observatory at Axial Volcano was successfully installed again, with two interactive samplers and a bottom pressure recorder. Progress continues in the development of this new and difficult technology to monitor the composition of hydrothermal vents in an active volcano. Water samples were collected again at Axial Volcano using the hydrothermal fluid and particle sampler. At Explorer Ridge, north of the Juan de Fuca ridge off of Vancouver Island, hydrothermal vents were mapped and sampled. Analysis is underway. Galapagos vents were sampled and analyzed in 2002.

Life in Extreme Environments Project
Butterfield collaborated with H. P. Johnson, John Baross, and his graduate students on linking the microbial community structure and hydrothermal fluid composition at two sites on the Juan de Fuca ridge (NeMO Axial Volcano observatory and the Main Endeavour Field) and two sites on the eastern flank of the Juan de Fuca ridge (Baby Bare seamount and Ocean Drilling Project Hole 1026B). The fieldwork for this project went well, including the successful use of a new breakaway coring instrument to penetrate 1.5 to 3 meters below the seafloor at Baby Bare seamount and collect fluids from the stainless steel spikes. Fluids were also recovered from Ocean Drilling Program Hole 1026B, Endeavour Main Field, and Axial SE caldera. The second of two cruises will take place in July 2003 as part of this project to understand sub-seafloor microbial communities in varied environments, including active, volcanically driven hydrothermal systems on the Juan de Fuca ridge axis, and older hydrothermal systems operating at lower temperatures on the east flank of the Juan de Fuca ridge.

Keck Foundation Proto-Neptune
Butterfield is working with a large cast of investigators from the University of Washington and several other institutions on experiments to link seismic activity and hydrothermal processes (especially chemical and microbiological processes) along the Endeavour segment of the Juan de Fuca ridge. This work involves instrument development and experiments in the field.

Lost City vent field, Mid-Atlantic ridge
Butterfield and Kevin Roe participated in a research cruise to the peridotite-hosted Lost City vent field on the mid-Atlantic ridge from April 21- May 20 2003. A large number of

samples from a range of vents in the new class of hydrothermal field were recovered. The Hydrothermal Fluid and Particle Sampler were used on the submersible *Alvin*. A large portion of the heat coming from this system may result from exothermic chemical reactions between seawater and mantle rocks (peridotites).

Geoffrey Lebon, Research Scientist
Lebon's primary responsibilities include calibration, maintenance, and operation of the XRF system and SEM system at PMEL. This equipment is used to analyze particulate samples from the NOAA Vents program as well as aerosol samples from the Ocean Climate Program. Other users include NMFS and the UW School of Fisheries and Oceanography.

In the past year, Lebon represented PMEL on the Ocean Exploration cruise aboard University of Washington's *Thomas G. Thompson*. Duties included sampling for trace metals in search of a possible active seafloor vent sites. Lebon also participated on the Vents cruise aboard the R/V *Thompson* to collect samples for particulate analysis and oversee deck operations of the CTD.

Bill Martin, Research Scientist
Over the past year Martin's work has been split into four areas. He has been working in the lab performing different chemical analyses on hydrothermal vent fluid samples. He has been using a thermodynamic modeling program to model in situ vent fluid chemical characteristics. Martin has also been working with NemoNet data, performing data analysis, and developing realtime display on the web. He also prepared for and sailed on several research cruises.

Joseph Resing, Research Scientist
Resing directs and conducts field and laboratory research on the chemistry of hydrothermal vents and their resultant hydrothermal plumes. By understanding, identifying, and detecting tracers of hydrothermal activity in these plumes, he delineates the chemical and physical state of subseafloor hydrothermal processes. His research contributes to understanding the impact of hydrothermal venting on the biogeochemical cycles of elements in the ocean, with emphasis on the impact of submarine volcanic carbon dioxide on the carbon cycle. He detects elemental tracers using both bench-top and in situ chemical technologies and continues to develop and identify new technologies. The technologies that he develops are also applicable to understanding trace element dynamics in the ocean, including understanding the origin and fate of trace elements in the ocean.

To achieve these ends, Resing participated in a variety of field activities in FY 03-04. He participated in cruises to the Explorer Ridge and Axial Volcano in the NE Pacific, and to the Mariana Arc Submarine Volcanos in the Western Pacific. In addition, he is part of a research effort to examine patterns of aerosol Fe-deposition to the world's oceans, and he has placed instruments to measure iron concentrations in the Gulf of Alaska. One of his most significant findings in 2003 was the presence of Fe-rich volcanic emissions from

the Marian Arc Volcanos to the oceans. Of the volcanos with large Fe plumes, six were within 450m of the oceans surface, making these volcanos potentially large sources of Fe to the surface oceans.

Kevin Roe, Research Scientist
Roe's research interests are in the inorganic chemistry of vent fluids and the identification of chemical reactions that occur in sampling equipment that mask in situ conditions.

Roe participated in four research cruises totaling 95 days at sea. The first was the fifth annual trip to Axial seamount as part of the NeMo program (NEw Millennium Observatory) and included revisiting the Explorer Ridge off Vancouver Island, B.C. Roe used the fluid sampler in conjunction with the Canadian submersible ROPOS to get samples and led the processing of Remote Axis Sampler (RAS) samples. The second cruise was called LEXEN (Life in EXtreme ENvironments) where he ran the High Temperature Fluid Sampler (HFS) that was aboard the new Woods Hole Oceanographic Institute submersible JASON II. In addition to HFS samples, Roe processed samples from a new system, the Lang Sampler (LS) and processed three deployments of the LS sampler and one RAS sampler deployment. He also stood a frame grabbing/data logging watch during the LEXEN cruise. The third cruise was an Atlantis/*Alvin* cruise to the Lost City site, 15 km off axis from the mid-Atlantic ridge and he was the lead scientist aboard one *Alvin* dive, to direct fluid sampling. Otherwise, Roe was engaged in maintenance and set-up of the fluid sampler before each deployment and analysis of sulfide, ammonia, and silica from the fluid sampler and titanium syringe samples. The fourth cruise of the year was a JASON cruise to the Endeavour Ridge hydrothermal fields where he was responsible for all of the inorganic analyses of vent fluid sampling. His onshore analytical results included ICP-MS trace element analyzes of vent fluids; flame and flameless atomic absorption and emission spectrophotometry for iron, manganese, and lithium; some titrations for calcium and chloride; and ion chromatography for major elements. Roe also processed two RAS sample sets from a year-long deployment in the land-based laboratory after these samples were delivered at Pier 66.

Estuaries

Estuaries Research Program

Research Staff: Burger, Newman, Titov, Venturato

Eugene Burger, Research Consultant

Burger supported the development of the OAR Science Information System. Software changes were implemented on this system during the last year to give users access to new project funding data. The team migrated existing software, and added new software to facilitate the system to accept data from a new data source. Burger traveled to DC to coordinate with other NOAA line offices on the rollout of the new data provider. Two new databases, one an Oracle and the other an SQL Server, were installed to enable this data migration and conversion. He compiled the specifications for the new data server on which these databases are housed. He wrote software that runs on the SQL Server to do the data conversion. One of the Science Information System components was altered to accept the new data. Although the initial port to the new data source was completed in February 2003, he has been working on maintaining these databases and adding capability for new datasets.

Burger investigated link-checking software available on the market that would allow automated link checking of the numerous PMEL data access websites, and presented results at the OAR Web Shop.

Burger wrote a test web services application to test the applicability of this software with the OAR Science Information System. This demonstration application allowed a user to access the log up data downloads the team did from one of the data service providers.

Jean Newman, Research Scientist

Newman participated in research on tsunami and sea level dynamics. She designed and implemented user tools for the FACTS (Facility for the Analysis and Comparison of Tsunami Simulations) custom LAS (Live Access Server) interface. Newman developed, maintained, and documented computer codes and databases for the DART (Deep-ocean Assessment and Reporting of Tsunamis) system and the modeling, analysis, and display of data. She used DART and FACTS to develop tsunami forecasting tools for emergency managers and ran the MOST tsunami propagation model, interpreting results for reasonableness and troubleshooting code. She also developed and managed web pages and FTP data repositories.

Newman generalized code and added access to the DART database through the FACTS DART Interpretive Aid. She developed a first-estimate tool that uses only earthquake magnitude and location to simulate a tsunami in FACTS. Implemented data inversion in FACTS to find a best fit of the model data to the DART data. Managed the PMEL tsunami web site and the FACTS web site.

Vasily Titov, Research Scientist
Titov is involved with developing Tsunami forecasting tools in collaboration with the Tsunami Warning Center. He has implemented the tsunami data inversion scheme in collaboration with the Russian Academy of Sciences. He has also begun implementing the modeling tools into the Pacific Tsunami Warning Center procedures.

Titov serves as Associate Director for the Center for Tsunami Inundation Mapping Efforts (TIME). He has delivered the model results for the Tsunami Inundation Mapping of Seattle and the Inundation Map is being published by the state. Model runs for Bellingham and Anacortes are complete. The MOST model has been transferred to the Institute of Ocean Sciences (IOS), Canada. IOS has developed a tsunami model for Victoria, Canada in collaboration with TIME.

Angie Venturato, Research Scientist
Venturato is the primary support scientist at the NOAA Center for Tsunami Inundation Mapping Efforts (TIME). Her primary responsibilities include acquiring and assessing elevation data for use in numerical model simulation, archiving data and related materials for the National Tsunami Hazard Mitigation Program (NTHMP), contributing to scientific articles and reports, and developing GIS tools to increase efficiency within the program.

Venturato has developed 26 digital elevation models for use by modelers in Alaska, California, and Washington. She has contributed to a number of reports concerning potential tsunami hazards, tidal modeling efforts, GIS analysis, and model results. In addition, she has been learning to conduct inundation model runs and source scenario research.

Fisheries Recruitment

Cooperative Investigations on the Essential Fish Habitat for Alaska's Marine Fishery Resources, AFSC

Research Staff: Yeung

Cynthia Yeung, Research Scientist

Yeung's principal research focus has been on the community structure of benthic invertebrates in the eastern Bering Sea. This project is being carried out in collaboration with the Habitat Team of the Resource Assessment and Conservation Engineering (RACE) division of the National Oceanic and Atmospheric Administration (NOAA) Alaska Fisheries Science Center. Records of invertebrate bycatch in the eastern Bering Sea groundfish trawl surveys from 1982 to the present are being reviewed and standardized. These data are being used in multivariate analyses to elucidate community ecology, characterize benthic habitats, and discern fishing and environmental effects on these habitats. Forthcoming results will be the basis for developing projects to measure and assess the quality of habitat essential to important fishery resources. Her field research thus far has included the participation in the summer groundfish trawl survey in the Gulf of Alaska in June 6 – 24, 2003 to gather general background information on the Alaskan ecosystem.

Yeung's consultation and collaboration continue with the NOAA Southeast Fisheries Science Center and the University of Miami Rosenstiel School of Marine and Atmospheric Science on fisheries oceanography and larval ecology research.

Fisheries-Oceanography Coordinated Investigations Program, PMEL

Research Staff: Bahl, Bond, Denbo, Dobbins, Fabritz, Hermann, Jenkins, Merati, Moore, Rodionov, Sullivan, Wang, Zhu

Kimberly Bahl, Research Consultant

Kimberly Bahl began work in October 2002 as the web and database administrator for the North Pacific Ocean Theme Page (www.pmel.noaa.gov/bering/) and the North Pacific Ecosystem Metadatabase (www.pmel.noaa.gov/bering/mdb/np). Work involved maintaining the website and metadatabase and collecting project theme-related metadata. Special projects were to upgrade the metadatabase from Microsoft Access 98 to 2000, rename and readdress the website with automatic forwarding, expand metadata holdings from the Bering Sea to North Pacific, add expanded research information from the Bering Sea to North Pacific Ocean, and create an automated e-mailer.

Nicholas Bond, Research Scientist

Bond conducted research in three primary areas. (1) He completed his study on the effects of the Madden-Julian Oscillation (MJO) on precipitation and flooding in the Pacific NW, and related work involving the MJO's impact on the Arctic has been carried out. (2) His work in support of FOCI consisted of evaluating time series of air-sea interactions in the Bering Sea and Gulf of Alaska, and collaborating on other high-

latitude climate-ocean-ecosystem investigations. (3) He continued his efforts supported by PACS involving the collection and analysis of PBL observations in the eastern equatorial Pacific. The bulk of this work consists of analysis of data from the Eastern Pacific Investigation of Climate Processes (EPIC) program.

Donald Denbo, Research Scientist
Denbo's primary responsibilities include EPIC, a Pacific Marine Environmental Laboratory (PMEL) project providing data analysis tools, OceanShare, a NOAA/High Performance Computing and Communications (HPCC) funded project to enable collaborative exploration of data and model results, development of a network-enabled data-based query tool funded by NOAA/HPCC, enhancing the Secure Document Repository (SDR), a NOAA/HPCC funded project to simplify management of the SDR, Active Presentation, a NOAA/HPCC funded project to create an easy-to-use Model/Data presentation application, Network Tools, a NOAA/HPCC funded project to develop tools to determine network bandwidth and improve communications throughout and an ESDIM project to allow Open-source Project for a Network Data Access Protocol (OPeNDAP) access to the Climate Data Portal.

As EPIC manager, Denbo works closely with PMEL researchers to meet their local data management needs. He continues to provide tools, like ncBrowse, that PMEL researchers are using to improve their exploration of data stored in netCDF files (Over 3700 unique sites worldwide have downloaded ncBrowse since its March 20, 2000 release.) Denbo is also a resource to PMEL researchers on modeling, data analysis, and visualization.

Denbo has updated and expanded the capabilities of OceanShare, a collaborative tool for the interactive exploration of ocean data by teams of researchers. OceanShare was rewritten to use JavaSpaces to create the collaborative capabilities. JavaSpaces replaces Habanero, which has not been actively supported since 1999. OceanShare was also enhanced with new annotation capabilities and the ability to have persistent sessions. OceanShare is freely available on the web.

Denbo has developed and distributed the Scientific Graphics Toolkit (SGT) version 3.0Beta, a Java package that is used in many of the projects described above. SGT has recently been extended to enable novice users access to Java scientific graphics through the SGT Beans interface. The SGT class library and source code are available from the web.

Denbo extended ncBrowse to allow OPeNDAP users to browse their netCDF compatible data files using ncBrowse. Donald also oversaw the addition of 3-D visualization capabilities to ncBrowse using the Visualization for Algorithm Development (VisAD) library. The software and source code are freely available on the web.

Elizabeth Dobbins, Research Scientist
Dobbins's main responsibility is to maintain, update, and run the North Pacific (NPAC) and Northeast Pacific (NEP) configurations of Regional Ocean Modeling System (ROMS) in support of Al Hermann's modeling efforts. Major improvements were made

to the ROMS code this year. Dobbins upgraded to ROMS 2.0 and helped with debugging this new version. She added a biology module based on Sarah Hinckley's 10 compartments Nutrient - Phytoplankton - Zooplankton (NPZ) model, and experimented with several methods of differentiating inshore and offshore water using iron; she also developed a 1-D configuration of ROMS for testing the biological module and compared the results to those of the original C code.

Dobbins also developed several new types of forcing files, adding biological variables, variables required by the new bulk flux atmospheric formulation, and year-specific river data, and creating climatological averages of all these. She created several MATLAB scripts to automate the generation of forcing files, including the new types of files required by ROMS 2.0. She also ported the code to an upgraded supercomputer cluster and a smaller LINUX cluster used by colleagues Tom Powell and Craig Lewis at the University of California at Berkeley.

These advancements made nesting the NEP model within the NPAC model possible, a key GLOBEC goal. Dobbins also worked with Nick Bond and Rick Steed, at UW, to use their high-resolution atmospheric model of the Gulf of Alaska to force the NEP model, another GLOBEC goal.

Jason Fabritz, Research Consultant
Fabritz participates in research with observational oceanographic and meteorological data sets and numerical model results, including time series data and hydrographic data. He performs research in the development of collaborative tools for the display and analysis of scientific data, distributed object technologies, computer data visualization, Geographical Information System (GIS) integration, and distributed data access utilizing client/server architectures. His software development uses state-of-the-art computer technologies and techniques including Java, JDBC, XML, XSLT, MySQL, Microsoft, and ESRI technologies and object-oriented analysis and design principles.

Over the past year, Fabritz has worked with the Financial Database Management System (FDMS) team to create a consolidated on-line reporting system for NOAA budgetary information. The system retrieves information from various database sources and provides a central consolidated view of the information on an intranet website.

Fabritz continued to extend and improve ShipTracker, a system that provides an external website showing near real-time observational information from NOAA ships at sea. The automated system processes messages received through NOAA ship operations from vessels at sea and displays this information on a public website. Additionally, he leveraged this effort on other projects, including a site that plots the movement of beluga whales in Cook Inlet, Alaska.

Fabritz continued to work to improve and expand the previously created library of software named Carta. Carta, written in the Java programming language, provides utilities for translating GIS data between different formats.

Albert Hermann, Research Scientist
Hermann's primary responsibilities are to develop and implement regional ocean circulation models, collaborate with fisheries and biological oceanographers on the development and coupling of biological models with physical models, develop techniques for visualizing three-dimensional output, compare output with field data, and publish results in peer-reviewed scientific journals. This work contributes to explorations of how physical factors on multiple time scales affect the dynamics of coastal marine ecosystems in general and economically important fish stocks in particular. A general summary of research activities is available through his web site: www.pmel.noaa.gov/~hermann; also see www.pmel.noaa.gov/~dobbins/nep.html.

In previous work, a global circulation model was coupled to a regional circulation model of the Coastal Gulf of Alaska (GOA-1), and results compared with Lagrangian and Eulerian data from the region. A regional model of the Bering Sea was also developed.

In the past two years, in collaboration with colleagues, Hermann has developed and improved one of a suite of nested physical and biological models to serve GLOBEC, SSLI, and FOCI programs. Each of the nested physical models is based on the Regional Ocean Modeling System (ROMS), a primitive equation circulation model with highly efficient mixing and advection schemes. These models have been implemented on a distributed memory, massively parallel computing platform at the Forecast Systems Laboratory of NOAA, with generous assistance from their staff. The implementation of parallel code has allowed Hermann's group to run the model at much finer resolution, and for much longer time periods, than were previously possible.

Developments toward a multi-scale nested modeling system in the past year included upgrades of ROMS-based primitive equation models of: the North Pacific at 40 km resolution (NPAC), the NE Pacific (from Baja, California through the Bering Sea) at 10 km resolution (NEP), and the Gulf of Alaska at 2.5-km resolution (GOA-2, in collaboration with researchers at the University of Alaska Fairbanks). NEP model hindcasts of years 1997-2001 have been compared with satellite and moored data from the Gulf of Alaska. Models of California at 2.5-km resolution, and the eastern equatorial Pacific at 10-km resolution, have been developed by colleagues, using the output from NEP and NPAC models as boundary conditions. Improvements to our modeling approach in the past year include the use of bulk formulae for atmospheric forcing, and more accurate pressure gradient algorithms developed by the ROMS group.

A lower trophic level (NPZ) model with emphasis on juvenile salmon prey items has been implemented in three-dimensional form, ultimately to be driven by circulation model output. Prey fields generated from the NPZ model will be used in bioenergetic-based models of salmon, developed with other researchers within GLOBEC. An initial coastal NPZ model is being expanded to include the deep ocean; in particular, new algorithms to account for iron limitation have been developed.

A new initiative within the MEAD program entails coupling an atmospheric model (WRF) with an ocean model (ROMS) across nodes of the Teragrid. Hermann is involved

as a scientific user/tester of this system. A related program, funded by HPCC, entails coupling these models across platforms within NOAA.

In the past year, Hermann and colleagues have implemented new hardware to allow large-screen, web-based immersive (stereographic) visualization at very low cost. The system uses passive filters and commodity (that is, low-cost) projectors and screens. Systems of this type are commonly known as "Geowalls."

Hermann was recently appointed affiliate faculty, University of Washington Department of Oceanography.

Antonio Jenkins, Research Scientist
Jenkins is working with the Fisheries-Oceanography Coordinated Investigations Group (FOCI) in support of the Steller Sea Lion Research Programs, FOCI base, and United States Global Ocean Ecosystems Dynamics Program (U.S. GLOBEC). He troubleshoots, maintains, and upgrades oceanographic instruments aboard the charter fishing vessel *Great Pacific*. These instruments observe and record oceanographic parameters in conjunction with zooplankton and juvenile salmon net tows in efforts to relate abiotic variables to the distribution of young salmon. Jenkins is also responsible for processing the data collected by these instruments. Data was collected during mid-July to early-August of 2001 and 2002. Acoustic Doppler Current Profiler (ADCP) data collected during these periods was processed by Jenkins. He also took part in a FOCI study aboard the NOAA Ship *Miller Freeman* on October 4-9, 2002. The purpose of this cruise was to investigate the physical, chemical, and biological mechanisms acting in the coastal Gulf of Alaska. This study was also in support of the programs listed above. Jenkins has recently been involved in troubleshooting the ADCP aboard the *Miller Freeman*, and designing instrumentation to measure physical and biological oceanographic parameters aboard a vessel of opportunity operating in the Gulf of Alaska in support of a proposal to fund such work.

Nazila Merati, Research Scientist
Merati's work was mainly in support of data integration, access, and visualization using GIS. Merati worked on several NOAA-funded projects including data rescue of North Pacific Sea CAT data, integrating real-time data from ships and marine mammals into GIS based map services. Merati successfully completed work with other visualization experts for a tech transfer of visualization expertise to the National Marine Mammal Laboratory and the National Marine Sanctuaries Program of NOAA. Merati spent time managing and assisting with shiptracking projects with the NOAA Marine and Aviations Operations. Merati also worked with other scientists to develop GIS geoprocessing tools to create tools for web-based GIS processing and map serving.

Merati was successful in securing funding on two new projects with NOAA PIs. The first project is to develop enhancements to the Motion Tracker system of creating real-time maps via Internet Map Servers for tracked objects. The second project is to explore the use of bar coding and wireless devices to help facilitate the deployment and retrieval of NOAA/PMEL buoy systems in the North Pacific.

Merati continued to work with the Marine Data Model Group tasked with developing an GIS based model for inputting marine data types into a geographic information system.

Merati was nominated to the NOAA Enterprise GIS working group by OAR in March 2003. The working group consists of members from each NOAA line office. The group is tasked with assessing the needs of NOAA for an enterprise-wide GIS system.

Christopher Moore, Research Scientist
Moore is involved with the development and implementation of a coupled ocean and atmosphere primitive-equation model run on massively parallel machines, high-end graphics interfaces for visualization of model output and in-situ data, and networking applications that allow for model and visualization packages to run on remote clusters.

Moore splits time on several projects this year. The first project involves coupling a primitive-equation ocean model with an atmospheric model, running on a distributed memory supercluster. This project involves collaboration with researchers at the National Center for Atmospheric Research (NCAR) and Argonne National Laboratory as part of an NCSA project involving running this coupled model over the TeraGrid.

The second project is to create a toolkit that measures network bandwidth to allow client applications to adjust behavior based on network metrics. The project runs on a test network at the Pacific Marine Environmental Lab (PMEL).

Lastly, Moore worked on a project to create a server for 3-D rendered graphics using NOAA's Live Access Server (LAS). This work, done in collaboration with JISAO researcher Al Hermann, is described in detail at www.pmel.noaa.gov/vrml/las.

Sergei Rodionov, Research Scientist
Rodionov's research has been focused primarily on climate variability in the Bering Sea. This research has been conducted within the framework of the North Pacific Research Board (NPRB) project "A Protocol for Detection of Change in the Bering Sea Ecosystem." The goals of the project are to develop several measures of ecosystem status (metrics) for the Bering Sea based on retrospective data and design a protocol for detection and tracking of change. At the first phase of this ongoing project a particular attention was paid to the Aleutian low, which is the main climate feature influencing the Bering Sea. A new classification scheme of atmospheric circulation over the North Pacific based on the strength and geographic position of the Aleutian low has been developed. The obtained types of atmospheric circulation are used along with other environmental variables to keep track of changes in the Bering Sea ecosystem.

To facilitate access to this information a new website devoted specifically to the Bering Sea climate (www.BeringClimate.noaa.gov) was set up, with Rodionov being the lead contributor. Currently the site keeps track of 42 variables organized in five groups: climatic indices, atmosphere, ocean, fisheries, and biology. Each variable is accompanied by a description of its relevance to the ecosystem and analysis of recent trends. Soon the

web site will be expended by adding two new sections: 1) multivariate analysis and 2) regime monitoring. This web site is also a step toward PMEL's contribution to Ecosystem Considerations Chapters issued annually by the Alaska Fisheries Science Center.

Rodionov is also involved in Steller sea lion research. He is the lead author of the forthcoming paper on Aleutian climate variability to be published in a special issue of *Fisheries Oceanography* devoted to the problem of Steller sea lion decline.

Margaret Sullivan, Research Scientist
Sullivan is working on two multi-author manuscripts. One is based in the region of the Aleutian Islands, and will address currents and circulation through the Aleutian passes. This entails working with mooring and NNRP data and in-house software to process and help analyze the data. The second manuscript addresses the Inner Front area on the shelf of the Bering Sea, and the impacts on the ecosystem that are related to current and temperature data fields and productivity.

Sullivan has been processing and working with CTD and SeaCat data from cruises, mooring data, and with an annual body of atmospheric data. She has initiated and is involved in a collaboration to create a comprehensive in-house data archive of mooring data.

Sullivan has taken the lead in getting in-house resources on the web and maintaining these resources. Web work includes a site for pre-cruise mooring planning, a site for access to mooring data plotted from archive data, and upkeep of two major project sites (Steller Sea Lion and GLOBEC. She is using web technologies to tie data and project functions to web interfaces, and has also just began revamping the main PMEL/FOCI web site.

She has continued with data rescue work in collaboration with Alaska Fisheries Science Center (AFSC). After creating a framework of scripts and code and a quality control phase, she has a year of Microbathythermograph (MBT) Trawl data online and publicly accessible through NOAA/PMEL's EPIC data access system. The data are bundled with self-documenting metadata. Data for two additional years have gotten through the QC stage and are close to being added to this data archive. She also acts as liaison between PMEL/FOCI and AFSC for their personnel who need data from our system, want data put into our system, or generally need help with hydrographic data.

Muyin Wang, Research Scientist
Wang continued her research work on climate processes in the middle and high latitudes of the Northern Hemisphere, and their influence on variability in the Pacific basin and Arctic. In particular, during the past year, she constructed the time series of vegetation index over the Arctic (50-90°N) based on Koppen climate classification for the past 100 years using surface temperature data. She also studied the climate variations in the SE Bering Sea, and discussed its relationship with the large-scale modes and extreme

weather conditions. Most of her time is spent on analyzing data from various sources: NCEP/NCAR reanalysis, CRU/UEA, and Satellite NDVI data.

Willa Zhu, Research Consultant
Zhu's primary responsibilities and research interests include several areas: (1) software development and maintenance to support oceanographic and climate research, (2) acting as team leader and supervisor in development of software application and climate data portal project, (3) participating in joint research projects with other universities, NOAA institutes, and data centers, (4) participating in proposal writing jointly with other research institutions, and (5) writing technique papers and reports.

Zhu developed the High-Resolution Multibeam Bathymetry Data Web Access System that provides a centralized repository for the processed high-resolution multibeam bathymetry from the surveys and tools for efficiently disseminating the data in a variety of useful forms (multibeamdata.noaa.gov). She played a leadership role in the design and development of the Ocean Surface Current Analyses – Realtime (OSCAR) web access system. It provides operational ocean surface velocity fields from satellite altimeter and vector wind data (www.oscar.noaa.gov). Zhu developed the Bering Sea climate data web access system, www.beringclimate.noaa.gov. She supported and maintained the UNAAMI time series, www.unaami.noaa.gov/ that provides easy access to a collection of time series data for scientists to study the interrelated atmospheric, oceanic, and terrestrial changes in the Arctic. Zhu continued to provide user support for EPIC software that underlies the oceanographic in-situ data for the Unix desktop and web access. In that context, she is responsible for (a) maintaining, developing, distributing, and documenting the EPIC system library, which provides data file Input/Output for use with the EPIC system for management, display, and analysis of oceanographic and meteorological data, (b) the MexEPS software, an interface between Matlab and netCDF, ASCII, and classic EPIC files, which has been used by oceanographers and graduate students all over the world, (c) the EPIC database (MySQL and postgreSQL) system which provides back-end database access, (d) support local PMEL scientists in using the EPIC software, (e) support the EPIC web browser implemented at the International Pacific Research Center at the University of Hawaii, and (f) EPIC web development and maintenance www.epic.noaa.gov/ and www.epic.noaa.gov/epic/ewb/, the on-line access to oceanographic and meteorological in-situ data sets.

In addition, she is also responsible for maintenance and installation of web (Apache) servers, maintaining the NOAAServer (which provides centralized access to NOAA data at distributed data centers.

Fisheries Oceanography Research Theme: Steller Sea Lion Research Program

Research Staff: Kachel, Ladd, Mordy, Proctor, Righi

Nancy Kachel, Research Scientist

Kachel's primary responsibilities are to process and analyze oceanographic data and lead field operations. Analysis duties include the use of existing software and sometimes the development of innovative analysis techniques. The chief scientist's duties include the development of cruise instructions and coordination of projects and participants, production of cruise reports, and insuring that program objectives are met.

Kachel acted as chief scientist for two research cruises. The first was a hydrographic cruise aboard the NOAA Ship *Miller Freeman* from October 5-10, 2002, which concentrated on nutrient mixing over the banks south and east of Kodiak, AK. The second, which combined physical, chemical and biological research aboard the new research vessel, NOAA Ship Ka'imimoana from April 27 -May 18, 2003, focused on processes affecting the cross-shelf transport and mixing of nutrient-rich waters in the northern Gulf of Alaska. These cruises were in support of the research of the United States Global Ocean Ecosystems Dynamics and Climate Change/NorthEast Pacific/Gulf of Alaska Program (GLOBEC/GOA), a program of the Coastal Ocean Program, Sea Lion Research Studies and Fisheries Oceanography Coordinated Investigations (FOCI).

As part of the FOCI effort related to the North Pacific GLOBEC/GOA program of the Coastal Ocean Program and the Sea Lion Research Studies, Kachel is involved in research, in cooperation with chemical, biological, and atmospheric scientists to ascertain the physical conditions and processes that lead to the high productivity in the Gulf of Alaska. This effort includes data collection, processing, quality control, and analyses.

Carol Ladd, Research Scientist

Since her appointment in July 2002, Ladd has conducted research on the physical oceanography of Alaskan waters, including the North Pacific and the Bering Sea, using a combination of gridded and in situ data. She has participated in interdisciplinary research (collaborating with biologists, atmospheric scientists, and others) focusing on interactions between the physical oceanography, atmospheric forcing, and biology.

Calvin Mordy, Research Scientist

Mordy has worked on projects in both the Ocean Climate and the Ocean Environment Research Divisions (OCRD and OERD respectively) at PMEL. In OCRD, his work relates to understanding ocean circulation and the carbon dioxide cycle. Work was completed on the intercalibration of nutrient data from the World Ocean Circulation Experiment (WOCE), and these results were presented at the "WOCE and Beyond" conference in San Antonio, TX. In the past year, a new long-term global hydrographic monitoring program was proposed and funded through the Climate Variability and Predictability (CLIVAR) program. The initial cruise of this new program sailed from Iceland to Brazil on June 19 - August 11, 2003. Mordy was the primary nutrient analyst, and sailed on the first leg of the voyage.

In OERD, Mordy's work focuses on nutrient supply to the Alaskan shelf, the ultimate food source of this abundantly productive region. He moored four in-situ nutrient analyzers in the Gulf of Alaska, and was responsible for nutrient analysis on five hydrographic cruises as part of the Global Ocean Ecosystem Dynamics (GLOBEC) program. He sailed on one of these cruises (April 18 - May 18, 2003).

Peter Proctor, Research Scientist
Proctor's main emphasis has been on processing and analysis of Conductivity-Temperature vs. Depth (CTD) data that has been accumulated during previous years. The data from 2001 has been completely processed and is awaiting transmittal to the National Ocean Data Center (NODC), the national data repository. Data from 2002 is approximately 70% completed and 2003 data is being processed as it is received.

Proctor has also participated in two research cruises to the Bering Sea and Gulf of Alaska. These cruises were aboard the Canadian Coast Guard ship *Sir Wilfrid Laurier* and the University-National Oceanographic Laboratory System (UNOLS) R/V *Maurice Ewing*, respectively. The *Laurier* cruise was primarily focused on recovering and deploying current meter moorings while the *Ewing's* focus was on a CTD and plankton survey of the Gulf of Alaska.

Dylan Righi, Research Scientist
Righi's research has focused on using the Regional Ocean Model System (ROMS) as a tool to simulate transports in the Gulf of Alaska and Bering Sea regions. Other current projects Righi is involved in are analysis of hydrographic and satellite data studying a 1997 eddy in the Bering Sea and using ROMS simulations in support of a study of transports across the Bering Sea Shelf Inner Front.

Righi also participated in two oceanographic research cruises, both in the Gulf of Alaska. The first was in May – June of 2002 and the second April – May of 2003. His responsibilities on both cruises included the collection and quality assurance of CTD data and management of the scientific on-board computer system. On the 2003 cruise Righi branched out and also took on the role of biologist in the collection of biological samples.

Retrospective Analysis of Ichthyoplankton Data from the Gulf of Alaska: Understanding Ecosystem Dynamics in Relation to Steller Sea Lion Decline

Research Staff: Doyle

Miriam Doyle, Research Scientist
Doyle's primary work is to analyze an extensive set of ichthyoplankton data spanning 23+ years (1977-2000 and beyond) and encompassing the western Gulf of Alaska, the South East Bering Sea, and the U.S. west coast. Doyle is taking the lead in investigating spatial and temporal patterns in occurrence and abundance of species of fish eggs and larvae, primarily in the Gulf of Alaska, and relating the observed patterns to the oceanographic environment. Of particular interest are potential changes that may occur

in spawning patterns and early life history dynamics of fish populations in response to oceanographic regime shifts and climate change in the above regions, particularly the Gulf of Alaska for which the longest time-series of data exists.

Component 1 – trends in abundance: A time-series of Gulf of Alaska spring ichthyoplankton data, 1981-2000, is being examined for interannual trends in occurrence, abundance, and larval size of numerically dominant ichthyoplankton species in the vicinity of Shelikof Strait. Local physical oceanographic data and model output, along with basin-scale climate/ocean indices are being utilized to investigate trends in the ichthyoplankton in relation to interannual trends in ocean temperature, production, and circulation in this region. The goal of the study is to elucidate the potential links between fluctuating ocean conditions and the early life history dynamics of fish species in the northwest Gulf of Alaska.

Component 2 – trends in spatial patterns: The same data are being used to investigate interannual variation in spatial patterns and assemblage structure in the ichthyoplankton of this region.

Early Life History Studies of Individual Species: A review study is underway of the early life history of the forage fish species Pacific sandlance (*Ammodytes hexapterus*) in the Gulf of Alaska, also based on our ichthyoplankton data time-series.

Individual-based Modeling of Steller Sea Lion Foraging Behavior and Bioenergetics, AFSC

Post-Doc: Carlos M. Alvarez-Flores
UW Advisor: John Horne, Research Assistant Professor, Aquatic and Fishery Sciences

Flores worked on developing an individual based model (IBM) of Steller sea lion (SSL) foraging behavior to investigate the potential effect of fisheries-related localized depletions of Pollock, one of the sea lion's main prey. The SSL model simulates foraging trips in which individuals need to search, find, and consume fish. The duration of the trip and the diving behavior are counter balanced with the bioenergetic gain obtained by successful food ingestion and in the case of mature females, their need to return to land to feed their offspring. The SSL model is linked to a three-dimensional model of fish dynamics being developed by a graduate student in the UW School of Fisheries and another model of the dynamics and behavior of the fishing fleet being developed by researchers in the Alaska Fisheries Science Center of the National Marine Fisheries Service.

The main structure of the computer program for the SSL IBM has been developed. Components that represent the travel and diving behavior as well as the bioenergetic process are functional in a coarse way. These components need to be refined to be able to track the internal biological process in a scale of seconds and meters for an animal that may be traveling for at least 24 hours and probably over 100 kilometers. Also, the linkages between the different components need to be improved.

New Metrics for Ecosystem Change: Bio-diversity and Dynamics of Ichtyoplankton Assemblages, AFSC

Post-Doc: Wiebke Boeing, Research Associate
UW Advisor: Bruce Miller, Professor Emeritus, Aquatic and Fishery Sciences

Dramatic changes in the fish community have occurred in the Gulf of Alaska (GOA), which are likely due to regime shifts. Consequences of the 1976 climatic regime shift in the North Pacific Ocean on the ecosystem were only recognized at higher trophic levels almost a decade afterward. Lower trophic levels (fish larvae, zooplankton, phytoplankton) might be most responsive and reflect changes due to environmental perturbations before they propagate upwards and affect higher trophic animals, making them potentially useful as early indicators of ecosystem perturbations. Boeing's research goal is to create a variety of sensitive indices that could be useful for assessing ecosystem integrity and predicting ecosystem change by exploring lower trophic level dynamics, especially the ichthyoplankton. She is analyzing 20+ years of ichthyoplankton data from the Gulf of Alaska (GOA) (collected by the Recruitment Processes Program of the Alaska Fisheries Science Center) to develop new metrics to evaluate ecosystem change. Indices calculated from biological data offer scientists and managers an ecologically based method for assessing ecosystem integrity and evaluating ecosystem change.

Complex System Dynamics and Climate Change, AFSC

Post-Doc: Lorenzo Ciannelli, Research Associate
UW Advisor: Robert Francis, Professor, Aquatic and Fishery Sciences

During the past year Ciannelli has been involved in different projects studying biological biocomplexity in the North Pacific. During these studies he has collaborated with well-known scientists in the field of population biology, marine ecology, biocomplexity, and statistics. The primary focus of his research has been on the shift of density dependence in the recruitment of walleye Pollock in the Gulf of Alaska. Applying state-of-the-art nonlinear statistical analysis, he found that the intensity of density dependence changes according to the background level of environmental variables (predation, temperature, wind). The significance of such a result is profound to the management of pollock (and other marine species) in the face of underlying climatic variability. Results from this analysis are now in review for publication in the Proceedings of the National Academy of Sciences. A sequel manuscript, on the significance of the density dependence results on Pollock recruitment, is ready to be submitted in *Marine Ecology Progress Series*.

Ciannelli has been involved in the analysis of spatial and trophic interactions between cod and capelin in the Bering Sea, in comparison with similar interaction in the Barents Sea. The underlying object is to understand why capelin is the primary prey of cod in the Barents Sea, while it is almost insignificant in the diet of Pacific cod in the Bering Sea. He hypothesizes that the different landscape between these two bodies of water contribute to the different spatial overlap between prey and predators. So far results are validating the hypothesis, in that the spatial overlap in the Bering Sea is strongly influenced by hydrographic features that have minimal interannual variability.

Ciannelli is working with scientists at NMFS AFSC and University of Oslo (Norway) studying the relationship between physical forcing and early life history dynamics of subarctic gadoid fish. His focal area of study is the eastern Bering Sea.

Ecological Forecasting of Walleye Pollock Recruitment in the Gulf of Alaska and Bering Sea, AFSC

Post-Doc: Yong-Woo Lee, Research Associate
UW Advisor: Vincent Gallucci, Professor, Aquatic and Fishery Sciences

Lee started his JISAO research associate position in February 2003. His work is on improving the Pollock recruitment forecast in the Bering Sea and Gulf of Alaska using innovative numerical methods of artificial neural network and fussy logic. Before the actual application of those analytical techniques to real recruitment data, he decided to test the performance of the methods along with other conventional statistical methods that are commonly used for recruitment forecast on the simulated recruitment data with known properties. This will allow the group to compare the methods regarding their weaknesses and strengths in their applications to the recruitment type of data.

Feasibility of Using Ecosystem Metrics to Characterize the Status of the North Pacific Ecosystem and Detect Climate Change Signals, AFSC

Post-Doc: Franz Mueter, Research Associate
UW Advisor: Andre Punt, Research Associate Professor, Aquatic and Fishery Sciences

Franz Mueter joined JISAO in November 2002 to develop, jointly with Bernard Megrey at the Alaska Fisheries Science Center (AFSC), ecosystem metrics for the Gulf of Alaska and Bering Sea ecosystems in support of an ecosystem-based approach to fisheries management. Franz has compiled and is currently analyzing biological and physical time series that may provide useful metrics to describe the status of the Gulf of Alaska and Bering Sea ecosystems.

Climate Change, Hydrographic Fronts, and Energy Flow in Pelagic Forage Fishes in the Gulf of Alaska Ecosystem, AFSC

Post-Doc: Jari Paakkonen, Research Associate
UW Advisor: David Beauchamp, Assistant Professor, Aquatic and Fishery Sciences

Bioenergetics modeling was used to integrate fish distribution, size and diet data with environmental variability (°C, prey) for evidence of geographic variation in the production of potential prey species for Stellar seal lions. The research started with walleye pollock (Theragra chalcogramma) because of their importance in the diet of Stellar sea lions and because model parameters were already available. Oceanographic features (e.g., fronts) may be associated with high productivity and therefore represent optimal sea lion foraging areas. The study is based on data collected during September 2000 and 2001 between the Shumagin Islands and Shelikof Strait. The objective of the study is to examine the effect of environmental conditions and food web structure on

energy acquisition and energy allocation of juvenile walleye pollock in the Western Gulf of Alaska. A bioenergetics model was used to examine how the food consumption and growth rates of walleye pollock are influenced by prey type.

Biophysical Models of Pollock Recruitment in the Gulf of Alaska and Bering Sea, AFSC

Post-Doc: Carolina Parada, Research Associate
UW Advisor: John Horne, Research Assistant Professor, Aquatic and Fishery Sciences

Parada is using a set of biophysical computer simulation models to examine the recruitment of walleye pollock in the western Gulf of Alaska. These models integrate the early life history of pollock, a nutrient-phytoplankton-zooplankton model that provides food to the young pollock, and a three-dimensional current model to transport pollock and their prey through the western Gulf. Initial tasks include revising the computer code and adding additional biological terms to the models. The goal is to design model simulations to quantify the relative importance of factors influencing recruitment of walleye pollock.

Task III Program

The Task III program supports University of Washington research in areas compatible with the Institute's major research themes.

Task III Funded Research Programs

Climate and Global Change: Center for Science in the Earth System (CSES)

CSES: Climate Dynamics Group

Director/PI: Sarachik
Faculty Collaborators: Battisti, Kamenkovich, Sarachik, Wallace
Research Staff: Mitchell, Vimont
Graduate Students: Biasutti, Li, Roberts, Yin

Edward Sarachik, Professor, Atmospheric Sciences
In addition to his role as project director, Sarachik has been involved in many of the projects described below. Much of his effort has been devoted to the leadership activities described at the end of this section.

David Battisti, Professor, Department of Atmospheric Sciences
The Tropical Atmosphere-Ocean (TAO) array of moored buoys in the tropical Pacific Ocean is a major source of data for understanding and predicting El Niño/Southern Oscillation (ENSO). Despite the importance of the TAO array, little work has been performed to date on the number and locations of observations required to predict ENSO effectively. Battisti's study begins to answer these questions by performing a series of observing system simulation experiments (OSSEs) with an intermediate, stochastically forced, dynamical ENSO model. The experiments demonstrate, first of all, that it is possible to use an OSSE framework to compare different observing networks for ENSO prediction. They also indicate that, at least using this model and experimental setup, subsurface ocean data is relatively unimportant for ENSO prediction compared to sea surface temperature data. To the extent that the simplified model dynamics represent ENSO dynamics accurately, these results suggest which observations and which regions are most important for ENSO prediction. In short, this study provides insights on how to design a cost-efficient observing system that will suffer a very small degradation of forecast skill (compared to the 'perfect forecast').

With graduate student Will Roberts, Battisti has used a different approach to examine the relative importance of SST and subsurface data on the skill of the ENSO forecasts. In the second part of this study they also uncovered, to their surprise, that the tropical Atlantic SST anomalies provide some important predictive skill for ENSO, two to three seasons in advance.

Igor Kamenkovich, Research Professor, JISAO
Kamenkovich's research supported by NOAA focused on a role of the oceans in climate and on climate variability in the Southern Ocean. In particular, one of his currently active projects is an investigation of variability in the surface winds and in the sea surface temperatures in the Southern Ocean. Another study addresses the processes that control the sea ice near the Antarctica. He devoted a significant amount of time to developing a coupled model that consists of a comprehensive ocean and sea ice models and of a model of the atmospheric boundary layer. An effective method of reducing errors in the sea surface temperature and salinity in ocean general circulation models was developed in collaboration with Sarachik.

In collaboration with his colleagues at the Massachusetts Institute of Technology, Kamenkovich used a coupled atmosphere-ocean model of intermediate complexity to study a response of the Atlantic thermohaline circulation to changes in climate. The results from these simulations are used in the Coordinated Coupled Model Experiments (part of the Coupled Model Intercomparison Project), and in the EMIC (Earth system models of intermediate complexity) Intercomparison Projects.

Kamenkovich has completed the investigation of the dynamical role of the Southern Ocean eddy transports in the Atlantic thermohaline circulation. He and collaborators have analyzed roles of the Antarctic Intermediate Water and the Antarctic Bottom Water in controlling the North Atlantic overturning and how the properties of these water masses are affected by eddy fluxes.

He also has completed the investigation of a new method of reducing errors in an ocean model forced by restoring surface boundary conditions. In particular, he and collaborators analyzed the origins of the errors in the simulated values of temperature, salinity, and surface fluxes in the Southern Ocean. He also analyzed the roles of the Antarctic Intermediate Water and Antarctic Bottom Water in affecting subsurface values of temperature and salinity.

Currently, he is investigating a role of the daily variations in the surface winds over the Southern Ocean.

Todd Mitchell, Research Scientist/Meteorologist
Mitchell collaborated with J. M. Wallace to document the non-ENSO contributions to trends in Darwin, Tahiti, and Southern Oscillation Index pressure indices, and ongoing studies were continued to relate daily Pacific Northwest daily weather to ENSO and the Northern Annular Mode variability, and to characterize global variations in aerosols. Mitchell also participated in weekly meetings of the CIG.

Daniel Vimont, Visiting Scientist
Vimont worked in collaboration with J. Chiang, investigating analogous climate variability in the tropical Atlantic and Pacific. From October 15, 2002 through the end of March 2003, Vimont was not employed by JISAO, but was granted permission to use

JISAO resources while investigating the impacts of ENSO and greenhouse warming on precipitation in Indonesia. This project was through Columbia University.

Michela Biasutti, Graduate Student
Biasutti has been working on the annual cycle in the Tropical Atlantic, with the specific goal of understanding the role played by temperature and precipitation changes over Africa and South America in determining the annual cycle over the Atlantic. This work has been described in a series of three papers, and in her dissertation.

Camille Li, Graduate Student
Li's research focuses on the influence of the high latitudes on global climate. Of particular interest to her is the possibility that sea ice extent has a significant effect on the mean state of the atmosphere, not just locally, but equatorward all the way to the tropics. Her ultimate goal is to determine if this idea is supported by models (and perhaps even in observations), and if so, to arrive at a dynamical understanding of the phenomenon. In this context, she is currently running a series of land-free GCM experiments in order to first gain some insight into possible mechanisms for high-latitude influence on the tropical circulation in an idealized scenario. She has also recently started a collaborative study to investigate internal variability in high latitudes during the glacial times.

William Roberts, Research Associate, Graduate Student
Using a linear inverse modeling technique, Roberts produced a forecast for Tropical Pacific sea surface temperature (SST). This model exhibits greater forecast skill than other far more complicated and computationally heavy models. Using this same technique he found that if SST data from the Tropical Atlantic is included with Pacific SST data, an even better forecast can be derived. Roberts is seeking a physical explanation for this effect of the Atlantic on the Pacific using a variety of models.

Jeffery Yin, Research Associate, Pre-Doctoral Graduate Student
Yin wrote, revised, and defended his Ph.D. dissertation, "The peculiar behavior of baroclinic waves during the midwinter suppression of the Pacific storm track." He graduated in August 2002.

CSES: Climate Impacts Group (CIG)

Director/PI:
Edward Miles, Professor, School of Marine Affairs

Faculty Collaborators:
David Fluharty, Research Associate Professor, School of Marine Affairs
Robert Francis, Professor, Aquatic and Fishery Sciences
Dennis Lettenmaier, Professor, Civil and Environmental Engineering
Robert Palmer, Professor, Civil and Environmental Engineering
David Peterson, Professor, Ecosystem Sciences Div, Forest Resources

Staff Collaborators:
Nathan Mantua, Research Scientist, JISAO/CIG
Alan Hamlet, Research Engineer, Civil and Environmental Engineering
Philip Mote, Public Information Specialist, JISAO/CIG
Robert Norheim, Research Scientist, Forest Resources
Eric Salathe, Research Scientist, JISAO/CIG
Amy Snover, Research Scientist, JISAO/CIG
Lara Whitely-Binder, Outreach Specialist, JISAO/CIG

Graduate Students:
Vera Agostini, Jeremy Littell , Elizabeth Petras, Nathan Van Rheenen
Patrick Zahn

Sub-Contractors:
Richard Slaughter, President, RSA Associates, Inc.
Joel Hamilton, Professor, Agricultural Economics and Statistics,
University of Idaho
Donald Reading, Consultant, Ben Johnson Associates
Ruby Leung, Senior Research Scientist, Pacific NW National Laboratory, Battell

The Climate Impacts Group's (CIG) research on the impacts of climate variability and change in the Pacific Northwest (PNW), and the application of this information to PNW resource management, has led to significant contributions to the fields of science and natural resource management in the PNW. The following summarizes many of the CIG's successes, including promising developments in new research. These contributions are grouped in terms of the CIG's five broad goals.

Goal: *To contribute to our scientific understanding of climate impacts in the Pacific Northwest*

✦ *Defining the Pacific Decadal Oscillation*. CIG Scientists demonstrated a solid connection between interdecadal variations in North Pacific climate and the abundance of salmon and other marine species in the PNW and Alaska, and in so doing named and defined the "Pacific Decadal Oscillation (PDO)." The PDO is now recognized

internationally as a major climate driver with wide-scale impacts on natural resources in the western U.S., Canada, and eastern Russia.

✦ *Documenting the influence of climate variability on PNW winter climate*. The CIG characterized PNW climate variability and trends, noting, for example, (1) the association of warm-dry and cool-wet winters with warm and cool phases of ENSO and PDO, and (2) the links between several other large-scale climate modes (e.g., Pacific North America pattern and the Arctic Oscillation) and extreme weather events such as windstorms, cold air outbreaks, and snow.

✦ *Identifying climate impacts on key PNW resources.* The CIG has demonstrated how the El Niño/Southern Oscillation (ENSO), PDO, and other aspects of climate influence key natural resources in the PNW, including snowpack, streamflow, flooding, and droughts; forest productivity and risk of forest fire; salmon returns; and quality of coastal and near-shore habitat. Warm phases of ENSO and/or PDO, for example, increase the probability for reduced snowpack, streamflow, flooding, salmon returns (PDO only), and coastal and near-shore habitat quality, while increasing the probability for drought and forest fires. Warm phase PDO also contributes to increased tree growth and forest productivity at higher elevations (with the opposite effect at lower elevations). Cool phases of ENSO and PDO increase the probability for the opposite effects.

✦ *Identifying 20th century trends*. The CIG analyzed 20th century trends in temperature, precipitation, and snow water equivalent (an important indicator for predicting summer water supplies) for the PNW. The research finds that annually averaged PNW temperature and precipitation increased more than the global average during the 20th century. The research also identified significant decreases—up to 60% at some locations—in PNW snow water equivalent over the second half of the 20th century. These results, which can only in part be explained by natural climate variability, are consistent with projected climate change impacts for the PNW and, as such, have generated significant interest among water resources managers throughout the PNW.

✦ *Utilizing proxy data.* In an effort to extend the understanding of PNW climate and climate variability beyond the current instrumental record, the CIG has utilized tree rings and geoduck shells to place 20th century climate in a broader historical context. As a result of this research, the CIG has been able to conclude, for example, that droughts during the 1840s and 1920s-1930s were far more prolonged and sever than those that occurred since 1950, and that the potential for multi-year droughts has probably been underestimated. The research also placed the 1990s as the warmest decade of the last 154 years for March-October sea surface temperatures in the Strait of Juan de Fuca. The extension of the PNW's climatological record provides valuable insight into the potential range of climate variability in the PNW, potentially allowing for more complete evaluation of infrastructure planning needs and future climate impacts.

✦ *Evaluating the impacts of global climate change.* CIG scientists have taken a lead role in researching the impacts of climate change on the PNW, conducting the nation's first comprehensive examination of climate change impacts on the PNW and using the results

of that work as a foundation for outreach and continued research. The CIG's research projects significant challenges in the decades ahead for the region's water resources, salmon, forests, and coasts as a result of human-caused global warming. These challenges include an increased risk of winter flooding, summer drought, salmon mortality in freshwater habitats and coastal erosion and flooding. Continued research on climate change impacts and the integration of this research into PNW resource management is a major focus of the CIG.

Goal: *To develop tools and other resources supporting the use of climate information in decision making*

✦ *Translating ENSO forecasts for use in resource management*. The CIG translates long-range ENSO forecasts into regional climate and water resource forecasts and works closely with agencies in applying these forecasts to resource management. As a result, many agencies, including Seattle Public Utilities and Bonneville Power Administration, now consider ENSO forecasts in resource management decisions.

✦ *Climate-based long-lead seasonal streamflow forecasts*. The CIG has developed new long-lead seasonal streamflow forecasting methodologies for the Columbia River basin incorporating (1) long-range climate forecasts for ENSO and PDO, and more recently, (2) seasonal climate model simulations. These forecasts, presented annually to more than 100 public, private, and tribal resource managers, provide probabilistic estimates of critical spring runoff 6-8 months sooner than the traditional forecasting method. According to CIG research, using these forecasts could provide additional hydropower revenues on the order of $100million/yr with almost no loss of reliability in other water resource management objectives. The CIG has expanded this forecasting capability to include the Snake River basin and other large western U.S. river systems. The forecasts are updated bi-weekly during the winter months and are available to the public for free on the web (www.ce.washington.edu/~hamleaf/DallesForecast.html).

✦ *Seasonal forecasts for coho salmon survival*. The CIG has developed a new method for predicting marine survival for Oregon coastal coho salmon. These forecasts, made in collaboration with NOAA Fisheries, provide coho program managers at Washington and Oregon Departments of Fish and Wildlife with additional, independent, and likely improved run-size estimates early enough to be considered in annual harvest decisions.

✦ *Forecasting extreme weather events*. The CIG has demonstrated strong associations between the statistics of extreme daily weather events and phases of the daily wintertime Pacific/North America (PNA) index in coastal Alaska, the PNW, the Great Lakes region, and the Southeastern US. Improved forecasting of the probability for extreme weather events, including extreme cold temperatures, extreme daily precipitation, freezing temperature days, snow days, maximum temperatures, and surface wind gusts, may provide significant benefits for utilities, water suppliers, and other resource managers. This work, combined with the persistence of the PNA pattern, shows that existing operational PNA forecasts can be used to generate skilled extreme event risk forecasts for select locations up to two weeks in advance.

✦ *Climate change streamflow scenarios for planning*. The CIG has developed an online decision support tool that allows users to easily obtain climate change streamflow scenarios for many rivers throughout the PNW for incorporation into existing agency planning frameworks. The data server, designed to facilitate consideration of climate change impacts in water resource planning, was developed in consultation with the Idaho Dept. of Water Resources and the Northwest Power Planning Council. The streamflow scenarios are available to the public for free on the web (www.ce.washington.edu/~hamleaf/climate_change_streamflows/CR_cc.htm).

✦ *Climate change impacts on municipal water supplies*. The City of Portland, Oregon commissioned the CIG to provide a detailed numerical analysis of the impacts of climate change and population growth on their future water supply and demand. The study found that by 2050, climate change impacts on Portland's water supply system would be, on average, 50% of the total impact expected from population growth in that same period. A similar study is underway with Seattle Public Utilities. The results of these studies will be used by their respective utilities to guide long-range planning decisions in the PNW's two largest metropolitan areas.

✦ *Technology transfers to the stakeholder community*. As understanding of the CIG's research grows within the stakeholder community, the CIG has been able to transfer research models and forecasting tools to utilities and agencies such as the USDA Natural Resources Conservation Service (NRCS) and the National Weather Service's Northwest River Forecast Center. The NRCS, for example, has begun implementing the distributed hydrology model developed by the CIG's hydrological team and plans to produce experimental long-lead streamflow forecasts for the Columbia basin using methods developed by the CIG. These transfers represent an important step in institutionalizing the use of climate information in resource management throughout the PNW.

✦ *Office of the State Climatologist*. The CIG, in partnership with the Washington State Department of Ecology, has reinstituted the Office of the State Climatologist for Washington State. The State Climatologist provides valuable support to public and private entities through the collection and distribution of climate data, forecasts, and other information. Philip Mote, a CIG researcher and outreach specialist, is now serving as State Climatologist in addition to his general research responsibilities at the CIG.

Goal: *To engage stakeholders in a dialogue on the impacts of climate variability and change in the PNW and the use of climate information in management and planning*

✦ *Annual climate and streamflow forecast meetings*. Since 1998, the CIG has conducted annual workshops on seasonal forecasts for climate and water resources. Well attended (80-100 persons per year) and highly regarded, the workshops are cited by public, private, and tribal PNW water resource managers as one of the most helpful educational opportunities they encounter. Agencies represented at these meetings have included: the Bonneville Power Administration, the Columbia River Intertribal Fish Commission, Washington Departments of Ecology and Fish and Wildlife, Idaho Departments of Water

Resources and Agriculture, Idaho Power Company, National Park Service, National Weather Service, Natural Resources Conservation Service (USDA), Northwest Power Planning Council, US Army Corps of Engineers, Bureau of Reclamation, the Environmental Protection Agency, and numerous Pacific Northwest city and county water and electric utilities.

✦ *Regional education about climate variability and change*. The CIG's education and outreach activities are largely responsible for the wide recognition of the impacts associated with climate variability and change in the PNW. As a result of the CIG's work, for example, the PNW water management community has become well versed with the water management issues associated with interannual climate variability and change, and understands and interprets climate forecasts and climate information for their systems and customers. When climate change is discussed, water managers talk knowledgeably about regional warming, loss of snowpack, and the potential for water resources impacts due to reduced water availability in summer. Water resource managers at public and private sector hydropower marketing agencies (e.g., Seattle City Light and Bonneville Power Administration) use information on climate variability to inform power marketing decisions. Fisheries managers, including those at the Washington and Oregon Departments of Fish and Wildlife and the federally established North Pacific Fishery Management Council, now routinely refer to the PDO in discussions of allowable catch. NOAA Fisheries, in both the Alaska Fisheries Science Center and the Northwest Fishery Science Center, is paying close attention to the PDO and ecosystem regime shifts; "regime-shifts" are one of the key issues behind a new NOAA Fisheries research initiative called "Fisheries and Their Environments (FATE)."

✦ *Increased agency interest in planning for climate change.* Five years ago, policymakers and other stakeholders saw little need to plan for climate change. Within the past few years, partly in response to media coverage of the CIG's work and outreach efforts, many agencies and planning efforts are beginning to take climate change into account. For example, at the urging of and in partnership with the CIG, the Idaho Department of Water Resources and the Northwest Power Planning Council plan to incorporate streamflows from future climate scenarios in their hydrological planning tools. Several watersheds participating in Washington State's Watershed Planning Program have begun to incorporate climate variability and change into long-range plans with the CIG's assistance. The Columbia River Intertribal Fisheries Commission has developed an alternative operating plan for the Columbia River water resources management system for use in a future world affected by climate change based on the CIG's streamflow projections. As a result of a briefing by the CIG, the City of Seattle's Office of Sustainability is working with Seattle City Light to consider use of the CIG's climate change information in projecting electricity supply and demand.

Goal: *To understand and document how alternative institutional history and structures impact regional and sub-regional adaptive capacity and resource conflict resolution and to use that understanding to derive lessons for institutional design for reducing vulnerability to climate variability and change.*

✦ *Tracking stakeholder needs and monitoring institutional barriers to the use of climate forecasts.* Since the empirical evidence reveals that institutional barriers to adapting to climate variability and change are especially significant, the CIG has focused on this problem as the central issue for its human dimensions work. One measure of adaptation is the ability and willingness of stakeholders to use climate forecasts in approaches to managing resources and other activities in the four sectors. Trends are systematically tracked using techniques of elite surveys every 5-6 years. The second such survey has been completed and analysis is underway comparing the results of the first survey in 1996-1997 with the current one.

✦ *Reducing vulnerabilities to climate variability and change.* The CIG's work ranges from assessing approaches to mitigating climate change at the global and regional level to exploring in detail how adaptation to climate variability has worked at the regional level. Detailed evaluations of institutional performance relative to the management of water resources in Washington, Oregon, and Idaho over the last 100 years have been worked out, lessons derived, and papers are being prepared for publication.

Goal: *To contribute to education at the University of Washington*

✦ *Graduate course on climate impacts in the PNW*. The CIG developed a permanent interdisciplinary University of Washington graduate course that examines the causes and consequences of regional climate variability and change as well as the natural, economic, and institutional contexts in which regional resource management decisions are made. The course is cross-listed among four major university departments: Atmospheric Sciences, Earth System Sciences, School of Marine Affairs, and Program on the Environment.

✦ *Graduate seminar on decision-making in the face of uncertainty*. The CIG conducted a university-wide graduate level seminar on risk-based decision-making in public sector natural resources management entitled "Decision Making in the Face of Uncertainty: Practitioner Views on Environmental Resource Management Challenges". The seminar brings public sector natural resource managers to the classroom to discuss how they address uncertainties in managing PNW resources.

✦ *Graduate course on the role of science in environmental decision-making*. The CIG developed a new graduate course on "The Role of Science in Environmental Decisions" in collaboration with the University of Washington's Evans School of Public Affairs. The course is required for the Environmental Management Graduate Certificate Program and is listed as a core quantitative course in the Evans School.

✦ *Graduate course on integrated assessment.* The CIG developed and taught an advanced graduate course on integrated assessment, applying the techniques and approaches developed by the CIG to marine policy problems. The course was developed in collaboration with the University of Washington's School of Marine Affairs.

✦ *Invited lectures.* CIG researchers are regularly invited to give guest lectures in classes, seminars, and special University-wide speaking engagements.

The CIG has been developing collaborations with researchers for several of the nearby NOAA laboratories.

✦ Mantua's research has involved CIG members Francis, Mantua, and Agostini and NOAA scientists Peter Lawson (Newport OR lab) and Elizabeth Logerwell (AFSC) to investigate climate impacts on coho freshwater and marine survival. To date, this team has completed studies on the impacts of coastal ocean variability on coho marine survival and climate and freshwater coho productivity. The results of these two studies are initial steps to the larger goal of constructing simulation models for exploring climate impacts on the full life cycle and multiple generations of coho salmon. Once the climate/coho life cycle model is complete, it can be used to examine questions related to the extinction risk for coho in the face of natural and anthropogenic climate and physical habitat change, as well as the efficacy of different restoration and recovery strategies.

✦ Mantua has been working with Philip Levin from NOAA's NWFSC (Montlake Lab) focuses on incorporating "climate-related uncertainty" into west coast rockfish population simulations, including scenarios for both natural and anthropogenic climate impacts.

✦ Mantua is also working with Steven Hare (International Pacific Halibut Commission) to produce a short status report detailing observed changes in the large scale climate and ecosystem conditions in the Bering Sea and North Pacific. This work will be part of a much larger report that will be part of the Alaska Fishery Science Center's annual stock assessments. The stock assessments are crucial scientific assessments used in commercial fishing allocation and harvest management decisions. The lead scientist in this effort is Pat Livingston (AFSC).

Members of the CSES have been active in influencing and leading national climate programs:

✦ Miles and Sarachik advise the International Research Institute for climate prediction, a unique institute of Columbia University's Earth Institute concentrating on the end-to-end production, analysis, and use of climate information for the benefit of society especially developing countries. (Sarachik chairs the Advisory Committee). The IRI is an absolutely unique institution devoted to demonstrating the use of (primarily) seasonal-to-interannual

climate information and is a natural outgrowth of the physical scientists' work on the El Niño problem over the years.

✦ Lettenmaier led the hydrology and water resources activity within the DOE-funded Accelerated Climate Prediction Initiative. He has also been active in national and international programs dealing with climate and hydrology. For instance, he was an invited participant in the September, 2002 OGP Climate Dynamics workshop at Princeton, and at the OGP Intraseasonal to Interannual Prediction Program (ISIP) planning meeting in Silver Spring in August, 2003. He chairs the external advisory panel to the Canadian Mackenzie River GEWEX Study (MAGS), and is a member of the Scoping Team for the joint WCRP/IGBP/IHDP/Diversitas Global Water Systems Project. He was a member of the USGCRP Water Cycle Study Group that wrote the so-called Hornberger Report ("A plan for a new science initiative on the global water cycle") in 2001, and sits on the NRC Committee on Hydrologic Science.

✦ NOAA/PMEL scientist D. E. Harrison chairs the NOAA Climate Observing Systems Council which evaluates observing systems within NOAA and makes recommendations about their utility and operational qualities and potential. (Sarachik also serves on this Council). Harrison also chairs the international committee (part of the Global Ocean Observing System project) responsible for coordinating and designing an ocean observing system.

✦ Sarachik chairs the UCAR Community Climate System Advisory Board which oversees the operations of one of the two major climate modeling facilites in the US and coordinates its operation with the other at the NOAA/Geophysical Fluid Dynamics Laboratory.

✦ Sarachik was a major participant in the Climate Change Science Program (CCSP) National Meeting in December 2002. He chaired sessions and gave talks on modeling in climate. He also reviewed the National Academy evaluation of this meeting. The CCSP is the major coordinating organization for climate studies in the US.

✦ Sarachik, Mantua and Battisti have proposed a new program on Pacific Decadal Variability to determine the current state and future evolution of decadal patterns over the Pacific Northwest. NOAA, NSF, and NASA were approached to fund a workshop on Pacific Decadal Variability. Scientific inputs to the workshop and a strawman program document are available at the meeting web page at www.usclivar.org/PDV_0203.html. The workshop was attended by about 50 members of the science, application, and fisheries communities. A writing committee was established to revise the document and a formal program document will soon be issued. The program has already been approved by US CLIVAR although it is not clear that funds exist for more than a modest program.

Climate

The ARGO Project: Global Ocean Observations for the Understanding and Prediction of Climate Variability

PI: Stephen Riser, Associate Professor, Oceanography

During the past year Riser received funds from NOAA via JISAO to continue participating in the Argo program. This international program is designed to deploy 3000 profiling floats in the world ocean (approximately 300 km resolution over the globe) that will collect profiles of temperature and salinity over the upper 1000 m of the world ocean at approximately 10-day intervals. This is the first subsurface global ocean observing system. The US is committed to provide about half of these floats. For the past 2 years the US has been providing about 300 floats per year, split among 3 institutions (SIO, WHOI, and UW). In the past year Riser received funds to build and deploy 105 floats. In fact, his group deployed about 160 floats, which included the allocation for this year plus some remaining instruments from last year that had not been deployed. The UW floats were deployed in the Indian Ocean, the Antarctic, and the Pacific. Most are working properly. At the present time the data are being used to examine the state of the Indian Ocean Dipole and the Pacific Decadal Oscillation in the N. Pacific. Additionally, researchers are examining the long-term (decade-to-century) scale of variability of salinity in the N. Pacific.

ASOF – Arctic Subarctic Ocean Flux Study

PI: James Morison, Principal Oceanographer, Polar Science Center, APL

SEARCH, the Study of Environmental Arctic Change, is a broad, interdisciplinary program to understand the complex suite of significant, interrelated, atmospheric, oceanic, and terrestrial changes occurring in the Arctic. Along with many other elements this involves monitoring and understanding the fluxes of mass, heat, and salt between the Arctic Ocean and the sub-Arctic seas. The Arctic Subarctic Ocean Flux Study is an international effort aimed at monitoring these fluxes, and has been incorporated as a major and high-priority component of SEARCH.

As part of NOAA's contribution to SEARCH, Roberta Boscolo is funded to provide support to ASOF. Boscolo works with Robert Dickson of CEFAS (Centre for Environment, Fisheries and Aquaculture Science, Lowestoft Laboratory, United Kingdom). Dickson heads the ASOF effort and is a member of the SEARCH Science Steering Committee. Boscolo contributes her scientific expertise to the ASOF Implementation Plan, provides meeting coordination, develops and maintains the ASOF website, and writes brochures and newsletters.

Arctic Surface Air Temperature

PI: Don Percival, Senior Mathematician, Applied Physics Laboratory
Affiliate Associate Professor, Statistics

There is compelling evidence suggesting that the temperature in the Arctic was unusually warm in the 1990s. It is important to place this evidence in an historical perspective. This would allow us to understand if the observed increase is truly unusual or if similar increases have been routinely observed in the past. To address this question, instrumental records of surface air temperatures from stations in the Arctic were examined. There are 11 such stations beginning in 1886, 20 stations from 1912 and on, and 45 from 1936 and on. Using graphical and statistical techniques that stay as close as possible to the actual data (i.e., that avoid any sort of interpolation schemes), we were able to extract large-scale spatial and long-term temporal patterns in the surface air temperatures. The preponderance of evidence supports the conclusion that the warm surface air temperatures in spring in the 1990s had the greatest longitudinal extent in the instrumental record.

Observation and Modeling of the Fresh-Water Dynamics Connecting the Arctic and Atlantic: A Feasibility Study

PI: Peter Rhines, Professor, Oceanography and Atmospheric Sciences

Rhines's work proposed to initiate a design study for climate studies in the subpolar Atlantic Ocean and its connections with the circulation of the Arctic Ocean; to plan the first deployments of the Eriksen Seaglider, an autonomous undersea vehicle, in the subpolar Atlantic, and to examine numerical ocean circulation models and coarse resolution climate models to assess the interaction between Arctic and Atlantic regions.

Rhines's work has centered on: (i) logistical preparations for hydrographic sections in the subpolar Atlantic using the Seaglider; (ii) analysis of oceanic transport of volume, heat and fresh water through Davis Strait, west of Greenland; (iii) analysis of the Arctic-subArctic circulation in a high-resolution ocean model (OCCAM); (iv) analysis of current meter mooring observations on the Labrador Slope; and, (v) final analysis of the Labardor Sea eddy field. Rhines and collaborators have also carried out analysis of observations and laboratory simulations of the polar atmospheric circulation, under the influence of mountainous continents.

Ocean Climate Observations West of Greenland in Support of ASOF

PI: Peter Rhines, Professor, Oceanography and Atmospheric Sciences

This project supports the deployment of an acoustic Doppler current profiler in the Barrow Strait, as part of the ASOF monitoring of Arctic outflows, with Simon Prinsenberg. It also will support the first deployment of Seagliders in the Labrador Sea.

Environmental Chemistry

Exploring the Submarine Ring of Fire

PI: John Baross, Associate Professor, Oceanography

During the past year research supported by the grant continued in seeking to understand the phylogenetic, metabolic, and physiological diversity of microorganisms that are indigenous to subsurface habitats associated with submarine hydrothermal systems at Axial Volcano, Explorer Ridge, and Endeavour Ridge. All of this research is in collaboration with NOAA scientists. Results show that a highly diverse community of bacteria and archaea exists and are unique to the subsurface. Included in this group are thermophilic and hyperthermophilic organisms that fix CO_2 and oxidize H_2 using elemental sulfur or polysulfides as the electron acceptors. This is a new group of bacteria that evidently use a unique metabolic pathway to fix carbon dioxide. Other unique microorganisms isolated from subsurface fluids include thermophilic iron-reducing bacteria and archaea. The preliminary analyses on the diversity of microorganisms in the subsurface that harbor the *nif*H gene that is involved in nitrogen fixation was also completed. This study was initiated because N_2 is the only abundant form of nitrogen in the hot subsurface at many mid-ocean ridge sites. The data identified the presence of a diverse community of potentially nitrogen-fixing archaea and bacteria from the hot, anaerobic habitats in the subseafloor. These results are supporting evidence for the hypothesis that there exists a unique subsurface microbial community that is not dependent on electron acceptors and nitrogen compounds produced by photosynthetic organisms.

Carbon Isotope Constraints on Ocean GCM Simulations of Anthropogenic CO_2 Uptake

PI: Paul Quay, Professor, Oceanography

Oceanic Uptake Rates Determined from an Ocean-Wide $^{13}C/^{12}C$-DIC Data Set
A primary goal of the project was to merge the δ^{13}C-DIC data sets (n=25,000), measured at the NOSAMS laboratory at WHOI and the Stable Isotope Laboratory (SIL) at the UW during the WOCE and OACES cruises in the 1990s. They determined an interlaboratory offset for δ^{13}C-DIC measurement between NOSAMS and SIL of 0.01±0.02 ‰ based on an exchange of laboratory standards (n=10). Independently, a comparison of deep water δ^{13}C-DIC values, measured at depths >1500 m at WOCE stations (n=15) sampled on repeat cruises in the Indian Ocean, yielded an interlaboratory offset of 0.02±0.03 ‰ within the precision of the measurement (±0.025 ‰). These δ^{13}C-DIC data has been quality controlled and submitted as part of the WOCE data set and are available at whpo.ucsd.edu/onetime.htm. A subset of the δ^{13}C-DIC data was used to determine the anthropogenic change in the ocean δ^{13}C. Quay and colleagues determined a global mean surface ocean δ^{13}C-DIC decrease of –0.16±0.02 ‰ decade^{-1} between the 1970s and 1990s. The global mean air-sea δ^{13}C disequilibrium in 1995 was estimated at 0.60±0.10 ‰ with basin-wide disequilibrium values of 0.73, 0.63, and 0.23 ‰ for the Pacific, Atlantic, and Indian oceans, respectively. The global mean depth-integrated

anthropogenic change in $\delta^{13}C$ between the 1970s and 1990s was estimated at –65±33 ‰ m decade^{-1}. The air-sea $\delta^{13}C$ disequilibrium and depth-integrated $\delta^{13}C$ changes yield an oceanic CO_2 uptake rate of 1.5±0.6 Gt C yr^{-1} between 1970 and 1990 based on the atmospheric CO_2 and $^{13}CO_2$ budget approaches of Quay and others. Box-diffusion model simulations of the oceanic uptake of anthropogenic CO_2 and its $\delta^{13}C$ perturbation indicate that a CO_2 uptake rate of 1.9±0.4 Gt C yr^{-1} (1970-1990) explains both the observed surface ocean and depth-integrated oceanic $\delta^{13}C$ changes.

In another study, the time rate of anthropogenic change in the $\delta^{13}C$ and CO_2 in the N. Atlantic Ocean was determined using a subset of the WOCE $\delta^{13}C$-DIC data. It was found that the mean anthropogenic $\delta^{13}C$ decrease along isopycnals was –0.26±0.02 ‰ decade^{-1} and the CO_2 increase was 12.1±0.7 μmol kg^{-1}/decade using calculations of preformed values and CFC ages. These results indicate that surface waters in the N. Atlantic that ventilate these isopycnals (outcropping regions between 36° and 60°N) were approximately equilibrated with atmospheric CO_2 and had a decade lag for atmospheric $\delta^{13}C$ equilibration, as expected.

This experimental work was complemented by an effort to become proficient in the use of the ocean general circulation model (OGCM) developed at Princeton University and the NOAA Geophysical Fluid Dynamics Laboratory. Rolf Sonnerup (NOAA/PMEL), a co-PI on this grant, visited Princeton this spring and worked with Jorge Sarmiento's modeling group. Sonnerup has successfully compiled the code to run anthropogenic $^{13}C/^{12}C$ and CO_2 simulations using the Princeton OGCM on a local workstation at PMEL. He has just started anthropogenic $\delta^{13}C$ simulations on the OGCM. They also have begun to expand their calculations of the anthropogenic $\delta^{13}C$ change in the ocean using reconstructions of the $\delta^{13}C$-DIC changes based on the preformed method, and are initially applying this method to the $\delta^{13}C$ data collected during WOCE cruises.

Multiwavelength Measurement of Aerosol Absorption Coefficient

PI: David Covert, Research Professor, Atmospheric Sciences

The light absorption coefficient of atmospheric aerosols from worldwide combustion emissions and soil resuspension (and the ratio of light scattering to light extinction, or single scattering albedo) are important for radiation transfer and climate forcing. Present measurement of absorption at 550 nm is accurate to ±20%, at best while the measurement of light scattering coefficient over the visible range is accurate to ±7%. The best determinations of single scattering albedo (SSA) have an uncertainty of about ±0.03 around a central value of 0.90 in continentally influenced aerosol. For many surface albedo conditions this is near the SSA above which the aerosol will cool the atmosphere and below which it will warm the atmosphere. For climate and photochemical modeling purposes, greater accuracy in the measurement of absorption coefficient is clearly needed as are measurements at other wavelengths in the solar spectrum.

We have designed, built, calibrated, and used an absorption photometer to measure absorption coefficient at three wavelengths in the visible spectrum ranging from 450 to 700 nm. The instrument is intended for routine, practical use by international (WMO), national, and regional agencies for the measurement of aerosol absorption. Field measurements with the instrument have been made in collaboration with major NOAA, NASA, and DOE field projects. Comparison of our results with other more expensive and elaborate techniques both on the ground and in aircraft, indicate we are meeting our goals of improved accuracy.

Gas Chemistry of Explorer Ridge Hydrothermal Fluids

PI: Marvin Lilley, Research Professor, Oceanography

Lilley's laboratory participated in an oceanographic cruise to the southern Explorer Ridge in summer 2002. The objective was to collect water samples from hydrocasts and measure the concentration of methane in an effort to find new venting sites. Graduate student Brooke Silvers participated in the cruise. A total of 28 hydrocasts were conducted. In addition his laboratory analyzed 11 high temperature samples collected by John Lupton's (NOAA/PMEL) lab on a separate submersible cruise. These samples were analyzed for hydrogen, methane, carbon dioxide, hydrogen sulfide, nitrogen, argon, and carbon monoxide.

The lab also participated in the Feb 9, 2003 to Mar 2, 2003 cruise to the Marianas backarc region and provided shipboard analysis of over 400 hydrocast samples for methane. These analyses helped to locate potential dive targets for an upcoming ROV cruise in the same area.

Analysis and Modeling of Intraseasonal and Interannual Variability of Warm Season Precipitation in the East Pacific, Central America, and North America

PI: Dennis Hartmann, Professor, Atmospheric Sciences

Hartmann's research shows that Madden Julian Oscillation (MJO) anomalies propagate eastward into the Central American Region and that wind and convection anomalies precede SST anomalies there on the MJO time scale.

Further Analysis of the TEPPS Data: Relation of ITCZ Convection to Large-Scale Cross-Equatorial Flow

PI: Robert Houze, Jr., Professor, Atmospheric Sciences

The study examined the synoptic scale variability of the precipitation in the ITCZ in the region of the Tropical East Pacific Process Study (TEPPS). Easterly waves and Kelvin wave activity strongly affect and modulate the precipitation in this region during late northern hemisphere summer. Using Tropical Rainfall Measuring Mission (TRMM) satellite data it was shown that the ITCZ in the TEPPS region has a greater percentage of stratiform precipitation than in other parts of the tropics, especially during the warm phase of ENSO. The researchers linked the higher stratiform percentage of rainfall in the

part of the ITCZ represented by the TEPPS region to a vertical profile of heating that has a higher altitude maximum than in the western Pacific. A climate model response to this trans-Pacific variation in the height of the heating maximum produces a distinct vertical structure in the atmospheric circulation, especially during the warm phase of ENSO. The structure of the ENSO circulation is incorrectly represented if the horizontal variation in the vertical heating profile is not taken into account. This work was supported partly under this grant and partly under a NASA grant.

GCIP/GAPP Missouri River Water Resources Demonstration Project

PI: Dennis Lettenmaier, Professor, Civil and Environmental Engineering

The Missouri River drains about one-fifth of the land area of the continental U.S. Its flow is regulated by several large reservoirs that are used primarily for water supply, hydropower generation, navigation, and flood control. The project investigated the potential to more efficiently operate these reservoirs through the use of more accurate forecasts of future streamflow at lead times from months to years. The factors controlling hydrologic predictability in the Missouri River basin can be segregated into (a) knowledge of hydrologic conditions at the time of forecast (primarily soil moisture and snowpack, when and where relevant), and (b) predictability of future precipitation and temperature, which we related to the Southern Oscillation Index (SOI) and the Arctic Oscillation (AO). Results showed that hydrologic (streamflow) predictability in the Missouri River basin derives primarily from hydrologic initial conditions, and to a lesser extent, and primarily in winter, from SOI and AO. A second study was then conducted to determine the economic worth of potential improvements in hydrologic forecast accuracy for reservoir operation, beyond those that can currently be extracted from knowledge of initial conditions. The potential improvements were relatively small (one or two percent of annual hydropower generation revenues), which was attributed to the large size of the reservoirs. When the sizes of the reservoirs were artificially reduced to make them similar to those present elsewhere in the west, the benefits increased somewhat, although they never exceeded a few percent of the mean annual hydropower generation revenue.

Fisheries Recruitment

Growth and Development of Salmon

PI: Walton W. Dickhoff, Professor, Aquatic and Fishery Sciences

The long-range goal of the research project is to understand the control of salmon growth and development by internal and external factors. Results of the project can be applied to a better understanding of how climate change may affect the growth of salmon. The salmon populations of the North Pacific Ocean show significant interannual variation and decadal trends in fish numbers, body size, and age at maturity. It is not clear to what extent these fluctuations are caused by external changes in climate or ocean productivity. The immediate goal of this study is to conduct studies of the endocrine and physiological systems controlling growth to better understand factors affecting the salmon life cycle and body size.

Work during the last year focused on examining the effects of feeding and fasting of salmon on the endocrine factors that regulate salmon growth:

(1) Feeding and fasting effects on factors regulating salmon growth: Juvenile chinook salmon were fed or fasted for four weeks and sampled every day for the first week and then approximately twice per week up to 29 days. Samples of liver and blood were taken for analysis of plasma growth hormone (GH), insulin, insulin-like growth factor-I (IGF) and IGFBP-3. Levels of IGF mRNA were determined in the liver. Results showed that insulin, IGF, and IGFBP-3 declined after four days of fasting and plasma GH increased. This is the most complete description of changes in endocrine factors for any fish species.

A study of seasonal (autumn) variation in growth regulating hormones shows that there are autumnal declines in growth hormone and IGF. Changes in growth rate reflected changes in IGF levels, but did not relate to growth hormone levels. This indicates that IGF is a better indicator of fish growth than is growth hormone.

Habitat Differences in Frontal Regions around the Pribilof Islands and their Importance to Juvenile Pollock Survival in the Bering Sea: Phase III

PI: Robert C. Francis, Professor, Aquatic and Fishery Sciences

PNW Climate Reconstructions using Geoduck Shells—Are Strom, Graduate Student, completed his Masters thesis research in December 2002. His research focused on reconstructing historical ocean temperature records from growth ring widths in geoduck clams (Panopea abrupta). Results indicate that this method shows considerable promise as a new tool for marine paleoclimate reconstruction.

Climate, habitat and productivity of sardine and hake in the California Current—The Ph.D. research of Vera Agostini, Graduate Student focuses on how the relationship between climate and ocean habitat for Pacific sardine and Pacific hake, throughout their life histories, affect manifestly different patterns in their population dynamics. Sardine is

notorious for its outbreaks of high abundance followed by large crashes in the population—patterns that have temporal coherence throughout the North Pacific. Hake, on the other hand, has shown high-frequency spikes in production in alternation with periods of low abundance. Both species seem to have close temporal and spatial overlaps in terms of their spawning off Mexico and southern California and seasonal feeding migrations to the Pacific Northwest.

The overall objectives of the project were to describe the spatial pattern of variability of sardine and hake habitat in the California Current and to link patterns of variability with changes in abundance and distribution geography of hake and sardine.

Oceanographic data for the coast of California Washington and Oregon, were assembled and analyzed, with emphasis on the spatial pattern of climate variability of hake and sardine habitat in the California Current System, the sardine and hake larval habitat distribution in the California current, and the adult hake habitat distribution in the California Current system. The work identified key questions to address pertinent to hake and sardine management.

Atka Mackerel Ecology

PI: Don Gunderson, Professor, Aquatic and Fishery Sciences

A model was developed a model that allowed tagging data to estimate the population size of Atka mackerel and rates of migration between areas that are closed to fishing and those that remain open. The PI helped NMFS to plan and organize the Atka mackerel tagging cruise that took place in 2002, and participated in it.

Trends in Fish Abundance and Productivity

PI: Don Gunderson, Professor, Aquatic and Fishery Sciences

A manuscript was completed on the basic reproductive biology and natural mortality rate of two species of thornyheads for the *Environmental Biology of Fishes*. While estimates of size at maturity are similar to those obtained previously, estimates of natural mortality rate indicate that both longspine and shortspine thornyhead are much longer-lived than previously suspected.

Another manuscript on indirect estimates of natural mortality for arrowtooth flounder and darkblotched rockfish was written for *Fishery Bulletin*. Variance estimation techniques were developed, and sources of bias compared.

A study on the length-fecundity relationships for longspine and shortspine thornyheads was completed and a manuscript on the results was submitted to *Fishery Bulletin*.

Studies continued on the reproductive biology and natural mortality rate of Greenland turbot, focusing on quantifying rates of egg resorption (atresia) and the length-fecundity relationship. Arrangements were made for collection of additional specimens in order to determine the length at maturity more precisely.

Nutritional Studies of Juvenile Sablefish

PI: Russell Herwig, Research Associate Professor, Aquatic and Fishery Sciences

The culture of marine fish is of interest for marine conservation programs, aquaria trade, and as source for seafood products. Many species of marine fish cannot be successfully cultured because of the inability to reliably grow these species through the early life stages. The primary objectives of the research are to develop suitable diets, understand the nutrition requirements, and elucidate the identity and role of microorganisms that are associated with cultured marine fish, particularly for fish larvae. Fish species used in this research included sablefish, lingcod, Pacific cod, canary rockfish, yelloweye rockfish, and China rockfish. Work continued on developing a method to study larval fish nutrition by studying the uptake and depletion of inert markers from rotifers and *Artemia*, two commonly used live-feed. Microparticulate feeds were developed for China and canary rockfish larvae and Pacific cod larvae. In addition, the intestinal microflora of yelloweye rockfish was monitored over a two-month period, and several bacterial cultures were isolated from the intestinal tract of yelloweye and China rockfish. These bacteria are presently being characterized and identified. Sablefish feeding trials was performed with diets containing different concentrations of lipids. Subsequently, we conducted proximate analysis and human sensory evaluation of fish from all feeding trials and on wild-caught sablefish. Lipid concentration in sablefish fed a 20% or 30% lipid was significantly higher than that found in wild-caught fish. An American taste panel detected differences between cultured and wild-caught fish, while a Japanese panel showed no preference.

University of Washington Graduate Student Stipend for Stock Assessment Training and Improvement

PI: Ray Hilborn, Professor, Aquatic and Fishery Sciences

The purpose of this grant is to augment the technical capability of NMFS in fisheries stock assessment. Specific areas include how to estimate the abundance of fish stocks and the potential harvest from the stocks. The current focus is using advanced statistical methods to determine how to use various indicators of stock abundance, including both scientifically designed surveys and vessel logbook and observer data to estimate the trends in stock abundance.

Fisheries Acoustics Research

PI: John Horne, Research Assistant Professor, Aquatic and Fishery Sciences

Horne completed projects, supervised graduate students, and initiated new research projects. One study examines how ontogeny, physiology, and behavior influence the reflection of sound by walleye pollock. Five graduate students are conducting projects within the fisheries acoustic laboratory. In June, Elliott Hazen successfully defended his Master's thesis, "A comparison of factors influencing backscatter for walleye pollock, *Theragra chalcogramma*." New research projects include examining the acoustic development of swimbladders as the fish grows, characterizing vocalizations in

individual killer whales from the southern resident population of Puget Sound, and developing visualizations of acoustic backscatter data from groups of fish.

Using Behavioral Models of Fishing to Assess Alternative Management Approaches for Reducing the Local Ecologicial Impact of Alaska Pollock and Cod Fisheries

PIs: Daniel Huppert, Professor, School of Marine Affairs
David Layton, Associate Professor, Evans School of Public Affairs

The investigators made substantial progress was made in (a) refining the database of observations on commercial trawlers, especially for "pollock catcher boats"—those vessels who depart ports in the Aleutian Island chain and return to deliver loads of fish to onshore fish processors, (b) developing and testing econometric models for estimating statistical distributions of fishing effort among catch areas, and (c) wrote preliminary drafts explaining the underlying discrete choice theory, statistical procedures, and estimated parameters. The next steps are to refine the analysis, broaden the empirical research to include additional aspects of the fishing operations, and complete publishable papers on the research.

The project team organized the workshop, Spatial Fisheries Economic Modeling Workshop: Application to the Bering Sea Pollock Catcher Boat Fishery on June 26 – 27, 2003, hosting a total of 8 local NMFS researchers and 7 academic contributors. The two-day workshop covered such topics as econometric challenges in discrete choice modeling of fishing behavior, means of incorporating dynamics into the models, policy issues and relevance of the spatial models, and topics for future research in the field.

Fish-Marine Mammal Interactions

PI: Bruce Miller, Professor, Aquatic and Fishery Sciences
Co-PI: Donald Gunderson, Professor, Aquatic and Fishery Sciences

This project was delayed until a suitable post-doc could be found. On June 1, 2003, Yunbing Shi was hired as the post-doc to lead this project. Shi has been doing a literature review on cod (Pacific and Atlantic) biology and mark-recapture methodology, especially for an open population. He also has been working with FIT members building a Pacific cod database. Findings to date are that the existing tagging data to will only provide a qualitative model of local migration patterns of Pacific cod because the tagging was not designed for an open population.

Shi will try the following approaches: (1) Analyze P. cod catch data to see if there is a temporal-spatial pattern in terms of CPUE; (2) Analyze available tagging data to investigate P. cod movements within season, and seasonal migration patterns (qualitative); and (3), he will propose a mark-recapture study for an open population in the current study area, or a closed population over the Bering Sea and Aleutian Islands, and the Gulf of Alaska.

North Pacific Marine Biological Interactions – Fish Interactions

PI: Bruce Miller, Professor, Aquatic and Fishery Sciences

Stomach Collection and Analysis: Field collection and laboratory scientists Ashley Forbes, Hilary Lee, Megan Lloyd, and Beth Matta participated in the collection of 11,951 stomach samples during groundfish resource surveys of the eastern Bering Sea and Aleutian Islands. They also contributed toward the laboratory analysis of 18,896 stomach samples during this past year. Experienced analysts also contributed to other projects to increase laboratory efficiency. Matta organized and catalogued laboratory reference specimens, and compiled taxonomic information into tabular format. Forbes produced osteological information on Ammodytidae and Osmeridae that will help distinguish among species using vertebral characteristics. Lee assisted with the development of a sample tracking and inventory system.

Ecosystem Indicators: Post-doctoral research associate Jennifer Boldt has been working on two main areas of research: (1) an ecosystem considerations chapter, and (2) an index of spawning pollock biomass anomalies in Shelikof Strait. The ecosystem considerations chapter is an appendix to the Stock Assessment and Fishery Evaluation (SAFE) report produced annually by the National Marine Fisheries Service (NMFS) and submitted to the North Pacific Fishery Management Council (NPFMC). The purpose of the chapter is to bring ecosystem status and trend information to the attention of scientists, the public, and the NPFMC so that we can better understand the ecosystem linkages between components and the role that climate, fishing, and other factors have in influencing the ecosystems of the Gulf of Alaska, Aleutian Islands, and the eastern Bering Sea. The ecosystems considerations chapter consists of contributions from different scientists and includes indicators of the North Pacific ecosystem. Boldt has been contacting past and potential contributors, as well as writing, editing, and compiling contributions. She met with a group of scientists collecting ecosystem metrics and creating ecosystem indices to discuss coordination and collaboration in the future collection of time series.

Boldt has been working on developing an index of spawning pollock biomass anomalies. The working hypothesis is that deviations from the expected biomass of pollock returning to spawn in Shelikof Strait may be driven by interannual variations in climate factors that change the intensity and/or complexity of flow through the strait. She has compiled previously collected CTD and mooring data and is in the process of analyzing it. A circulation model (SPEM) has been constructed for Shelikof Strait and Boldt is working with PMEL as well as other research biologists to get a time series of total flow and flow complexity through the Strait. This index could be used to adjust estimates of spawning pollock biomass that are incorporated into the stock assessment model.

Multispecies Modeling: Post-doctoral Research Associate Jesus Jurado-Molina has focused in the development of the multispecies statistical model (MSM) and the updating of the multispecies virtual population analysis (MSVPA) and the multispecies forecasting model (MSFOR) for the eastern Bering Sea. The multispecies statistical model was set up in Excel and now he is trying to set it up in AD model builder. The models involve only two species: walleye pollock and Pacific cod. The first version of the model is able to

estimate population numbers, fishing mortality, predation mortality, and the suitability coefficients. The second version set up in AD model builder does not estimate the suitability coefficients. These parameters are provided from the MSVPA model. Preliminary results suggest that the MSM (Excel version) is able to estimate the suitability coefficients reasonably. Final runs are being made. The second version is still under development but it is preferable that this version will be the tool that could be used in the management of the resources. Therefore the final version will include all the species (in previous study with MSVPA) and the actual techniques used in the single species stock assessments.

The MSVPA and the MSFOR models have been updated several times this year. In particular he corrected an equation in the MSFOR model that has improved the results in the forecast simulation of the system. The approaches for those updates are: (1) update to the 2001 catch at age data, (2) update to the 2002 catch at age data, (3) update using the 2002 catch at age data and the fishing mortalities estimated with the bycatch model developed by Jim Ianelli, and (4) update using the 1998 catch at age data to make a comparison with results from the ecosim and ecopath models set up for the eastern Bering Sea.

Jurado-Molina participated in the advisory committee of Claudio Gatica, graduate student from the Universidad de Concepción in Chile, and he attended Gatica's final M.S. presentation.

Ecosystem Modeling/Aleutian Islands ECOPATH modeling: Fishery Ecosystem Plans (FEPs) are currently being developed in the Northeast Pacific for the Eastern Bering Sea, the Gulf of Alaska, and the Northern California Current. The present study comprises a portion of the effort directed towards developing a FEP for the Aleutian Islands (AI). The starting platform to model food web interactions in these ecosystems has been Ecopath. This platform has now been applied by pre-doctoral student Ivonne Ortiz to the Aleutian Islands, complemented by a geostatistical approach.

Ortiz's activities include: (1) Define functional groups within the food web in the Aleutian Islands Ecosystem. (2) Assembly of relevant diet/biomass/production data for the functional groups within the Aleutian Islands. (3) Evaluate spatial scales at which functional groups operate in the Aleutian Islands. (4) Identify key driving environmental forces in the system. (5) Document all data used in the model (diets, biomass, production, fisheries, driving forces). (6) Evaluate quality, resolution, and availability of spatial data in the Aleutian Islands.

The above activities were conducted in close collaboration with Kerim Aydin (REFM, AFSC), John Fields (SAFS), and Sarah Gaichas (REFM/SAFS). Together they produced a mass balanced model of the Aleutian Islands. (Note: the model is currently being balanced and on the final stages of documentation.)

Development of Ecosystem Indicators for the North Pacific
PI: Bruce Miller, Professor, Aquatic and Fishery Sciences

Shannon Tribble, research technologist, has been analyzing 25 years of Bering Sea Trawl Survey data (1975, 1979 – 2002) to develop ecosystem indicators, focusing her analysis on changes in the species-aggregated size frequency distribution and k-dominance curves. Fish and invertebrates identified in the trawl survey were categorized into 75 species groups. These groups were further categorized into commercial and non-target species groups. Size frequency distribution analyses were run for All Fish, Commercial Fish, Noncommercial fish, All Invertebrates, Commercial Invertebrates, Noncommercial Invertebrates, and Fish and Invertebrates combined. Slopes and intercepts of the descending limb of the distribution curves were calculated for organisms 20-90 cm. Simple correlation coefficients were calculated to determine the contribution of environment and fishing effort on the results. Spearman rank correlation coefficients of catch per unit effort (cpue) by year and mean individual weight by year were also computed.

Migration Studies of Salmon in the Bering Sea
PI: Katherine Myers, Research Scientist, Aquatic and Fishery Sciences

The project is part of the U.S. contribution to North Pacific Anadromous Fish Commission (NPAFC; member nations Canada, Japan, Russia, and the United States) research efforts (especially U.S.-Russian cooperation) related to the Bering-Aleutian Salmon International Survey (BASIS), an international program investigating declines in runs of several Pacific salmon species (*Oncorhynchus* spp.) and changes in oceanographic conditions in the Bering Sea. Due to financial difficulties in Russia and subsequent uncertainties in scheduling, it has not yet been possible to place U.S. scientists on a Russian research cruise in 2003 to carry out research efforts related to the cruise. Instead, Myers and a research scientist R. Walker participated in leg 2 of the 2003 *Kaiyo maru* BASIS survey, and research scientist N. Davis participated in the 2003 *Wakatake maru* BASIS survey. Their shipboard research activities emphasized salmon tagging with archival data tags and disk tags and collection of salmon diet data for bioenergetic modeling of salmon in the Bering Sea and adjacent waters. N. Davis completed a Ph.D. dissertation pertinent to this research.

Cooperation and coordination of research with Russian scientists has proceeded in several areas. Myers and colleagues hosted visiting Russian scientists, Olga Temnykh and Vladimir Sviridov, Pacific Research Institute of Fisheries and Oceanography (TINRO Center), Vladivostok, Russia, at the University of Washington, School of Aquatic and Fishery Sciences, in May 2003. They facilitated exchanges of chum salmon scale samples collected during the 2002 R/V *Tinro* cruise, materials for making acetate scale impressions, information on scale laboratory methods, and instructions on genetic sampling. They provided the *Tinro* Center scientists with instructions and materials for collecting sockeye and chinook salmon genetic samples of interest to U.S. scientists during the 2003 R/V *Tinro* cruise. They assisted NMFS scientists in gathering information on scientific equipment and supplies requested by the *Tinro* Center and other

Russian agencies for BASIS research. They issued letters of invitation for U.S. visa applications by Russian scientists participating in Japanese and U.S. BASIS cruises, and assisted with travel arrangements for these scientists to participate in BASIS research cruises of the R/V *Kaiyo maru* and the F/V *Sea Storm*. They obtained sockeye salmon scale samples from KamchatNIRO (Kamchatka Research Institute of Fisheries and Oceanography, Petropavlovsk, Kamchatka) for stock identification studies of stocks taken in Bering Sea fisheries. These samples include 2002 baseline samples from the Ozernaya, Kamchatka, Bolshaya, Palana, and Khailulya rivers, and mixed stock fishery samples from the Bering Sea and the Petropavlovsk-Kommander subzone of the North Pacific (1995-97) and 2000 samples from the Karaginskaya subzone of the Bering Sea (operations of the vessel *Kumano maru-36*) and the northwestern Pacific and western Bering Sea (operations of the vessel SRTM-K *Altair*).

Myers and colleagues compiled catch statistics, tagging data, stock identification studies, and oceanographic information for a comprehensive review of distribution, migration, and interceptions of salmon in the Bering Sea. This review will include new maps of stock distribution using historical tagging data and mapping of research vessel catches in the Bering Sea.

N. Davis was appointed as a U.S. point of contact for salmon food habits and bioenergetics modeling for the BASIS Working Group, reviewing salmon food habits methods used by Russia and other countries for BASIS research.

Molecular Genetics of Pacific Salmonids

PI: Kerry Naish, Professor, Aquatic and Fishery Sciences

Several different research projects on Pacific salmonids in the area of conservation genetics have been performed. One project is attempting to assess the impact of hatchery practices on a wild population of steelhead. Another is looking at the interaction of pinnipeds with listed populations of salmon in the Columbia River. There is also a project that looks at the timing of juvenile migration of chinook salmon in the Columbia River estuary, and we are collecting genetic baseline data for steelhead in Washington and Oregon. JISAO funding was used to pay for fisheries biologists to collect the genetic data in the laboratory. Three manuscripts have been submitted for publication this year based on some of the research described above.

Quantitative Assessment of Estimates Based on Data Collected by Observers in the North Pacific Ocean

PI: John Skalski, Professor, Aquatic and Fishery Sciences

This project focuses on the optimal allocation of limited observed resources to achieve multiple objectives in a federally funded fishery.

The first few months were spent becoming familiar with the procedures used by the North Pacific Groundfish Observer Program to sample the groundfish fishery off of Alaska. The several sectors of the groundfish fishery in Alaska have different sampling

protocols used by the Program. This led to different hierarchical or multi-staged probabilistic models within the many strata that compose the fishery.

The last few months have been spent defining a probabilistic sample design that closely approximates the sampling protocols in the longline component of the groundfish fishery. A sample design is based on principles of finite sampling theory and other statistical models and leads to statistically based estimation procedures for fishery parameters that are important in modeling marine populations affected by fishing activities in Alaska. These populations include marine mammals such as Steller sea lions and seabirds, as well as a multitude of fish species.

The group is currently developing other probabilistic models for the sampling procedures implemented by the North Pacific Groundfish Observer Program in other components of the groundfish fishery and estimation procedures for various fishery parameters.

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959 Mofjeld, H.O., A.J. Venturato, V.V. Titov, F.I. Gonzalez, and J.C. Newman, 2002: Tidal datum distributions in Puget Sound, Washington, based on a tide model. *NOAA Technical Memorandum OAR PMEL-122*.

978 Sarachik, E.S., 2002: The Ocean in Climate. *Handbook of Weather, Climate, and Water: Dynamics, Climate, Physical Systems, and Measurements*, Thomas D. Potter and Bradley R. Colman (eds.), 1-5.

Selected Honors and Awards

Task II Program

Fisheries Oceanography Coordinated Investigation (FOCI) program research staff: Bahl, Bond, Denbo, Dobbins, Fabritz, Jenkins, Hamilton, Hermann, Merati, Moore, Rodionov, Sullivan, Wang, Zhu

- **Bronze Medal from the U.S. Department of Commerce:** for members of NOAA's Fisheries Oceanography Coordinated Investigations (FOCI) program

Christopher Moore

- **NOAA Research Team Member of the Month:** For his outstanding work in advanced visualization technology applications in research

Sonya Noor

- **Certificate for contributions:** NOAA Science Camp 2003, NOAA's "Bring Your Child to Work Day"

Task III Program

John Baross

- **Certificate of Appreciation from the National Research Council for the National Academy of Sciences:** for outstanding service as a chair of the Space Studies Board Committee on the Origins and the Evolution of Life

David Battisti

- **Named The Meriko Tamaki Professor of Atmospheric Sciences at the University of Washington**

Alan Hamlet, Daniel Huppert, Dennis Lettenmaier

- **Best Practice Oriented Paper:**

  Hamlet, A.F., D. Huppert, and D.P. Lettenmaier, 2002: Economic value of long-lead streamflow forecasts for Columbia River hydropower, *J Water Res Pl-ASCE,* **128**, 91-101.

  This paper explores the potential for operating the Columbia River's hydropower dams differently in different years based on information from ENSO/PDO based streamflow forecasts. Retrospective streamflow forecasts for 61 years were

produced, and an experimental operating plan for the Columbia hydro system was developed to make use of the year-to-year information in the forecasts. Benefits to non-firm hydropower revenues were on the order of $150 million per year on average in the simulations, while other management objectives were essentially unchanged.

Dennis Hartmann

- **Appointed Fellow:** Fellow of the American Geophysical Union

Edward Miles

- **Election to membership in the U.S. National Academy of Sciences:** for work in Human Environmental Sciences

SungKwon Soh, Post-doctoral student (advisor: Donald Gunderson)

- **Best Student Paper in 2001:** "The potential role of marine reserves in the management of shortraker rockfish and rougheye rockfish in the Gulf of Alaska" *Fishery Bulletin* 99:168-179, 2001

  This paper uses a population dynamics model and spatial analysis of fishing patterns to show that marine reserves can be used to greatly reduce discards and serial overfishing of substocks.

Count of Publications

	JI Lead Author		NOAA Lead Author		Total
	FY 01	**FY 02**	**FY 01**	**FY 02**	
Peer-reviewed	27	43	21	35	126
Non peer-reviewed	23	30	16	10	79
Totals	**50**	**73**	**37**	**45**	**205**

Employee Count (Fiscal Year 2002)

Visiting Scientists (Task I)

Job title	Degree level (Ph.D.)
Visiting scientist	3

Post Docs (Tasks I and II)

Job title	Total
Research associate—Task I	3
Research associate—Task II	2
Research associate—Task III	6

Graduate Students (Task III)

Job title	Total
Research assistant	5
Research associate	26
Totals	**31**

Staff (Task II)

Job title	Degree level				
	Associate's	Bachelor's	Master's	Ph.D.	**Total**
Research scientist	1	14	6	19	40
Research consultant		5	2	1	8
Totals	**1**	**19**	**8**	**20**	**48**

Staff (Task III)

Job title	Degree level						
	Unknown	No degree	Associate's	Bachelor's	Master's	Ph.D.	**Total**
Research scientist	4		2	4	5	4	19
Public information specialist					1	1	2
Software engineer	1				1		2
Senior computer specialist	1						1
Fish biologist				4			4
Editor				1			1
Lab helper				1			1
Hourly research staff	1			1			2
Temporary staff helper		1					1
Totals	**7**	**1**	**2**	**11**	**7**	**5**	**33**

Employee Count (Fiscal Year 2003)

Visiting Scientists (Task I)

Job title	Degree level (Ph.D.)
Visiting scientist	1

Post Docs (Tasks I and II)

Job title	Total
Research associate—Task I	1
Research associate—Task II	8
Research associate—Task III	4

Graduate Students (Tasks II and III)

Job title	Total
Research associate—Task II	2
Research assistant—Task III	5
Research associate—Task III	14
Totals	**21**

Staff (Task II)

Job title	Degree level				
	Associate's	Bachelor's	Master's	Ph.D.	**Total**
Research scientist	1	15	7	23	46
Research consultant		5	2	1	8
Totals	**1**	**20**	**9**	**24**	**54**

Staff (Task III)

Job title	Degree level						
	Unknown	No degree	Associate's	Bachelor's	Master's	Ph.D.	**Total**
Research scientist			2	10	6	4	22
Public information specialist					1	1	2
Research tech 3	1						1
Engineering tech				1			1
Field engineer	1						1
Software engineer			1				1
Lecturer part-time						1	1
Manager of program operations		1					1
Hourly research staff		1		1		1	3
Student assistant		2					2
Totals	**2**	**4**	**3**	**12**	**7**	**7**	**35**

Acronyms

AAAR—American Association for Aerosol Research
ABE—Autonomous Benthic Explorer
ACCP—Atlantic Climate Change Program
ACE—Aerosol Characterization Experiment
ADC—Apparent Digestibility Coefficient
ADCP—Acoustic Doppler Current Profiler
AFSC—Alaska Fisheries Science Center
AGCM—Atmospheric General Circulation Model
AGU—American Geophysical Union
AMS—American Meteorological Society
AO—Arctic Oscillation
AOML—Atlantic Ocean Marine Laboratory
APL—Applied Physics Laboratory
APROPOS—Advances and Primary Research Opportunities in Physical Oceanography Studies
ARCHES—NOAA Abrupt Climate Changes Studies Program
ARGO—Name for a broad-scale global array of temperatures/salinity profiling floats
ARM—Atmospheric Radiation Measurement or Aerosol Radiation Measurement
ASLO—American Society of Limnology and Oceanography
ASOF—Arctic-Subarctic Ocean Flux
ATG—Atmospheric Sciences–Geophysics Building
ATLAS—Autonomous Profile Line Acquisition System
ATMS—Atmospheric Sciences
AWRA—American Water Resources Association
AWWA—American Water Works Association
BAMS—Bulletin of the American Meteorological Society
BASIS—Bering-Aleutian Salmon International Survey
BAU—Business as usual
BBSR—Bermuda Biological Station for Research
BMRC—Bureau of Meteorology Research Centre – Australia
CAMS—Center for Analysis of Marine Systems
CARINA—Carbon Dioxide in the North Atlantic
CCM3—Community Circulation Model 3
CDC—Climate Diagnostic Center
CDEP—Climate Diagnostics and Environmental Prediction
CDIAC—Carbon Dioxide Information Analysis Center
CDP—Climate Data Portal
CFC—Chlorofluorocarbon
CGCM—Coupled General Circulation Model
CGI—Common Gateway Interface
CIG—Climate Impacts Group
CIRES—Cooperative Institute for Research in Environmental Sciences
CLIC—Climate and Cryosphere
CLIVAR—International research program on climate variability under WCRP
CMAQ—Community Multiscale Air Quality modeling system
CMDL—Climate Monitoring and Diagnostics Lab
COAST—Coastal Observation And Simulation with Topography
COFS—College of Ocean & Fisheries Sciences
CORBA—Common Object Request Broker Architecture

CPC—Climate Prediction Center
CPUE—Catch Per Unit Effort
CRIEPI—Central Research Institute of Electric Power Industry, JAPAN
CSES—Center for Science in the Earth System
CSIRO—Commonwealth Scientific & Industrial Research Organisation
CTD—Conductivity Temperature Depth
CVS—Concurrent Version System
DART—Deep-ocean Assessment and Reporting of Tsunamis
DHSVM—Distributed Hydrology Soil Vegetation Model
DIC—Dissolved Inorganic Carbon
DMS—Dimethyl Sulfide
DOC—Dissolved Organic Carbon
DODS—Distributed Ocean Data System
DOE—Department of Energy
DSR—Deep Sea Research
DWR—Department of Water Resources
DYNAMO—Ocean Modeling Project, Institut fuer Meereskunde, University of Kiel, Germany
ECFS—Eastern Caribbean Fibre System
EFDC—Environmental Fluid Dynamics Code
ENSO—El Niño-Southern Oscillation
EOF—Empirical Orthogonal System
EOS—Earth Observing System
EPAP—Ecosystem Principles and Advisory Panel
EPIC—Eastern Pacific Investigation of Climate Processes
EPOC—Eastern Pacific Ocean Conference
ESDIM—Earth System Data and Information Management
ESRI—Environmental System Research Institute
ESUs—Evolutionarily Significant Units
FACTS—Facility for the Analysis and Comparison of Tsunami Simulations
FEP—Fisheries Ecosystem Plan
FGDC—Federal Geographic Data Committee
FOCI—Fisheries Oceanography Coordinated Investigations
FORTRAN—Computer programming language
GAPP—GEWEX Americas Prediction Project
GASEX—Gas Exchange
GCCP—Global Carbon Cycle Program
GCIP—GEWEX Continental-scale International Project
GCM—General Circulation Model
GCMD—Global Change Master Directory
GCP—Global Carbon Project
GEWEX—Global Environmental Chemistry
GFDL—Geophysical Fluid Dynamics Laboratory
GH—Growth Hormone
GIS—Geographical Information System
GLNPZ—GLOBEC Nutrient Phytoplankton Zooplankton
GLOBEC—Global Ocean Ecosystem Dynamics
GOA—Gulf of Alaska
GOALS—Global Ocean Atmosphere Land System
GOOS—Global Ocean Observing System
GSI—Genetic Stock Identification
GSM—Global Spectral Models

GTSPP—Global Temperature-Salinity Profile Program
HAZMAT—Hazardous Materials
HFS—High-temperature Fluid Sampler
HPCC—High Performance Computing and Communications
IABP—International Arctic Buoy Programme
IBM—Individual Based Model
IC— Ion Chromatography
ICES—International Council for the Exploration of the Sea
ICP-MS—Inductively Coupled Plasma Mass Spectrometer
IDL—Interactive Data Language
IDWR—Idaho Dept of Water Resources
IGAC—International Global Atmospheric Chemistry
IGBP—International Geophysical and Biology Program
IGCO—Integrated Global Carbon Observing
IGF—Insulin-like Growth Factor
IGFBP—Insulin-like Growth Factor Binding Proteins
IGOSS—Integrated Global Ocean Services System
IHDP—International Human Dimensions Programme
IIPS—Interactive Informational and Processing Systems
IMET—Improved Meteorological Instrumentation
IMPROVE—The Improvement of Microphysical Parameterization through Observational Verification Experiment
IOS—Institute of Ocean Sciences, Canada
IPSL—Institute Pierre Simon LaPlace, France
IR—Infrared
IRI—International Research Institute for Climate
ISTAC—International science and Technology Advisory Committee
IT—Information Technology
ITCT—Intercontinental Transport and Chemical Transformation
ITCZ—Intertropical Convergence Zone
JAM—Journal of Applied Meteorology
JAMSTEC—Japan Marine Science and Technology Center
JASMINE—Joint Air-Sea Monsoon Interaction Experiment
JASONs—July, August, September, October, November (Group of individuals)
JAVA—Computer programming language
JAVADISPLAY—Java Database Connectivity
JCOMM—Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology
JGOFS—Joint Global Ocean Flux Study
JGR—Journal of Geophysical Research
JHC—JISAO/Hayes Center
JISAO—Joint Institute for the Study of the Atmosphere and Ocean (UW)
LAS—Live Access Server
LDEO—Lamont Doherty Earth Observatory
LEXEN—Life in EXtreme ENvironments
LOI—Letter of Intent
LS—Lang Sampler
LSCOP—Large Scale Carbon Dioxide Observational Plan
MAP—Mesoscale Alpine Programme
MATE—Marine Advanced Technology Education
MBARI—Montery Bay Aquarium Research Institute

MESDIP—Marine Ecosystem Data Integration Project
MIX—Name for an approach to the project
MJO—Madden-Julian Oscillation
ML—Mixed Layer
MM5—Mesoscale Model
MOC—Meridional Overturning Circulation
MODIS—Moderate Resolution Imaging Spectroradiometer
MOM—Modular Ocean Model
MOR—Mid-Ocean Ridge
MOST—Method of Splitting Tsunami model
MSCAGEAN—Multispecies Catch at Age Model
MSFOR—Multispecies Forecast
MSM—Multispecies Statistical Model
MSVPA—Multispecies Virtual Population Analysis
MTPRs—Mini Temperature Pressure Recorders
NACP—North American Carbon Plan
NAM—North Hemisphere Annular Mode
NAME—North American Monsoon Experiment
NAO—North Atlantic Oscillation
NAS—National Academy of Sciences
NASA—National Aeronautic and Space Administration
NCAR—National Center for Atmospheric Research
NCCE—Northern California Current Ecosystem
NCDC—National Climatic Data Center
NCEP—National Centers for Environmental Prediction (formerly NMC)
NCSA—National Center for Supercomputing Applications
NDP—Numeric Data Package
NEAQS—New England Air Quality Study
NeMO—New Millennium Observatory
NEP—Northeast Pacific
NMFS—National Marine Fisheries Service
NOAA—National Oceanic and Atmospheric Administration
NOPP—National Oceanographic Partnership Program
NORM—Northwest Regional Meeting
NOSAMS—National Ocean Sciences Accelerator Mass Spectrometry Facility
NPAC—North Pacific
NPFMC—North Pacific Fishery Management Council
NPZ—Nurtrient-Phtoplankton-Zooplankton
NRC—National Research Council
NRCS—Natural Resources Conservation Service
NSF—National Science Foundation
NSSL—National Severe Storms Laboratory
NTHMP—National Tsunami Hazard Mitigation Program
NVODHub—National Virtual Ocean Data Hub
NWFSC—Northwest Fisheries Science Center
OACES—Ocean Atmosphere Carbon Exchange Study
OAR—Office of Oceanic and Atmospheric Research
OCRD—Ocean Climate Research Division
OERD—Ocean Environment Research Division
OGCM—Ocean Global Circulation Model
OGP—Office of Global Programs (NOAA)

OIP—Ocean Inquiry Project
ONR—Office of Naval Research
OPeNDAP—Open-Source Project for a Network Data Access Protocol
OSCAR—Ocean Surface Current Analyses – Real time
OSMO—Osmotic Sampler Observing System Simulation Experiments
OSSE—Observing System Simulation Experiments
OSTP—Office of Science and Technology Policy
OSU—Oregon State University
PACJET—Pacific Landfalling Jets Experiment
PACLIM—Pacific Climate Workshop
PACS—Pan American Climate Studies
PBS—Public Broadcasting System
PC—Principal Component
PCC—Program on Climate Change
PCM—Parallel Climate Model
PDO—Pacific Decadal Oscillation
PDV—Pacific Decadal Variability
PFEL—Pacific Fisheries Environmental Laboratory
PHP—Hypertext Parser
PI—Principal Investigator
PICES—North Pacific Marine Science Organization
PILS—Particles Into Liquid Sampler
PIRATA—Pilot Research Moored Array in the Tropical Atlantic
PMEL—Pacific Marine Environmental Laboratory
PNA—Pacific North American
PNW—Pacific Northwest
POM—Princeton Ocean Model
PR—Precipitation Radar
PRIMER—Plymouth Routines In Multivariate Ecological Research
PRISM—Puget Sound Regional Synthesis Model
PS—Particulate Sulfur
PWB—Portland's Water Bureau
PWS—Prince William Sound
QJRMS—Quarterly Journal of the Royal Meteorological Society
R2K—RIDGE 2000
RAS—Remote Axis Sampler
RCM—Regional Climate Model
RDI—RD Instruments, Inc.
REFM—Resource Ecology and Fisheries Management
RIA—Radioimmunoassay
RISA—Regional Integrated Sciences and Assessments
ROMS—Regional Ocean Modeling System
ROPOS—Remotely Operated Platform for Ocean Science
ROV—Remotely Operated Vehicle
RSA—Richard Slaughter Associates
SAFS—School of Aquatic and Fisheries Sciences
SAT—Surface Air Temperature
SCIAPP—Science Applications
SCOR—Scientific Committee for Oceanographic Research
SCRUM—S-Coordinates Rutgers University Model
SDR—Secure Document Repository

SEARCH—Study of Environmental Arctic Change
SEBSCC—South East Bering Sea Carrying Capacity Program
SEC—Space Environmental Center
SEM—Scanning Electron Microscopy
SFM—Seasonal Footprinting Mechanism
SGT—Scientific Graphics Toolkit
SIESIP—Seasonal to Interannual Earth Science information Partner
SIFT—Short-term inundation Forecasting of Tsunamis
SIL—Stable Isotope Laboratory
SISCA—Jackson School of International Studies, Canada
SMA—School of Marine Affairs
SMP—Synthesis and Modeling Project
SOI—Southern Oscillation Index
SOLAS—Surface Ocean-Lower Atmosphere Study
SOLO—State of Lake Ontario
SPASM—South Puget Sound Area Synthesis Model
SPCZ—Pacific Convergence Zone
SPEM—Semi-spectral Primitive Equation Model
SQL—Structured Query Language
SSA—Single Scattering Albedo
SSLI—Steller Sea Lions Initiative
SST—Sea Surface Temperature
STC—Subtropical/Tropical Cell
TAO—Tropical Atmosphere and Ocean
TCODE—Technical Committee on Data Exchange
TEPPS—Tropical Eastern Pacific Process Study
TIME—Tsunami Inundation Mapping Efforts
TMAP—Thermal Mapping and Analysis Program
TMI–TRMM—Tropical Rainfall Measurement Mission–Microwave Imager
TOGA—Tropical Ocean Global Atmosphere
TOPEX—The Ocean Topography Experiment
TOPP—Tagging of Pacific Pelagics
TOVS—TIROS-N Operational Vertical Sounder
TRITON—TRIangle Trans-Ocean Buoy Network
TRMM—Tropical Rainfall Measurement Mission (U.S. and Japan)
UBC—University of British Columbia
UCAR—University Corporation for Atmospheric Research
UCSD—University of California, San Diego
UKMO—UK Met Office
UNAAMI—Arctic Data Collection
URI—University of Rhode Island
USACOE—U.S. Army Corp of Engineers
USDA—U.S. Department of Agriculture
USF—University of South Florida
USGS—United States Geological Survey
UW—University of Washington
VENTS—Hydrothermal Venting Research program
VIC—Variable Infiltration Capacity
VRML—Virtual Reality Modeling Language
WCRP—World Climate Research Programme
WEBS—Water & Energy Budget Synthesis

WG13—Working Group 13
WHOI—Woods Hole Oceanographic Institute
WOCE—World Ocean Circulation Experiment
WRF—Weather Research & Forecasting
WWU—Western Washington University
XRF—X-Ray Fluorescence