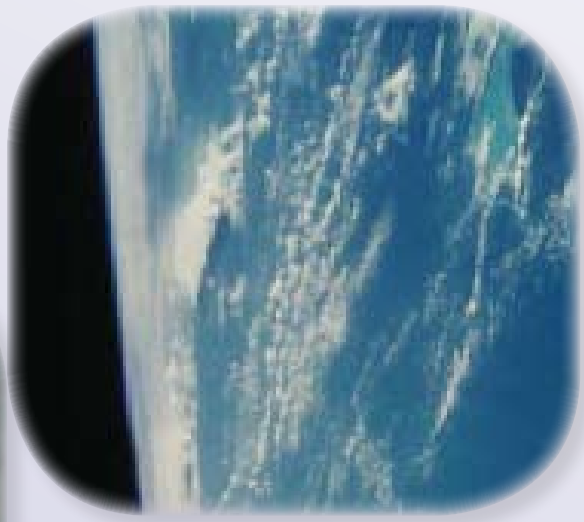
JOINT INSTITUTE FOR THE STUDY OF THE ATMOSPHERE & OCEAN (JISAO)

ANNUAL REPORT

JULY 1, 2005 – JUNE 30, 2006



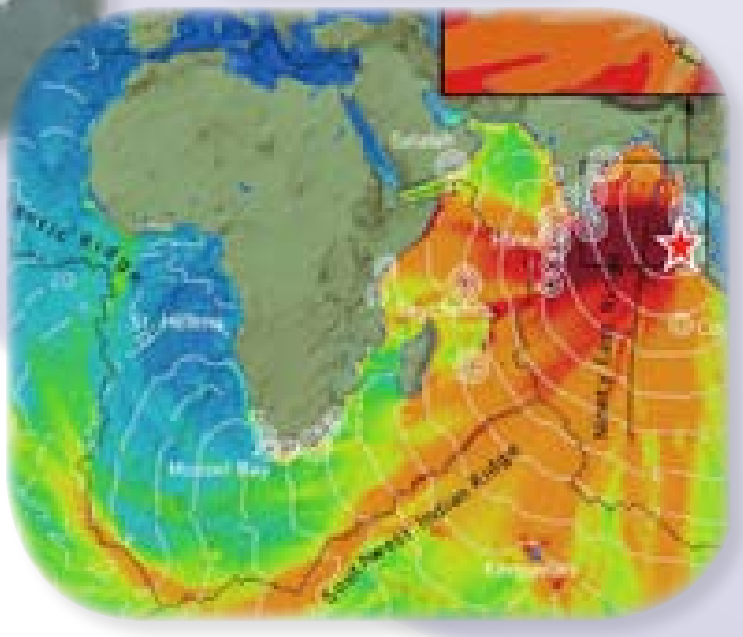


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TABLE OF CONTENTS

EXECUTIVE SUMMARY

INTRODUCTION

Established in 1977 at the University of Washington (UW), the Joint Institute for the Study of the Atmosphere and Ocean (JISAO) is a Cooperative Institute sponsored by the National Oceanic and Atmospheric Administration (NOAA). JISAO's major purpose is to foster collaborative research between NOAA and the UW on a broad range of global and regional topics of concern to residents of this nation and, in particular, to local citizens of the Pacific Northwest by:

- **enhancing** research capabilities of UW and NOAA scientists, utilizing the diverse array of scientific and technical expertise and specialized research facilities within both institutions;
- **facilitating** the training of the next generation of NOAA's scientists by capitalizing on the UW's extraordinary strength in the geosciences and its degree granting authority;
- **providing** UW students the opportunity to participate in NOAA research, thereby enriching their educational experience;
- **offering** educational and outreach activities to our local and regional communities through K-12 programs, student internships, training and recruitment programs, through media contacts and publications; and,
- **developing** relationships with government agencies and industries in the state of Washington and throughout the Pacific Northwest with a view toward assisting NOAA in tailoring its climate forecasts and assessments to meet the needs of stakeholders.

JISAO's four major research themes, **Marine Ecosystems, Climate, Environmental Chemistry** and **Coastal Oceanography**, encompass the wide range of mutual interests of NOAA scientists and UW faculty and, as described in the 2005 JISAO Review report, are closely aligned with the goals of NOAA's Strategic Plan[1]. The four themes are broken down into the following focus areas:

Marine Ecosystems

- Impact of natural and human-induced climate variability on the Bering Sea and Gulf of Alaska marine ecosystems
- Linkages between physical, chemical and biological processes in the marine environment
- Prediction of climatic and human impacts on ecosystem dynamics

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[1] University of Washington, Joint Institute for the Study of the Atmosphere and Ocean (JISAO), 2005 NOAA / JISAO Review Binder, pp. 9-14, http://jisao.washington.edu/review2005/

Climate

- Seasonal-to-interannual climate prediction
- Climate change in the Arctic
- Impacts of climatic variability and change on the Pacific Northwest

Environmental Chemistry

- The carbon cycle
- Aerosols and trace gases
- Hydrothermal vents

Coastal Oceanography

Estuaries Research

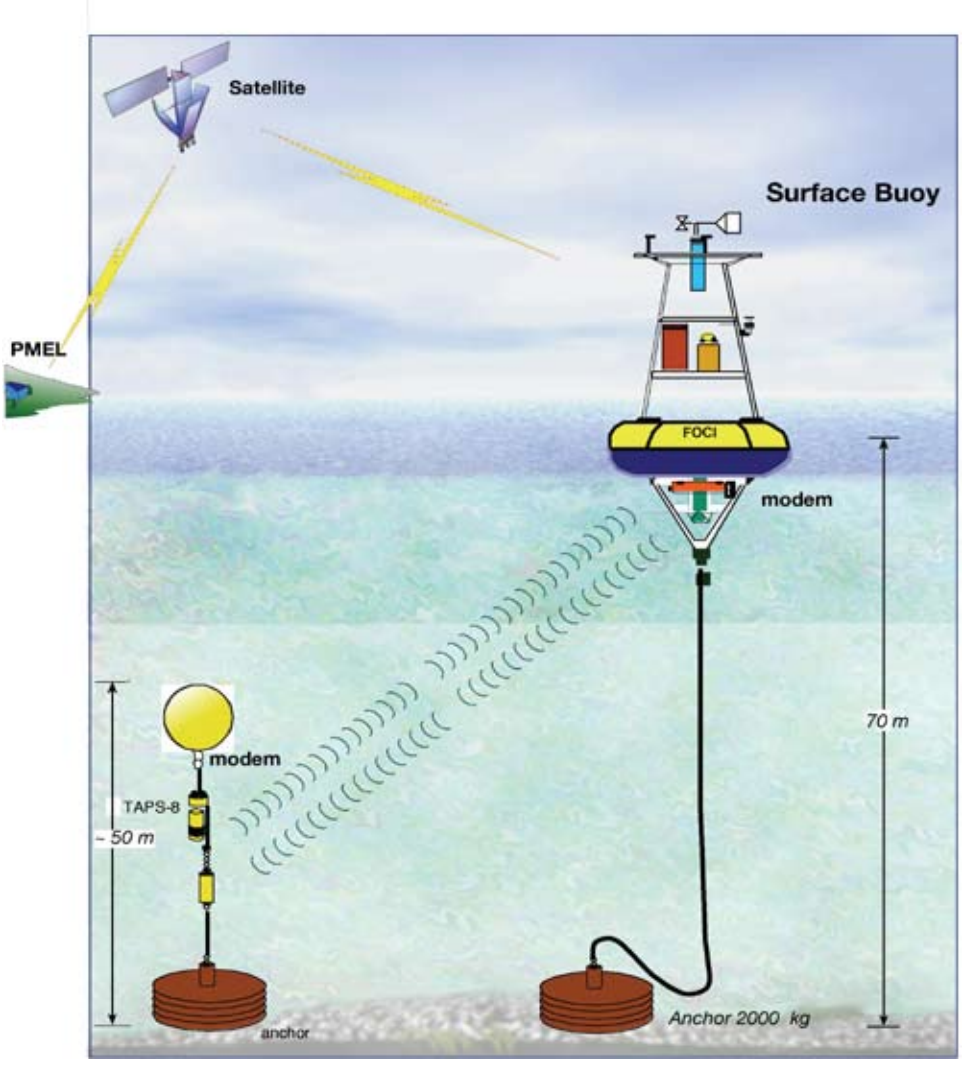
An additional group of JISAO employees focuses on facilitating access to JISAO datasets and research results. Included in this category are website management and the development of web-based tools for accessing, managing, graphically representing, visualizing, and interactively exploring today's voluminous multi-dimensional datasets.

SCIENCE HIGHLIGHTS

MARINE ECOSYSTEMS / FISHERIES RECRUITMENT

Collaborations in marine ecosystems are increasing, as evidenced in the number of projects in this area that were funded this year as a result of JISAO's continued efforts to foster closer relationships between NOAA's Alaska Fisheries Science Center (AFSC), Northwest Fisheries Science Center (NWFSC) and the UW School of Aquatic and Fishery Sciences.

One of the major efforts in this collaboration is the Ecosystems and Fisheries-Oceanography Coordinated Investigations (EcoFOCI) project co-directed by Nicholas Bond of JISAO and Phyllis Stabeno of NOAA/PMEL and involving staff from NOAA/AFSC as well. Adapting acoustic data relay technology to the M2 biophysical mooring in the Bering Sea and enabling monitoring of temperature, salinity, fluorescence, and zooplankton abundance are among this year's accomplishments. Data from the buoys are made available in real time to scientists and decision makers via the Internet.



M2 biophysical mooring used in the EcoFOCI project

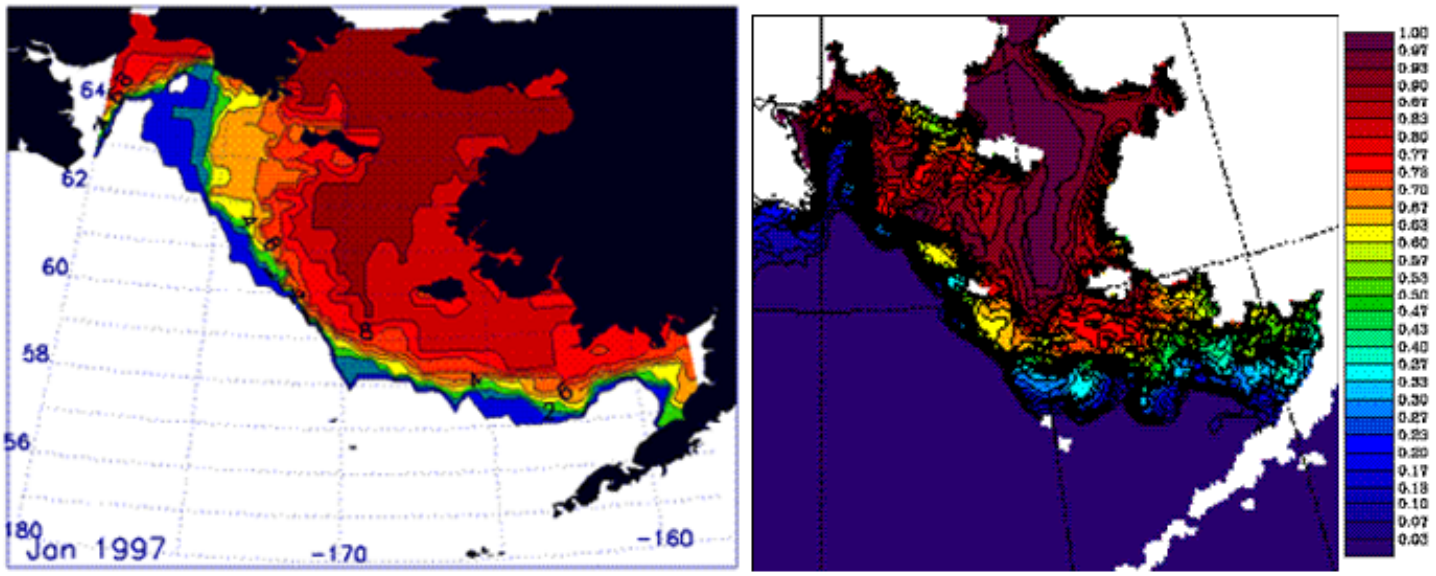
In partnership with NOAA/ NMML and the AFSC Midwater Assessment and Conservation Engineering (MACE) program, EcoFOCI personnel conducted a multi-disciplinary cruise along the ice edge of the Bering Sea in spring of this year to document how the location and characteristics of the marginal sea ice zone in this region are changing in response to the changing climate. Many living marine resource species (e.g., snow crabs, ribbon & ringed seals) depend upon the ice or some property associated with the presence of ice in the ecosystem. Other marine resources (e.g., pollock) may use the physical fronts in water properties that tend to form along the ice edge to find prey at elevated concentrations.

This year the EcoFOCI project completed a multi-year investigation of the influence of weather and climate on a single commercially valuable species: northern rock sole. Successful recruitment of this species is thought to be determined by the transport of larvae into the Bristol Bay region of the eastern Bering Sea. EcoFOCI scientists collected and analyzed larval samples at various depths and developed a new numerical model to simulate the three-dimensional structure of the ocean circulation over the entire Bering Sea. The model resolves scales of motion as small as 10 km and it incorporates sea-ice dynamics. The model can be used to predict the transport paths of the larvae of any species over the course of the year, and to investigate how the transports are changing from one year to the next and from one decade to the next in response to changing wind patterns. AFSC scientists will be using the model in assessing flatfish populations. Work has begun on the implementation of a simple biological model that will be run in conjunction with the hydrodynamic model to simulate the seasonal and year-to-year variations in the abundance of various species of fish at the lower levels of the food web.

EcoFOCI serves as an umbrella for a group of projects sponsored under JISAO's Marine Ecosystem/

Fisheries Recruitment theme. The domains of study include the Bering Sea, the Gulf of Alaska and the Pacific Northwest coast and topics of interest range from physical forcing of lower-trophic level community structure to mechanisms responsible for variations in the populations of top predators such as salmon and seabirds. A large share of this ongoing work involves developing the understanding required for an ecosystem-based management of the huge, and commercially valuable, walleye pollock stocks in Alaskan waters which are the primary constituent of fish sticks and imitation crab.

R/V *Thomas G. Thompson* leading an expedition to examine climate influences on the ice-edge ecosystem.

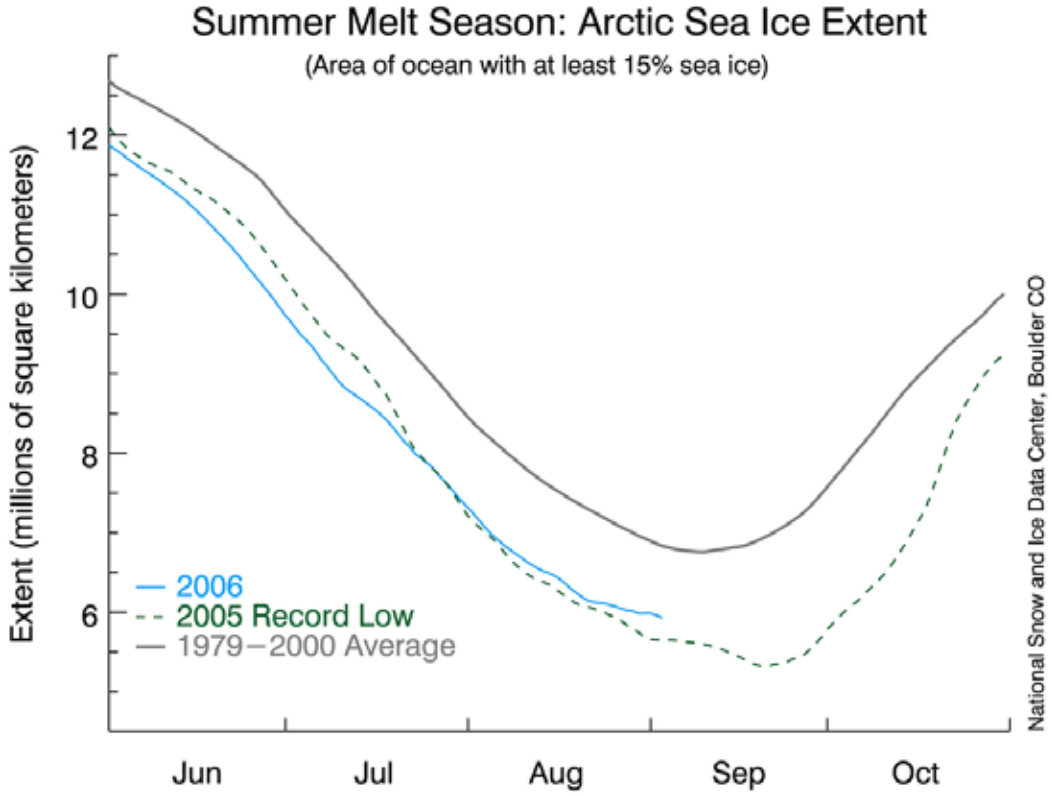


Comparison of fractional sea ice cover in the Bering Sea for Jan 1997 from (left) EcoFOCI ice-inclusive hydrodynamic model and (right) actual observations.

CLIMATE

Climate continues to be JISAO's dominant research theme, accounting for a large percentage of the combined Task II and Task III budgets (see pie chart in the Financial Management section). A major component of JISAO's climate research is devoted to supporting NOAA's ocean monitoring programs. Stephen Riser in the UW School of Oceanography and Greg Thompson at PMEL have been collaborating in the deployment of Argo profiling floats which will eventually be distributed throughout the world ocean with a horizontal resolution of around 300 km. JISAO staff are also involved in the TAO project office at PMEL, which is responsible for maintaining the TAO and PIRATA arrays of moored buoys in the tropical Pacific and Atlantic and for providing real time data derived from the moorings to the research community via the internet. JISAO also administers grants to UW scientists Ignatius Rigor and Ronald Lindsay at the UW Applied Physics Laboratory for purchasing and deploying buoys used in monitoring Arctic sea ice.

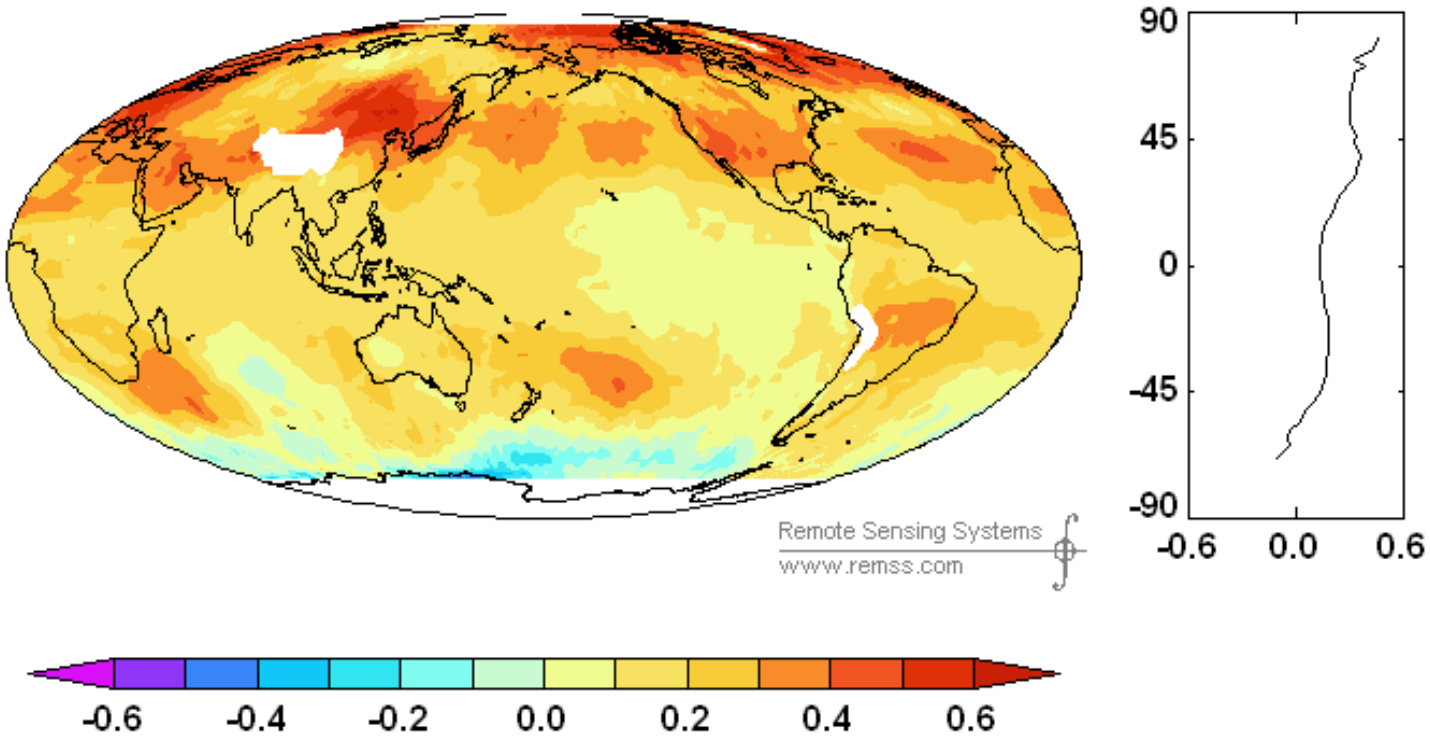
The monitoring of Arctic sea ice is directed toward improved sea-ice forecasts in time scales ranging from weeks to seasons and it also contributes to our understanding of why the areal extent of Arctic sea ice has declined so precipitously since the 1980s. Year-to-year and decade-to-decade variations in sea-ice extent along the north slope of Alaska have a strong impact on whaling operations at Barrow and other North slope Native American communities and on shipping and logistics in support of oil drilling operations at Prudhoe Bay. Record low areal coverage of Arctic pack ice was observed during September 2005 and the coverage this summer, though not quite as extreme, is well below the 1979-2000 average.



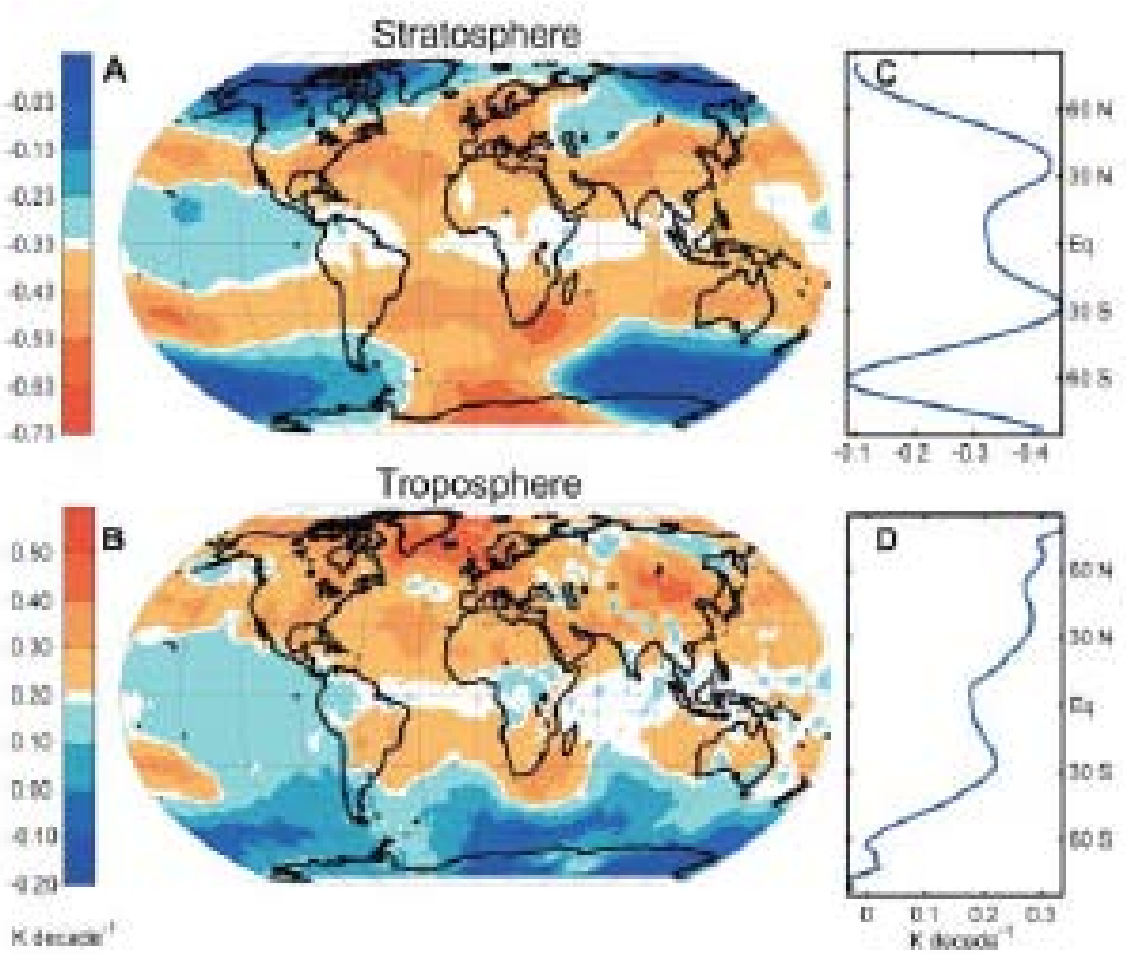
Comparison of day-by-day areal extent of Arctic sea ice with average conditions for 1979-2000.

The sea ice group at the Applied Physics Laboratory (APL) has drawn attention to the influence of the wintertime circulation over the Arctic upon sea-ice extent during the subsequent summer. The anomalously large expanses of open water observed during recent summers appear to be due, at least in part, to the extended interval of anomalous wintertime surface winds during the 1990s, which flushed most of the thicker, multi-year ice out of the Arctic basin, leaving behind younger, thinner ice that is much more susceptible to summertime melting.

Work of Qiang Fu and collaborators in the UW Department of Atmospheric Sciences, supported by NOAA through a grant administered by JISAO, was influential in stimulating a reexamination of temperature trends of the lower atmosphere. Prior to their work it was widely believed that although temperatures at the Earth's surface have been warming rapidly since the 1970s, the temperature of the layer extending upward from the Earth's surface to about 10 km, as inferred from satellite measurements, was warming very little, if at all. The apparent lack of consistency between the temperature trends at the Earth's surface and aloft was troubling because climate models indicate temperatures aloft should be rising at least as rapidly as temperatures at the Earth's surface. Fu and collaborators devised a new algorithm for retrieving temperatures from the satellite measurements. In contrast to previously published work, their results indicated that the lower atmosphere is warming at a rate consistent with model predictions. Subsequent studies by other groups have borne out the reliability of Fu et al.'s trend estimates and they have shown that the algorithm used in prior estimates had a sign error which led to spuriously small trends. These studies lend greater confidence to the detection of human-induced global warming and they serve to reduce the level of uncertainty inherent in estimates of the rate of warming.



Color coded map of decadal trends tropospheric temperature (1979 - 2004) derived from satellite measurements. Data poleward of 82.5° North and 70° South, as well as areas with land or ice elevations above 3000 meters, are not available and are shown in white. Courtesy of Remote Sensing Systems: http://www.ssmi.com/msu/msu_data_description.html#rss_msu_data_analysis

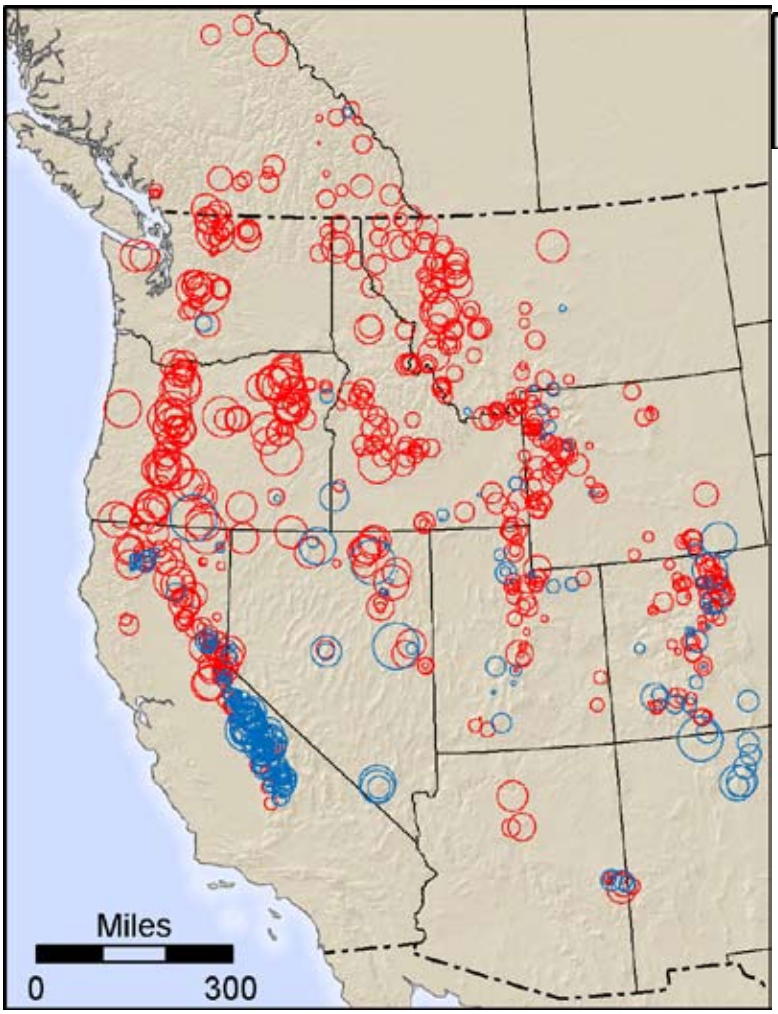


Global and latitudinal distributions of atmospheric temperature trends for 1979 to 2005 based on satellite-borne MSU observations. (A and C) Stratospheric trends with a global mean of -0.33 k per decade. (B and D) Tropospheric trends with a global mean of +0.20 k per decade. Orange shading represents enhanced rates of statospheric cooling and tropospheric warming relative to their respective global means, and blue shading represents suppressed rates. The polarity is reversed to facilitate comparison between (A) and (B).

Fu and his collaborators find that relative to the global-mean trends of the tropospheric and stratospheric layers, both hemispheres have experienced enhanced tropospheric warming and stratospheric cooling in the 15-45 degree latitude belts, a pattern indicative to a widening of the tropical circulation and a poleward shift of the tropospheric jet streams and their associated subtropical dry zones. Such shift, if it continues, could have important societal implications.

Over large areas of the western United States summers tend to be dry and much of the water supply and stream flow during the summer season is derived from melting mountain snow pack that builds up during the wetter winter season. Among the most serious impacts of greenhouse warming is the decreasing availability of water during summer due to the rise in wintertime freezing levels and the consequent reduction in the volume of water stored snow pack. As temperatures rise, runoff in rivers increases during the winter season and spring runoff occurs earlier in the year, leaving less water available during summer for human consumption and for maintaining stocks of salmon and other species of fish that depend on rivers. Over the past decade, the JISAO Climate Impacts Group (CIG) has been working to alert water managers to this threat, and to convince them to take it into account in their long range planning. Last year members of the Climate Impacts Group presented the results

of comprehensive analysis of snow pack data over the western United States dating back to the early 20th century (*Bulletin of the American Meteorological Society* 2005, 86(1):39-49). The paper showed evidence of declines of as much as 30% over areas of the Pacific Northwest where temperature is an important factor in determining wintertime snow pack. The only region of systematic increases was in the high Sierras of Southern California, where temperatures are cold enough (because of the high altitude) that virtually all the precipitation that falls during the winter season is stored in the form of snow, and year-to-year variability in snow pack is more sensitive to wintertime precipitation than to temperature. Some of the decline in snow pack over the Pacific Northwest is attributable to the change in the polarity of the Pacific Decadal Oscillation that took place during the late 1970s, but it is likely that a substantial fraction of it is attributable to human-induced greenhouse warming. In a related development, Philip Mote, the lead author of the snow pack study has been appointed as the State Climatologist for the state of Washington, and he now directs a small office that provides climate data tailored to the needs of state residents, business and government agencies.

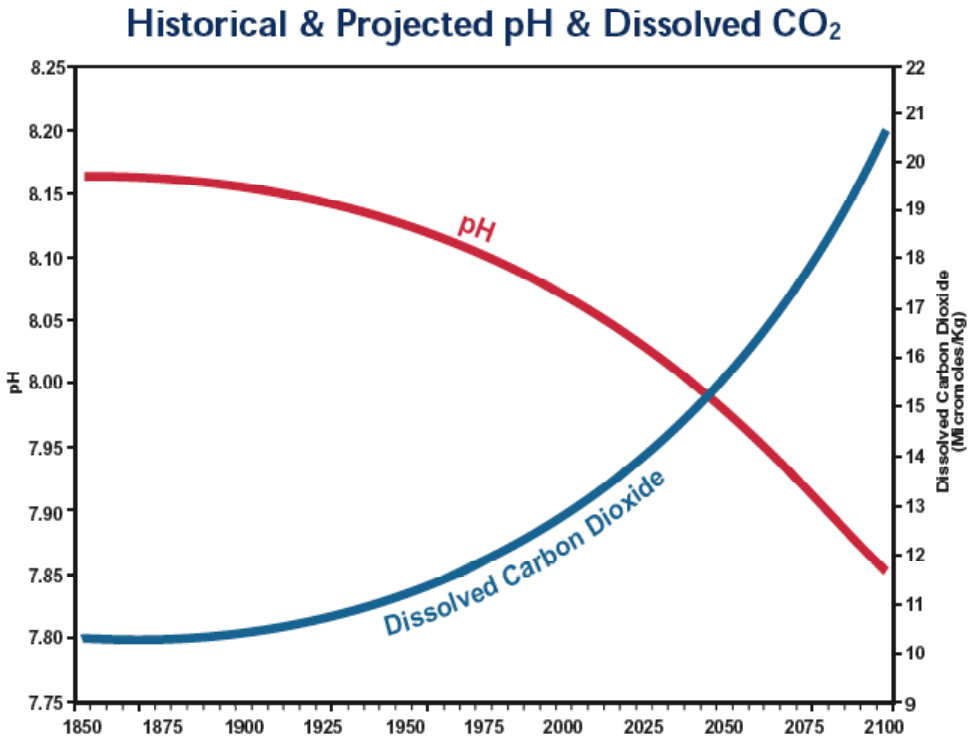


Trends in April 1 snow water equivalent, 1950-97. Negative trends indicated by red circles and postive trends by blue. From the article by Mote et al., (2005).

Among the other notable accomplishments of JISAO's Climate Impacts Group, under the direction of Professor Ed Miles during the past year, was the co-organization of a highly successful conference entitled *The Future Ain't What It Used To Be: Planning for Climate Disruption*, which brought together 675 participants from government, business, tribes, nonprofits and the community at large to discuss the projected impacts of climate change in the Pacific Northwest and how the region (particularly Washington State) can prepare to adapt to those impacts. The meeting was conceptualized and hosted by King County, Washington, as an outgrowth of the research conducted by the CIG. Materials that were developed in support of the meeting, including the plenary presentations on projected climate change, impacts, and planning approaches, are available on the CIG website. The large turnout at this workshop and the subsequent request of the Washington State Department of Ecology to produce watershed-scale climate change streamflow and flood scenarios illustrate the strong interest in climate on the part of long range planners in this part of the country and the strong and high repute of the JISAO Climate Impacts Group.

ENVIRONMENTAL CHEMISTRY

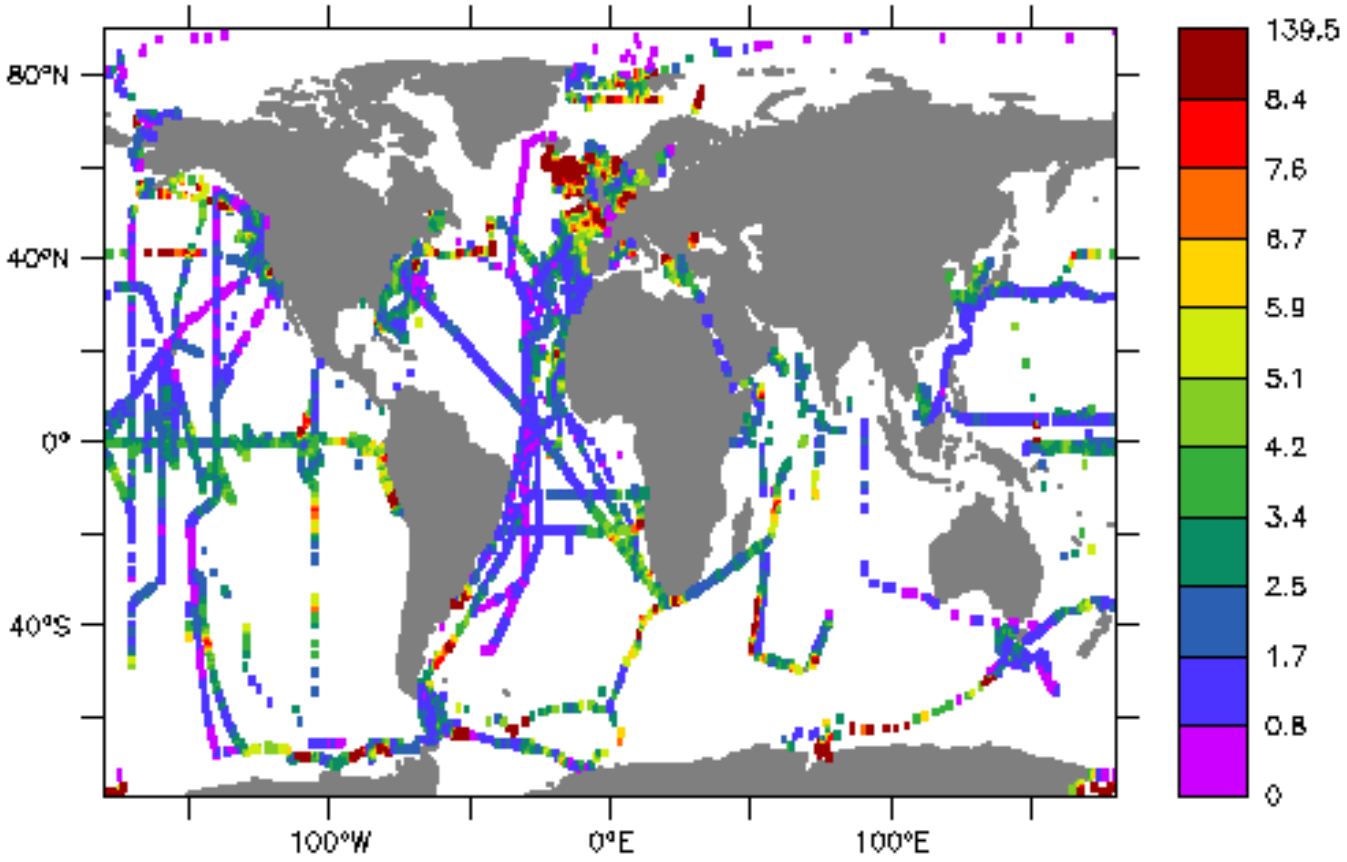
PMEL-JISAO collaborative research on the ocean carbon cycle has been very much in the headlines this year, following the discovery that the acidity of the oceans has been increasing in response to the uptake of carbon dioxide. The paper by Sabine et al. (*16 July 2004, Science*), which was instrumental in this discovery, has already been cited nearly 100 times. Prior to this discovery it was widely assumed that the oceanic uptake of roughly half the carbon dioxide injected into the atmosphere by the burning of fossil fuels is a good thing, because it slows the rate of buildup of greenhouse gases in the Earth's atmosphere. Now, it is evident that this oceanic uptake of carbon dioxide is not without a price. When carbon dioxide is dissolved in seawater, it dissociates to form a dilute solution of carbonic acid. As the acidity of seawater increases, calcium carbonate, the primary constituent of the shells of sea animals, tends to dissolve. The companion *Science* paper by Feely et al. Reported that the current rate of increase in the acidity of the oceans is considered to be fast enough to constitute a serious threat to coral reefs and the marine organisms that depend on them for their survival over the course of the next century. This research has led to an intensified effort to monitor the carbon content of the oceans and the effect of the increasing acidity on marine organisms, as detailed in the body of the report. The PMEL/JISAO ocean chemistry group is taking some of the key measurements in support of this effort.



As the ocean concentration of carbon dioxide increases, so does acidity (causing pH to decline).

JISAO's atmospheric chemistry group has devoted its efforts to narrowing the uncertainties in the so-called "climate forcing" due to the presence of particles in the atmosphere, including those due to human activities such as power generation and biomass burning. The direct climate forcing is defined as the net downward flux of radiation at the top of the atmosphere that would result if the particles were instantaneously injected into the atmosphere. Aerosols are believed to produce a net cooling effect by reflecting solar radiation that would otherwise be absorbed at the Earth's surface back to space before it reaches the ground. Making use of intensive measurements of atmospheric aerosols that have been carried out in recent field experiments over the Indian Ocean, over the western Pacific downstream of Asia, in the Gulf of Maine, and in the Gulf of Mexico, JISAO scientists have modeled and compared the climate forcings in these four regions. The regional cooling due to the presence of aerosols was estimated to range from about 3 watts per square meter over the Indian Ocean to as much as 14 watts per square meter over the

western Pacific, under clear sky conditions. For comparison, in the global-average, the rate of warming of the atmosphere due to the presence of greenhouse gases injected into the atmosphere by human activity is on the order of 2.5 watts per square meter. Estimates such as these provide a check on estimates of climate forcing derived from climate models, and the extensive data sets from which they are derived provide "ground truth" for more extensive remote measurements of aerosols by satellite.



Concentrations of DMS in sea water as represented in the JISAO online database.

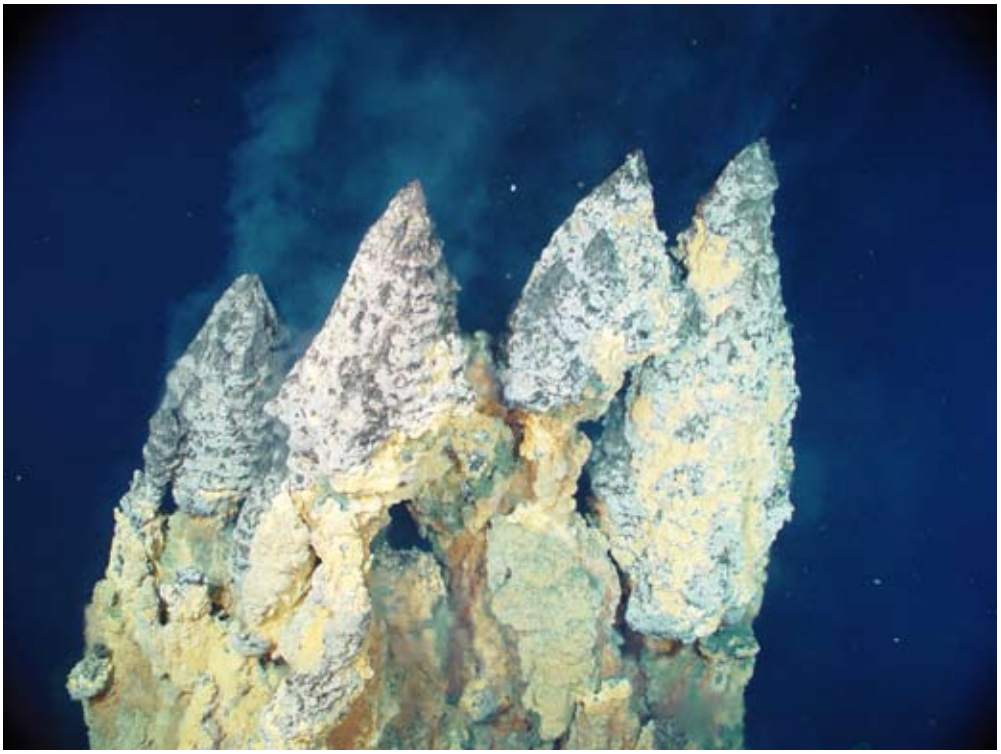
JISAO's atmospheric chemistry group is a world leader in investigations of biologically-produced dimethyl sulfide (DMS), the atmosphere's most important natural source of sulfur. Atmospheric DMS is oxidized to form sulfate particles indistinguishable from those introduced by human activity. Atmospheric concentrations of DMS vary widely in response to variations in the biological and chemical properties of sea water. JISAO maintains a database consisting of more than 30,000 measurements of DMS concentrations in surface sea water that is widely used in chemical transport models. JISAO also continues to host the office for the International Global Atmospheric Chemistry (IGAC) project with funding from NOAA, NSF and NASA, which is committed through June 2009. During the past year IGAC organized 4 international specialty workshops and initiated 2 new international research projects.

The past several years have seen some important scientific discoveries relating to submarine hydrothermal vents on the seafloor. Vents occur along the mid-ocean ridges where the plates are diverging, along volcanic arcs, where the plates are converging, and more sporadically in off-axis

environments. JISAO scientists David Butterfield, Joseph Resing, Kevin Roe, and Geoffrey Lebon have been involved in ocean exploration programs in all three kinds of environments. The research is concerned with the hydrothermal systems themselves and how they respond to local and regional tectonic or volcanic events and with the links between the chemical environment and the microbial communities in the vicinity of the vents.

Vents along the so-called "ring of fire", a system of volcanic arcs in the western Pacific, have been visited regularly since 2003, yielding the first direct observations of lava eruptions in the deep sea, overlapping venting and photosynthetic ecosystems, active molten sulfur lakes and flows, extreme acid alteration of volcanic rocks, volcanic gas emission in the upper ocean and a variety of novel ecosystems, as illustrated in the accompanying photos, provided by the NOAA Ocean Exploration and PMEL VENTS Program.

Highly altered volcanic rock and gas bubbles in natural ambient light at 120 meters depth at Giggenbach volcano, Kermadec arc. Many shallow submarine arc volcanoes have hydrothermal systems that penetrate the thermocline and photic zone. This raises many important questions related to ecosystem dynamics,



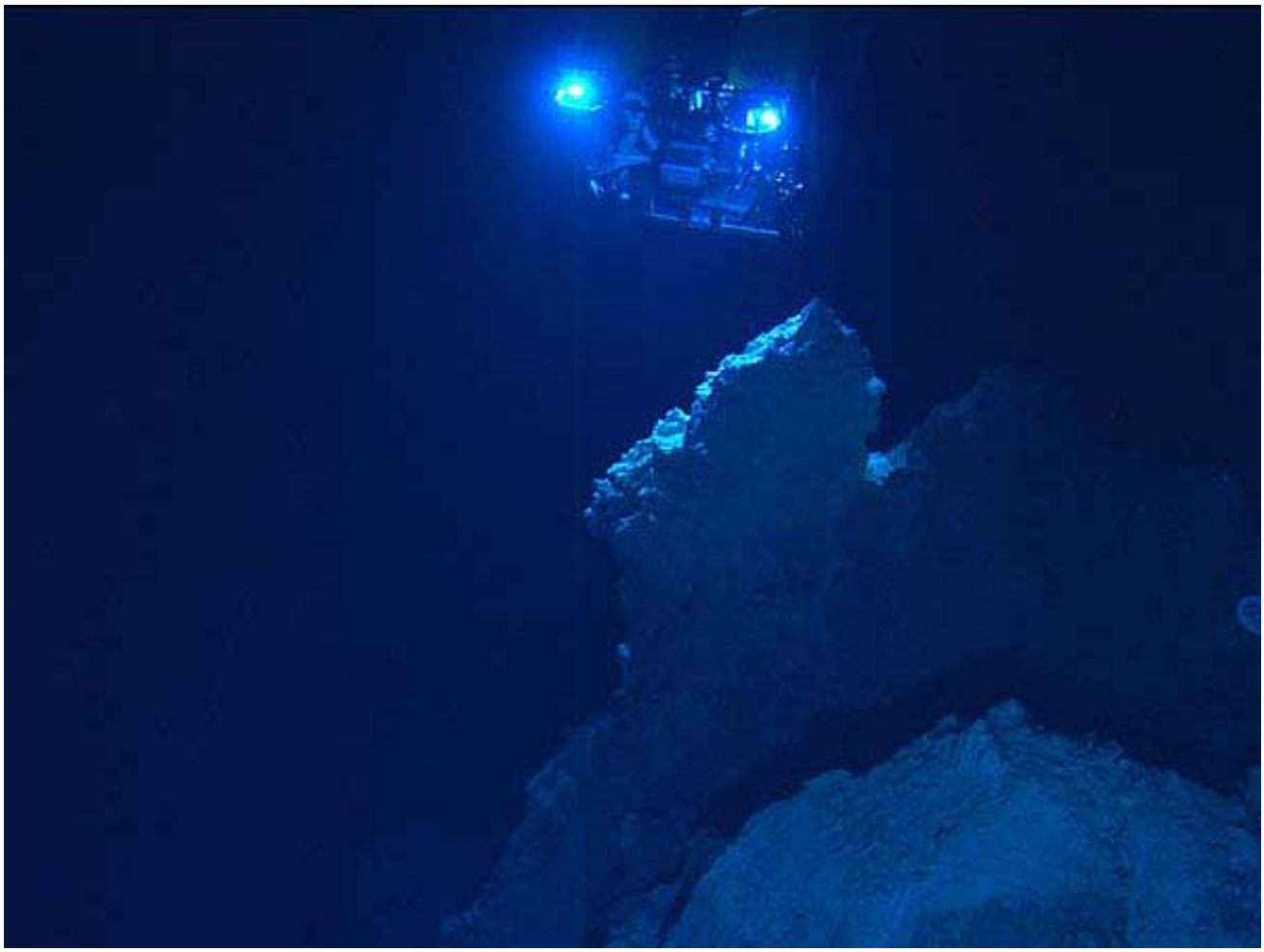
Black smoker chimneys at East Diamante caldera, Mariana arc. At a depth of 345 m, these are among the shallowest sulfide chimneys known.

Colorful soft coral community on an isolated pinnacle within East Diamante caldera, Mariana arc. This deep (>165m) photosynthetic community is very near a hydrothermal area.

JISAO scientists have made a number of important contributions to the technology that has been instrumental in these discoveries. The Hydrothermal Fluid and Particle Sampler (HFPS) developed by Butterfield has been used extensively since 1998 to determine the chemical and microbial makeup in the vicinity of vents. Resing and colleagues have also developed an *in situ* technique capable of measuring iron concentrations over a wide range of values. This sampler is being used both in fisheries investigations like FOCI near the ocean surface, where concentrations are very low but nonetheless perhaps important in regulating productivity, and in the plumes of vents where concentrations are orders of magnitude higher. JISAO scientists have also pioneered the use of acoustic satellite systems that enable two-way communication between the seafloor and shore-based laboratories.

In July 2005 JISAO scientists participated in a NOAA-funded study of the Lost City

hydrothermal field, an off-axis hot spring site near the mid-Atlantic ridge. This study made extensive use of a remotely operated vehicle (ROV), the *Hercules* on the NOAA ship *Ron Brown*. The experiment was novel in the sense that scientists situated at the University of Washington were able to provide scientific direction in real time, making use of a broadband connection from the ship that permitted transmission of large volumes of video and other data.



A view of the *Hercules* ROV hovering over giant carbonate chimney structures at Lost City field, Mid-Atlantic Ridge. Chemical and ecological conditions at these hydrothermal systems on exposed mantle rocks are completely different from all volcanic hydrothermal systems. Image courtesy of IFE, NOAA and University of Washington.

COASTAL OCEANOGRAPHY

Tsunamis have long been considered a serious risk to life and property on the US Pacific Coast. For over 20 years, JISAO and NOAA/PMEL have engaged in collaborative research aimed at improved tsunami warnings, funded under JISAO's estuaries research theme, now called coastal oceanography. Important elements in this work include:

- advancing the state-of-the-art of tsunami modeling which provides the scientific
- basis for forecasting wave heights and timing

- developing the deep-ocean assessment and reporting of tsunamis (DART) moorings which provide real-time detection of tsunamis and monitor their progress as they propagate across the vast expanses of the ocean.
- assessing the risk of inundation by tsunamis in communities in the Pacific Northwest.
- working with local authorities to enhance the effectiveness of tsunami warnings and to educate the public as to how to respond to them.

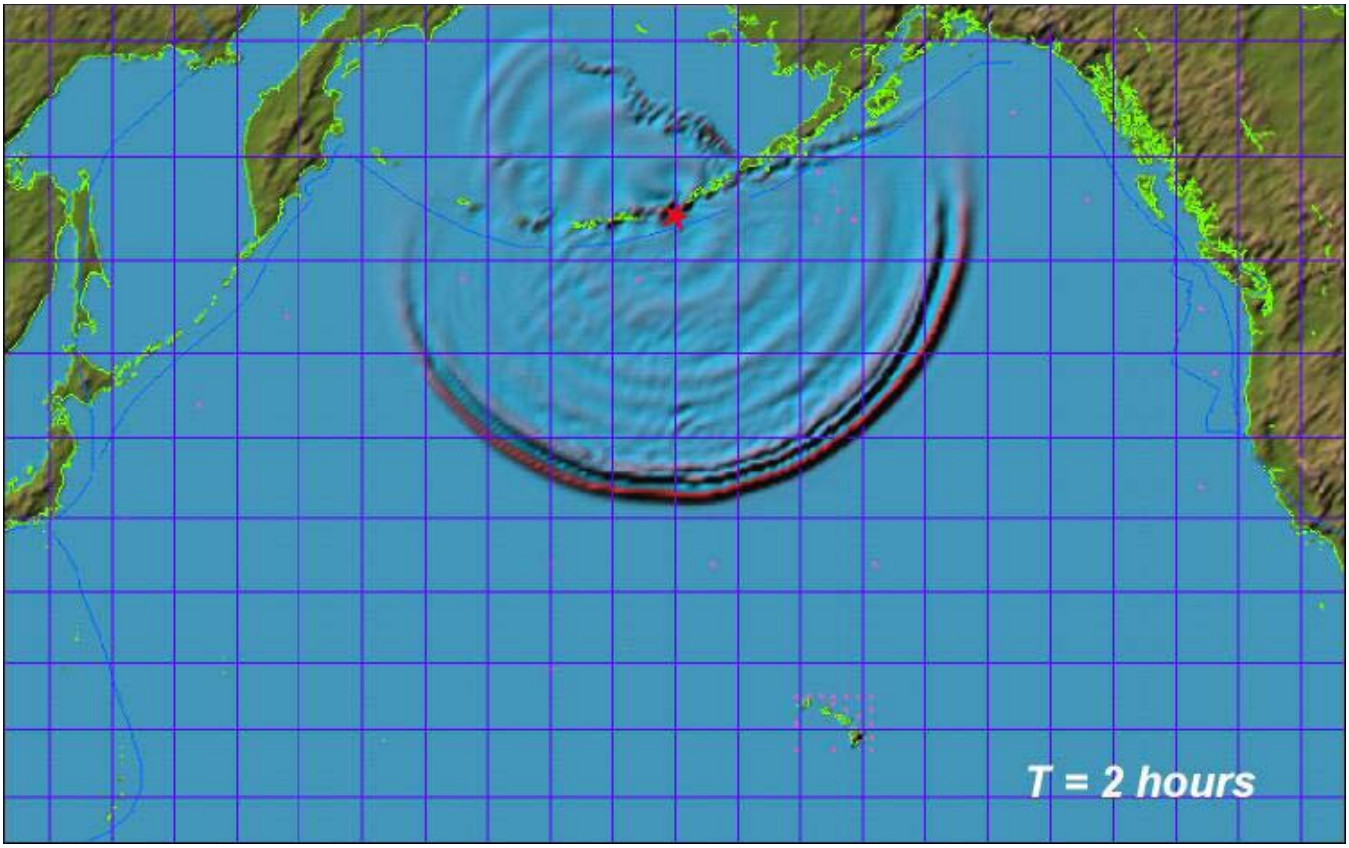
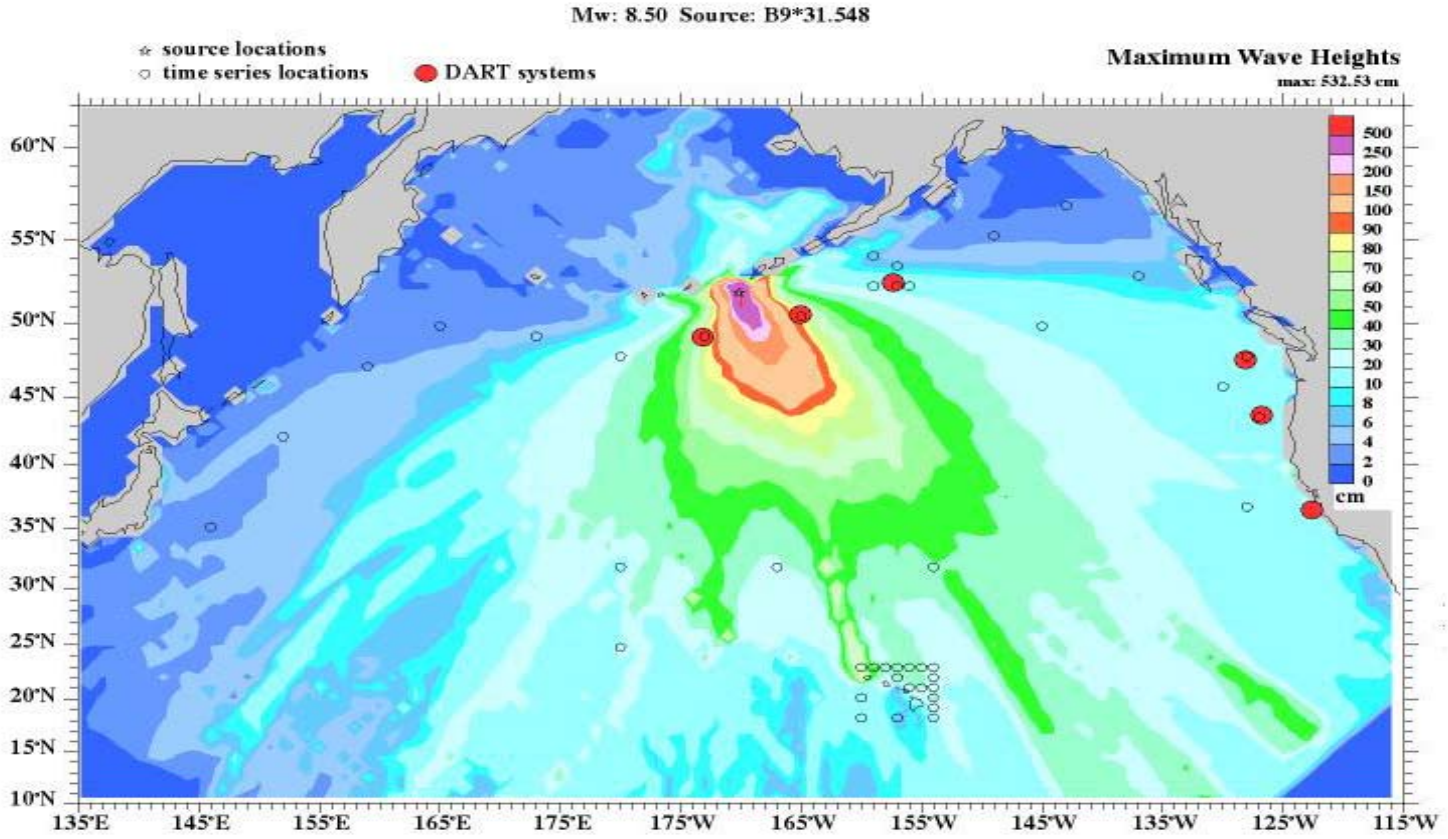
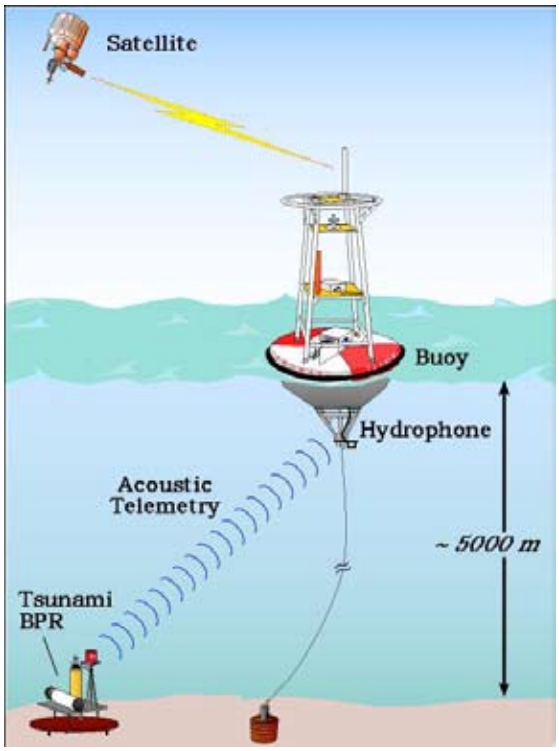


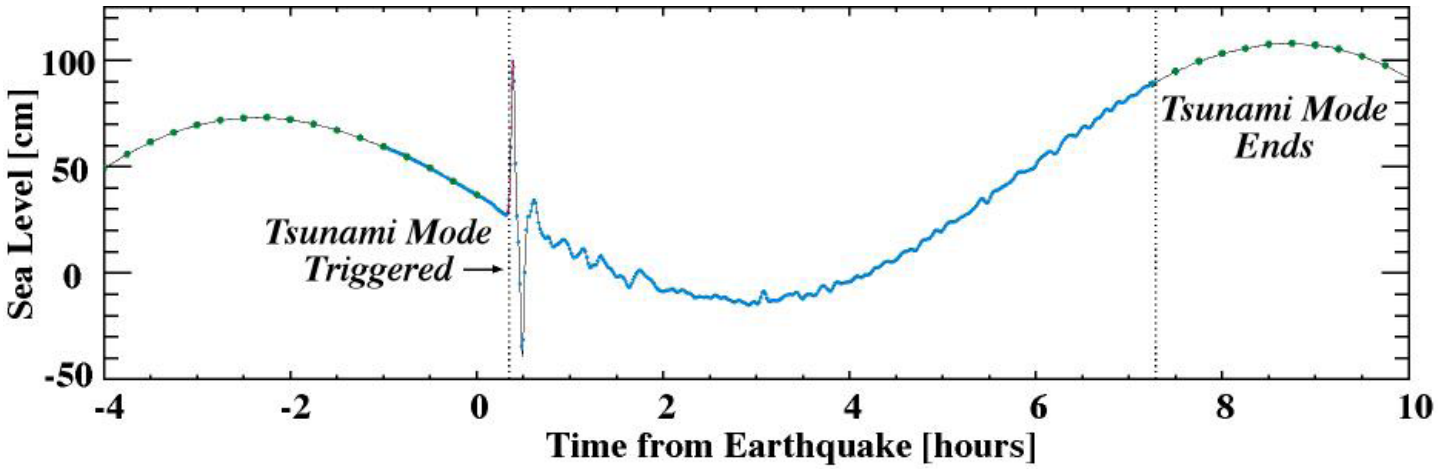
Image from a numerical simulation of a tsunami.



Maximum wave heights derived from a numerical simulation of a tsunami.



The DART mooring.



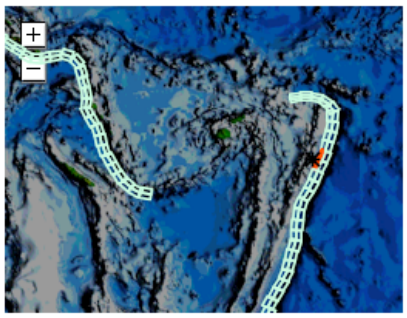
Simulated measurements from a DART mooring that records the passage of a train of waves from a distant tsunami.

Developing an effective system for tsunami warnings has assumed a renewed sense of urgency in the wake of the disastrous December 26, 2004 Indian Ocean tsunami. In October 2005, The NOAA Center for Tsunami Research (NCTR) was established to take the lead in this R&D effort, much of which is situated at NOAA/PMEL. Over the past year, JISAO has hired 12 additional scientists in support of the new Center. Specifics of the work of this group are provided in the body of this report. In order to increase the cooperation between the NOAA-supprted tsunami research in JISAO and the active program of tsunami research in the University of Washington's Department of Earth and Space Sciences, JISAO scientist Vasily Titov has been awarded affiliate faculty status in that department.

INFORMATION TECHNOLOGY

JISAO's information technology group, headed by Donald Denbo, supports JISAO science projects. A notable accomplishment of this group during the past year is the initial release of the Tsunami Forecast System to NOAA's Tsunami Warning Centers. The Tsunami Forecast System was developed within the auspices of the NOAA Center for Tsunami Research and a part of its mission is to transfer the models, methods, and procedures developed by its staff to an operational environment. It consists a modular set of computer programs designed to aid warning center operators meet their responsibilities in providing tsunami warning messages and information. To meet these requirements in an operational setting, the system is fast and reliable, and it runs equally well on Windows, UNIX, and other operating systems. Off the shelf components were used whenever possible and strict standards were followed in order to ensure compatibility. When an earthquake capable of producing a tsunami occurs, the system initially automatically computes the tsunami travel time and maximum wave height. An operator can manually re-run the products using modified event parameters.

Initial capabilities of the Tsunami Forecast System include tsunami travel time calculation and display, maximum wave height forecast, and combining multiple subduction zone sources for a more accurate results. Future capabilities will include the real-time processing of sea level and bottom pressure data, combining the bottom pressure measurements with the model forecast to improve accuracy, and the ability to run Stand-by Inundation Models to compute detailed inundation forecasts for specific at-risk communities. Through this project, JISAO is helping NOAA's Center for Tsunami Research provide state-of-the-art tools to NOAA's Tsunami Warning Centers to better enable them to accomplish their mission.



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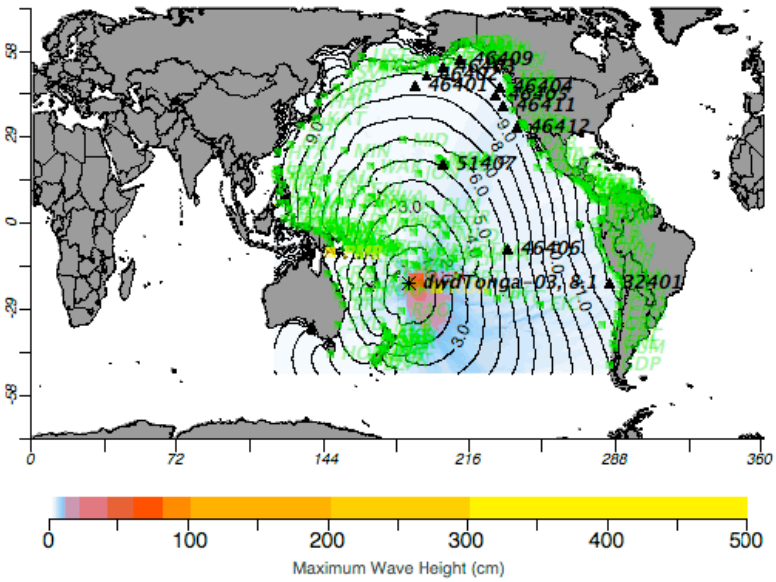

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NIU	03:26:35 UTC 03 May 2006	04:26:35 NUT 03 May 2006	00:00	162.0	Niue Is, Niue	O
ROR	04:31:35 UTC 03 May 2006	06:31:35 CKT 03 May 2006	00:00	79.8	Rarotonga, Cook Islands	O
PMB	09:34:35 UTC 03 May 2006	07:34:35 PGT 04 May 2006	02:00	62.7	Port Moresby, Papua New Guin...	O
PNR	05:14:35 UTC 03 May 2006	07:14:35 CKT 03 May 2006	00:00	37.0	Penryn Is, Cook Islands	O
PPT	06:01:35 UTC 03 May 2006	08:01:35 THAT 03 May 2006	00:00	36.2	Papeete, Fr Polynesia	O
PTC	08:28:35 UTC 03 May 2006	12:28:35 PST 03 May 2006	00:54	30.6	Pitcairn Is, Pitcairn	O
MLD	05:59:35 UTC 03 May 2006	07:59:35 LIST 04 May 2006	00:00	29.7	Malden Is, Kiribati	O
EIC	11:23:35 UTC 03 May 2006	05:23:35 EAST 03 May 2006	03:49	29.6	Easter Is, Chile	O

Tsunami Forecast System screen snapshot of the May 3, 2006 Tonga event results. Left, right, and bottom panels display the event source parameters, the maximum wave height and tsunami travel time, and a table of the arrival times and amplitudes for stations near the event, respectively.

A NEW RESEARCH GROUP

This year JISAO welcomed a new research area with the addition of the HAZMAT project, which engages in research and development activities in the dynamic natural and human processes that interact during releases of hazardous materials into the environment. The goal of this applied research is to improve access to critical response information in emergency situations and facilitate decision-making processes that will reduce the human and environmental impact of pollution events. The JISAO HAZMAT group is part of the NOAA Hazardous Materials Response Division, and it collaborates closely with the United States Coast Guard Office of Research and Development and EPA's Office of Emergency Management. Since the HAZMAT group was hired late into the current reporting period, a progress report will be provided in next year's annual report.

OUTREACH

In response to NOAA recommendations, JISAO staff over the past year have been planning and implementing a new initiative focused on diversity recruitment and community outreach efforts. The major goals of the program are;

- to create a more centralized effort for recruitment and retention of underrepresented groups into our workforce;
- to offer outreach activities to K-12 students and internship opportunities to university students;
- to increase JISAO's visibility and presence on campus, in the local and regional communities and within the NOAA national cooperative institute network.

UW GEARUP 2006: Participants prepare for a trip to the weather station on the roof of the Atmospheric.Sciences Building.

NOAA Science Camp 2006: Campers perform recovery and pre-deployment release maneuvers on a buoy.

NOAA Science Camp 2006: Nick Bond, JISAO scientist, helps campers with heat flux calculations.

The initial planning stages are complete and progress has been made towards these goals. JISAO faculty, staff and students are collaborating with existing UW programs including the Program on Climate Change, Washington Sea Grant Program, Center for Workforce Development, Washington State MESA (mathematics, engineering, science achievement), Do-It (Disabilities, Opportunities, Internetworking and Technology), and University of Washington GEAR UP (Gaining Early Awareness and Readiness for Undergraduate Programs).

In addition, JISAO continues to strengthen its collaboration with NOAA and is now a member of the NOAA Northwest Regional Education and Outreach Group. Through this group, JISAO scientists led much of the PMEL portion of the NOAA Science Camp this year, and the institute provided a number of scholarships to low-income youth who participated. All of these activities are being tracked on the JISAO website and will be updated as there is news to report (see *jisao.washington.edu*). A more detailed summary of JISAO diversity and outreach activities is included in Appendix 13.

JISAO personnel have also been working on a public relations plan to help the institute develop a stronger identity within our local community as well as within our national network of CIs. A major component of this work has been to update the website so that it becomes a more informative tool for users and provides meaningful research updates. Along with the other CIs across the country, JISAO continues to participate in the NOAA website 'hot items' posting which periodically highlights some of our most current and exciting research projects. JISAO was also featured on the main UW home page to inform the campus community about our work. A tracking system for print and other media contacts has been implemented so that this information can be posted on the web. The institute continues to track all JISAO-funded publications by assigning individual contribution numbers and keeping all information in a master database.

FINANCIAL MANAGEMENT AND ADMINISTRATION

JISAO's financial information for the past year is summarized below. Since 2003, there has been an 18.5% increase in scientific staff, mostly at the PMEL/JISAO location at NOAA, in Seattle. This growth has been supported effectively without an increase in administrative staff over the past three years. JISAO's Cooperative Agreement research is funded through three tasks:

Task I, the institute's "core program", also supported by the UW, includes:

- Two to three postdoctoral fellows on annual appointments, renewable for a second year
- Senior visiting scientists on leave from their home institutions
- Honoraria and travel expenses for short-term visitors
- Education and outreach activities

JISAO provides space, computer access, administrative support, and other services for post-docs and visitors supported on Task I. It also funds a small percentage of the salaries for the JISAO administrator and one program specialist, who manage the institute's business operations. Over the past year, Task I funding supported three postdocs (Taka Ito, Meredith Hastings and Andrew Rice) and the short-term

visitors and activities listed in Appendix 2. Three additional postdocs have been recruited for next year.

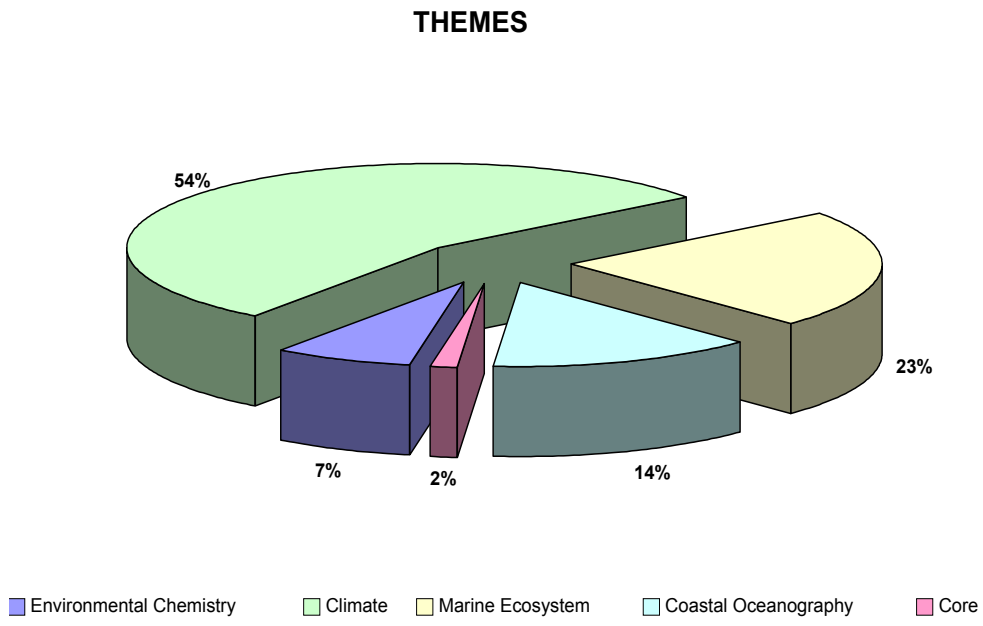
Task II serves as a vehicle for funding research scientists (UW professional staff), postdoctoral research associates and graduate students through the JISAO Cooperative Agreement grant. The Task II program supports directed, collaborative research efforts between NOAA and university scientists.

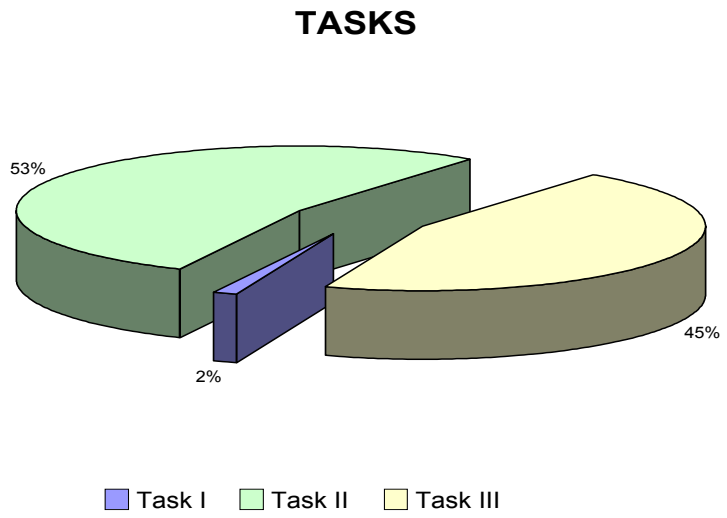
Task II funding supported a total of 80 professional staff housed at NOAA/PMEL (see Appendix 3). It also supported 5 post-doctoral research associates housed at PMEL and the Alaska Fisheries Science Center (AFSC).

Task III supports University of Washington research in areas compatible with the Institute's major research themes. Along with Task II, Task III programs serve as vehicles for funding research scientists (UW faculty and professional staff), postdoctoral research associates and graduate students through the JISAO Cooperative Agreement grant.

Task III supported 3 post-doctoral research associates housed at PMEL and AFSC. University of Washington grants and principal investigators on NOAA grants funded through Task III are listed in Appendix 4.

The JISAO/NOAA Cooperative Agreement funding for the five years ending on June 30, 2006 totals $60,284,132. JISAO's funding exclusive of the Cooperative Agreement for the same period amounts to another $6,880,000. The charts below break down Cooperative Agreement funding by themes and tasks for 2005-06:





JISAO underwent two separate audits during this year: an internal UW audit of payroll records and processes; and a federal audit conducted by the State Auditor's Office. Official reports have not yet been released, but preliminary results indicate that the systems and checks and balances designed and implemented by the JISAO staff to manage the institute's grants and contracts are in conformance with audit standards.

JISAO publications reported this year increased by about 30%. This is due to a more accurate and improved system for assigning JISAO contribution numbers and tracking them in a master database. The staff continues to work with all JISAO PIs to strengthen this process.

JISAO now looks forward to the major change in the next year of welcoming a new director. A top candidate has been identified after a long search committee process and negotiations are currently underway. Additionally, a new location for JISAO, either on or near campus, will be determined in the near future.

PROJECT SUMMARIES

MARINE ECOSYSTEMS

Project: Ecosystems & Fisheries-Oceanography Coordinated Investigations (EcoFOCI).

PI(s):
UW - N. Bond; NOAA - P. Stabeno

Other Personnel:
UW - A. Hermann, Y.-W. Lee, C. Mordy, F. Mueter, C. Parada, S. Rodionov, D. Righi, M. Sullivan, E. Dobbins, M. Wang, N. Kachel
NOAA - J. Napp, S.A. Macklin, B. Megrey, J. Overland

NOAA Primary Contacts:
PMEL and AFSC

NOAA Goals:
1) Protect, Restore and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management.

2) Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond.

Task: II & III

Objectives:

1. Improve and expand observational network necessary to monitor the ecosystem, verify models and develop indices.

2. Improve understanding of the effects of climate variability on the North Pacific marine ecosystem.

3. Describe and quantify temporal variability in the spatial distribution of individual ground fish species and ground fish assemblages.

4. Improve modeling capabilities in pursuit of ecosystem-wide forecast models for commercially valuable fish and shellfish, endangered species and related interdependent species.

Accomplishments:

1. EcoFOCI was successful in adapting acoustic data relay technology to the M2 biophysical mooring in the eastern Bering Sea. This development enabled real-time transmission of measurements of temperature and salinity (at two depths), fluorescence and zooplankton abundance. Following download at PMEL, the information is processed, assembled and distributed using World-Wide Web protocols. Thus, information is available to scientists and managers for real-time decision making.

2. EcoFOCI personnel partnered with the National Marine Mammal Laboratory and the AFSC Midwater Assessment and Conservation Engineering Program to conduct a multi-disciplinary cruise to the ice edge in the eastern Bering Sea during May 2006. The characteristics and location of the marginal sea ice zone in the eastern Bering Sea are changing in response to the changing climate. Many living marine resource species (e.g. snow crab, ribbon seals, ringed seals) depend on the ice or some property associated with the presence of ice in the ecosystem. Other living marine resources (e.g. pollock) may use the physical fronts created at the ice edge to find prey at elevated concentrations. Information obtained from this first look at ice edge patterns and processes, from ocean physics to seals, will greatly increase our understanding of ecosystem processes, and the role of climate in ecosystem dynamics. This will form a foundation for future efforts under the EcoFOCI, IPY (FY07) and Loss of Sea Ice (LOSI; FY08) programs.

3. During Quarter 1 of FY 2006, EcoFOCI researchers completed a multi-year study to improve understanding of the influence of climate and weather on the transport of larval northern rock sole (*Lepidopsetta polyxystra*), a commercially fished species, in the eastern

Bering Sea. Successful rock sole recruitment is thought to be determined by the transport of larvae into the Bristol Bay region of the eastern Bering Sea. Previous research at the Alaska Fisheries Science Center correlated transport with periods of successful recruitment, but only considered transport by wind-driven surface currents and assumed that all larvae were near the ocean's surface. EcoFOCI improved on this understanding by collecting and analyzing larval samples to determine their vertical distribution in the water column, and by developing a new ROMS-based circulation model to simulate currents throughout the water column. The new model can be used to predict the annual transport paths of larvae of any species, and as a tool to investigate the effects of changing climate on transport in this region. These results were presented at the recent International Flatfish Symposium, and are being prepared for submission to a peer-reviewed journal.

4. Advances in understanding and modeling ecosystem processes were achieved with development of a sea-ice-inclusive hydrodynamic model for the Bering Sea. This model advances our ability to predict consequences of climate change on ecosystems. Seasonal sea ice is a significant component of the Bering Sea ecosystem. All existing and to-be-developed ecological predictive models will benefit from linkages to this more advanced, ice-inclusive circulation model. EcoFOCI's new model, based on the Regional Ocean Modeling System (ROMS), resolves to 10 km and spans the entire Bering Sea. This version has been expanded to include ice dynamics. Hindcasts, driven by winds and heat fluxes, span the period 1955-present, and capture the observed inter-annual variability of ice cover in the Bering Sea. The model has been used to study ocean currents over the southeastern shelf; Alaska Fisheries Science Center scientists will use the model in the assessment of southeastern Bering Sea flatfish populations. Initial work has begun on the implementation of a simple lower trophic level model (NPZD) that will be run in conjunction with the ice-inclusive hydrodynamic model.

Project:
Atka Mackerel Food Habits.

PI:
UW - Vincent F. Gallucci

Other Personnel:
UW - Kimberly Rand; NOAA - Sandra Lowe

NOAA Primary Contact:
NMFS/AFSC/REFM

NOAA Goal:
1) Protect, Restore and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management.

Task: III

Objectives:

1. Study and relate large scale food habit differences to differential growth patterns of Atka mackerel, and to use food habit data to assess small scale habitat utilization.

2. Enhance understanding of important life history characteristics of Atka mackerel and provide temporal and spatial resolution of Atka mackerel food habits necessary to define essential fish habitat for feeding.

Accomplishments:

A preliminary analysis of Atka mackerel feeding patterns in Aleutian Islands, Alaska, has been carried out. The current qualitative analysis described in this report is useful in presenting habitat use patterns that could be of significant value, such as for the possible definition of feeding areas relative to the possible specification of trawl exclusion zones.

Three study areas are defined: Amchitka Island area, Sequam Pass, Tanaga Island area. Within each of the three study areas, many locations were untrawlable or proved to not be areas of high Atka mackerel aggregations. In examining some general diet trends, such as prey composition by month, age and area and stomach fullness by haul, month and area, we identified patterns that may require further analysis. Thus, progress toward fulfillment of both Objectives 1 and 2 has been made.

Laboratory analysis of approximately 2700 Atka mackerel stomachs was completed in October, 2005 in the REEM (Resource Ecology Ecosystem Modeling) Laboratory. Subsampling has provided information on length, weight, sex and otoliths for age estimation. Progress has been made incorporating oceanographic data such as temperature and depth profiles into the database for Atka mackerel. Preliminary analysis of growth profiles for the different study areas has also begun, including the specification and interpretation of growth patterns. Thus, further satisfactory progress toward fulfillment of Objective 2 has been made.

Number of students and postdocs working on the program: Kimberly Rand has completed all of her course work for the M.Sc. in the School of Aquatic and Fishery Sciences at the University of Washington. She is the only student employed on the project.

Project:
Analysis of Mysticete Whale Calls from Beaufort & Chukchi Seas.

PI:
UW - Kathleen M. Stafford

Other Personnel:
NOAA - Sue Moore

NOAA Primary Contact:
NMML and AFSC

NOAA Goal:
1) Protect, Restore and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management.

Task: III

Description:

Research conducted from September 2005-July 2006 was focused on analysis of an acoustic dataset from the Beaufort Sea.

Objectives:

The primary objective of the Beaufort Sea data set were to determine the seasonal occurrence of bowhead and gray whales off Pt. Barrow from October 2003-May 2004.

Accomplishments:

1. Gray whales vocalized year-round off Pt. Barrow, which was an unexpected result as it was thought that these animals were generally forced by ice cover to migrate south during the winter. These results were submitted as a paper to the scientific committee of the International Whaling Commission in 2005 and as a peer-reviewed manuscript to the journal *Arctic*. We are awaiting reviewer comments from the journal.

2. Bowhead whale vocalizations were only recorded at the beginning and ending of the dataset, that is in October 2003 and then April-May, 2004 which is what would be expected as they migrate past Pt. Barrow in the fall and spring. Results from this analysis are in preparation for a peer-reviewed article and will include measures of the variation of ambient noise during the winter.

A summer intern who will be entering UW as a freshman this fall assisted with both projects.

Project:
Graduate Students for Stock Assessment Training and Improvement.

PI:
UW - Ray Hilborn

Other Personnel:
UW - Teresa A'Mar

NOAA Primary Contact:
NMFS/, AFSC/REFM

NOAA Goal:
1) Protect, Restore and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management.

Task: III

Description:

The National Marine Fisheries Service has completed a Stock Assessment Improvement Plan. This plan is a comprehensive assessment of resource needs and strategies for improving the quality and quantity of fisheries stock assessments nationwide. A central element of this plan is the development of collaborative research programs between NMFS and universities, to ensure the training of students and to encourage innovative research.

Stock assessment scientists require strong backgrounds in biology, mathematics and statistics. However, biologists with solid quantitative skills, or quantitative experts with some biological background, are relatively rare and the pool of qualified applicants graduating from appropriate university courses is actually shrinking. The paucity of qualified applicants for advertised stock assessment scientist positions is evidence that insufficient people/students are being encouraged to enter this field and receive appropriate training.

This ongoing proposal involves support for a program between the University of Washington, School of Aquatic and Fisheries Sciences (SAFS) and Alaska Fisheries Science Center (AFSC) to prepare young scientists for careers in fish stock assessment. Successful candidates will compete for these funds by proposing a research program of mutual interest to the University of Washington and AFSC. AFSC and SAFS faculty members will review research proposals.

University of Washington faculty members include experts in stock assessment modeling, population dynamics, fisheries oceanography, fish ecology, and survey design. This combination of expertise, coupled with an emphasis on the fisheries of the Pacific Northwest, makes the University of Washington SAFS an ideal resource for this type of partnership. SAFS faculty members will chair the graduate committees for recipients of the stipend. Some of these faculty members will be partially funded by this grant.

Objectives:

1. Development of advanced stock assessment methods that address key areas of uncertainty.

2. Advanced stock projection modeling to improve the agency's ability to predict impacts of fishing on marine ecosystems.

3. Improved survey design to reduce measurement error and reduce uncertainty in stock assessments.

4. Research on the influence of natural and abiotic factors on vital rates.

5. Studies of climate impacts on production of marine fish stocks.

6. Studies of factors influencing the spatial distribution of marine fish stocks including: ontogeny of core species, impacts of fishing on school structure, and migratory behavior.

7. Detailed studies to establish parameters for key processes governing predator/prey relationships.

8. Application of the Management Strategy Evaluation approach.

Accomplishments:

One student, Teresa A'Mar, was funded under this project during 2005/06.

Teresa is finalizing the technical specifications of the operating model for the GOA walleye Pollock. She is developing an operating model which could be used as the basis for a Management Strategy Evaluation (MSE) to determine the likely performance of the assessment methods/decision rules used to manage walleye Pollock in the Gulf of Alaska. This operating model will be capable of mimicking the impact of changes over time in the values for biological parameters considered known when conducting stock assessments. She is developing an approach that generates the types of data used by assessment models for GOA walleye Pollock and determines a method to apply currently-used assessment methods to these data. She is also implementing the North Pacific Fishery Management Council (NPFMC) Tier system rules within the MSE framework, and is conducting initial evaluations of the management system.

Project:
Marine Biological Interactions in the North Pacific – Fish Interactions.

PI:
UW - B. Miller

Other Personnel:
UW - J. Boldt, K. Dodd, R. Hibpshman, J. Jurado-Molina, A. Whitehouse
NOAA - K. Aydin

NOAA Primary Contact:
NMFS/AFSC/REFM

NOAA Goal:
1) Protect, Restore and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management.

Task: III

Description:

This research project focuses on improving ecosystem based fishery management through increased understanding of predator/prey relationships, improved predator/prey models, and development of ecosystem indicators.

Objectives:

1. To investigate the feeding ecology of North Pacific fishes**.**

2. To collect stomach, plankton or benthic samples in the field.

3. To estimate and test parameters of single-species, multi-species and ecosystem models.

4. To develop ecosystem indicators.

Accomplishments:

1. Feeding ecology of North Pacific fishes. A total of 13,493 groundfish stomachs were analyzed in the laboratory. A two-year plan for stable isotope collection and analysis was researched and put in place. Substantial data analysis was performed and published in two NOAA Technical Memoranda on the food habits of Alaskan fishes (see publications list in Appendices).

2. Assisted with the collection of stomach, plankton or benthic samples. Collection and shipboard analysis of groundfish stomachs during the time period totaled 1,305 samples. JISAO personnel covered four cruise legs.

3. Modeling activities focused in the updating of the multi-species virtual population (MSVPA) and the multi-species forecasting model (MSFOR). Over 10 years of new data were examined and added to the model; the quantity of the new data allowed the beginning of work towards increasing the resolution

of predator diets within the model. Substantial progress was made towards completing a two-species version of the Multi-species Statistical Model (MSM). An interactive website for browsing model results was expanded to include new results and is available at http://www.afsc.noaa.gov/REFM/REEM/models/Default.htm.

4. Ecosystem indicators. The Ecosystem Considerations section of the North Pacific Stock Assessment and Fisheries Evaluation (SAFE) document was updated in the spring 2006 and provided to stock assessment scientists to incorporate into stock assessment documents. The web version of this document was substantially improved for more interactive viewing of time series and data. The website is available to the public at http://access.afsc.noaa.gov/reem/EcoWeb/index.cfm.
Work continued on Shelikof Pollock spawning anomalies and climate and Pollock cannibalism and water column properties.

Project:
Trends in Fish Abundance and Productivity.

PI:
UW - Donald R. Gunderson

Other Personnel:
UW - Susanne McDermott (graduate student)
NOAA - Dan Cooper, Katherine Pearson

NOAA Primary Contact:
NMFS/AFSC

NOAA Goal:
1) Protect, Restore and Manage the Use of Coastal and Ocean Resources through Ecosystem-based Management.

Task: III

Objectives:

The goal of this project is to improve methodology for studying the response of marine ecosystems to the direct and indirect impacts of fishing activities and fluctuations in climate.

Accomplishments:

In 2005/06, the team finalized work on determination of reproductive potential and natural mortality of thornyheads (two species) and Greenland turbot. Both of these species are important commercially, yet little is known about their ability to sustain harvests at current levels. In all cases, collections of ovarian tissue were made over as much of the year as possible, to document the reproductive biology for these species. Time of spawning, size at maturity, effective fecundity, annual reproductive effort, and natural mortality were all determined. Natural mortality rate (the mortality rate in unexploited stocks) is roughly equivalent to production per unit biomass, and determines the exploitation rate that a given stock is capable of sustaining. Natural mortality rate (M) is best estimated using age composition data, but in the case of thornyhead and Greenland turbot reliable age determination techniques have yet to be developed. As a result, M was estimated using the relationship between reproductive effort and natural mortality rate. Using the reproductive effort- M relationship, it was determined that both species of thornyheads have a much lower M than previously estimated, and probably live to be well over 100. Natural mortality rate for Greenland turbot was also estimated to be less than the value previously used in stock assessment (.11 vs .18). A new method of staining Greenland turbot otoliths for age determination was developed, and a manuscript on age determination is now in press. As with the work on reproductive biology, the results indicate that this species is much longer-lived than previously suspected (M=.12), and not capable of sustaining the harvests previously thought possible.

Project:
Biology of Skates.

PI:
UW - Don Gunderson

Other Personnel:
UW - Beth Matta, (graduate student)

NOAA Primary Contact:
NMFS/AFSC

NOAA Goal:
1) Protect, Restore and Manage the Use of Coastal and Ocean Resources through Ecosystem-based Management.

Task: III

Objectives:

The goal of this study is to document the reproductive biology, size at maturity, and fecundity of the Alaska skate (*Bathyraja parmifera*) and develop a technique for age determination.

Accomplishments:

Reproductive tissues, vertebrae, and other structures to be used in age determination were collected aboard NOAA survey vessels and commercial fishing vessels. Age determination was accomplished by examining both vertebral sections and caudal thorns, and used to determine growth curves. Sexual maturation occurs at age 9 for males and at age 10 for females, and fecundity was estimated to be 24 eggs per year. Natural mortality rate (M) was estimated to be 0.28 (males) and 0.25 (females) based on maximum age (15 and 17 years for males and females, respectively). This work served as the basis for an MS thesis by Beth Matta, entitled "Aspects of the life history of the Alaska skate, *Bathyraja parmifera*, in the Eastern Bering Sea".

Project:
JISAO Support Training of Graduate Student in Habitat Research for Development of Surveys in Untrawlable Habitat.

PI:
UW - Don Gunderson

Other Personnel:
UW - Jessica Hayden-Spear, (graduate student)

NOAA Primary Contact:
NMFS/AFSC

NOAA Goal:
1) Protect, Restore and Manage the Use of Coastal and Ocean Resources through Ecosystem-based Management.

Task: III

Accomplishments:

This project supports the training of Jessica Hayden-Spear in habitat research. Jessica participated in a NOAA survey of marine habitats and fisheries resources in untrawlable habitats off of Oregon and California, assisting NMFS personnel in processing camera data obtained from an AUV.

She also worked with UW and NMFS scientists in identifying a thesis topic for her Ph. D work.

Project:
Biophysical Models of Pollock Recruitment Processes in the Western Gulf of Alaska.

PI:
UW - Carolina Parada
NOAA - Sarah Hinckley

Other Personnel:
UW - John Horne, Bernard Megrey, Albert Hermann

NOAA Primary Contact:
NMFS/AFSC

NOAA Goals:
1) Protect, Restore and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management.

2) Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond.

Task: II

Description:

This project has involved the implementation of a spatially-explicit biological model (Individual-Based Model [IBM]) coupled to a hydrodynamic model, and has used these to study spatial and temporal recruitment variability and early life history of walleye Pollock (*Theragra chalcogramma)* in the western Gulf of Alaska. The suite of models was, also coupled to a nutrient-phytoplankton-zooplankton model simulating the dynamics of pollock prey. These coupled models were used to accomplish the following objectives:

Objectives:

1. Study the effects of the timing and location of spawning of pollock in Shelikof Strait on pre recruitment variability over the last several decades.

2. Study the inter-annual variability of transport in the Shelikof region related to recruitment success.

3. Study the importance of the Shumagin Islands as a nursery area, as well as alternative nursery, regions such as the Semidi Islands.

4. Study the spatial and temporal synchronization between modeled *Pseudocalanus* production and early stages of pollock.

5. Compare annual recruitment variability of walleye Pollock with pre-recruitment indices produced by the models.

6. Compare the spatial distribution of pollock produced by the models with the distribution of larvae and juveniles from surveys.

Accomplishments:

From objectives accomplished (2, 3, 5 and 6), a manuscript "Estimating walleye Pollock recruitment in the Gulf of Alaska using a biophysical model: analysis of physical processes and comparison with stock assessment models and data" by Carolina Parada, Sarah Hinckley, Martin Dorn, Albert Hermann and Bernard Megrey has been submitted to *Marine Ecology and Progress Series*.

In addition, following objective 4, we have completed a manuscript titled " An ecosystem model for the Gulf of Alaska: sensitivity analysis and data comparison", by Carolina Parada and Sarah Hinckley, which is currently in revision and will soon be submitted. From these two studies the scientists learned that their suite of coupled models misses several biological processes that seem relevant for pollock recruitment success, such as predation and directed swimming of juveniles.

Also, in the last modeling effort, the team used an IBM coupled to a hydrodynamic model (i.e. SPEM) and to an NPZ model. From this work, it was concluded that the boundaries of the SPEM model were too restricted, as it only allowed them to perform experiments for the Shelikof Strait to Unimak Pass region for which the physical model was reliable. This constrained their ability to completely accomplish Objective 1. To deal with this problem, model output from another hydrodynamic model (ROMS) is now being used with the IBM. A new particle-tracking tool has been developed to simulate the movement and life history of the modeled eggs through juveniles of pollock. This work is in progress. In addition, instead of using an offline NPZ model (such as the team did in the first part of the project), at the moment the team is running the NPZ model embedded in the ROMS model, so the NPZ model is now running online in a 1D version (they will then move to a 3D version). Their new objectives for the next year are to add the biology missing from the models, to regenerate the pre-recruitment indices, and to write one or several manuscripts on the results.

Research Highlights:

- Submitted the manuscript "Estimating walleye Pollock recruitment in the Gulf of Alaska using a biophysical model: analysis of physical processes and comparison with stock assessment models and data" by Carolina Parada, Sarah Hinckley, Martin Dorn, Albert Hermann, Bernard Megrey.
- Completed a draft manuscript "An ecosystem model for the Gulf of Alaska. sensitivity analysis and data comparison", by Carolina Parada and Sarah Hinckley.
- Development (in progress) of a Java tool that follows the trajectories of particles and examines the biological processes affecting young pollock.
- Implementation (in progress) of the NPZ model embedded in the ROMS model.

Project:
Fisheries Acoustics Research.

PI:
UW/AFSC - J. Horne

NOAA Primary Contact:
NMFS/AFSC

NOAA Goals:
1) Protect, Restore and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management.

Task: III

Objectives:

1. To characterize walleye Pollock aggregations.

2. To quantify the effect of ontogeny and pressure on acoustic reflectivity among individual fish.

3. To examine the effect of position in beam and yaw on acoustic reflectivity.

4. To increase student involvement and training in fisheries acoustic research.

Accomplishments:

1. The sensitivity analysis of the Echoview schools module algorithm was completed and submitted for publication to the *ICES Journal of Marine Research*. The aggregation detection algorithm is sensitive to changes in acoustic threshold values, in parameters that defined minimum aggregation sizes, connectivity among pixels, and less sensitive to changes in the size of the search ellipse. Revisions to the manuscript are underway. In a second effort, wavelet analysis was used to describe the distribution of density variance, and to compare observed patterns to those derived from landscape ecology metrics. High variance in fish densities were observed at the smallest and largest bin sizes. Local peaks in wavelet coefficient values corresponded to ranges observed in one-dimensional variograms. Two manuscripts are being prepared for submission.

2. Analyses of Donaldson trout (rainbow-steelhead hybrid) swimbladder and body growth (i.e. ontogeny) have been completed. A draft manuscript entitled, "Acoustic ontogeny of teleost fish" has been completed and will be submitted to the *Journal of Fish Biology*. Initial analyses of juvenile walleye Pollock (*Theragra chalcogramma*) changes in swimbladder shape and size with increasing pressure, have been completed. Swimbladders do not isometrically contract with increasing pressure, and the resulting decrease in acoustic reflectivity (i.e. target strength) is not predicted to be linear. The next stage in the analysis is to describe three-dimensional changes in shape.

3. The combined effect of fish position in beam and direction (i.e. yaw) on target strength has not been examined. Regression analysis of the *in situ* data showed that tilt, distance-off-axis, and the

interaction of yaw and distance-off-axis significantly ($p<0.05$) influenced target strength. For a large sample, a dispersion of yaw angles within an acoustic beam averages out the effect of individual target strengths. A draft manuscript entitled, " The influence of tilt, swimming direction, and beam position on fish target strength" has been completed and will be submitted to the *ICES Journal of Marine Research*.

4. This ongoing objective aims to provide education and training of students in fisheries and fisheries acoustics through active participation in research projects, abundance estimate surveys, and summer internships. One Master's program was completed this year with another three students working on externally funded projects in the laboratory. Two Ph.D. students are currently conducting research for their projects with another student starting in fall 2006. One undergraduate student completed his degree and is now working at the Alaska Fisheries Science Center (AFSC). Two research associates are associated with modeling and field sampling of fish species in the northeast Pacific. Three undergraduate students participated in the joint AFSC-School of Aquatic and Fisheries Science summer internship program this year.

Project:
The early life history dynamics of fish species and climate/ocean conditions in the Gulf of Alaska and southeast Bering Sea.

PI:
UW - Miriam Doyle

Other Personnel:
UW - Mick Spillane
NOAA/AFSC: Susan Picquelle, Kathryn Mier, Ann Matarese, Morgan Busby and Deborah Blood.

NOAA Primary Contact:
AFSC/RACE

NOAA Goal:
2) Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond.

Task: II

Description:

The broad goal of the study is the investigation of links between the early life history dynamics of fish species and climate/ocean conditions in the Gulf of Alaska and southeast Bering Sea, for the purpose of elucidating the potential effect of climate change on recruitment success among these fish populations. The Alaska Fisheries Science Center Ichthyoplankton Data Base, incorporating data from a total of 28 years of plankton collections in these regions, is the basis for this research, along with concurrent measurements of climate and oceanographic variables. Three components of this research, with a present focus in the Gulf of Alaska, are ongoing with publications in preparation from each component. The first component is a study of the inter-annual trends in late spring abundance of the dominant larval fish species in the Northwest Gulf of Alaska, in relation to climate and ocean variables at the local and basin scale. The second is an evaluation of the early life history strategies of ecologically important Gulf of Alaska fish species, with respect to resilience or vulnerability to fluctuating environmental conditions. A third component is the preparation of a review paper on the early life history of Pacific sandlance, an important forage species in the Gulf of Alaska ecosystem. The potential exists for similar review studies of other individual species.

Objectives:

1. The inter-annual trends component of the study has an objective of identifying, and providing an ecological interpretation of connections between the late-spring ichthyoplankton data time-series and climate/ocean conditions in the Gulf of Alaska.

2. The objective of the second component is to synthesize the available knowledge and data on the life history strategies, particularly the early life history phase, of the numerically dominant fish species in the Gulf of Alaska, and to evaluate these strategies with respect to potential resilience or vulnerability of individual species to fluctuating environmental conditions.

3. The third component objective is to prepare a review paper on the early life history of Pacific sandlance, an ecologically important forage fish species in the Gulf of Alaska, bringing together previously published work and new data from the ichthyoplankton data base.

Accomplishments:

1. Generalized additive modeling was used to investigate associations between larval fish species abundance and various physical variables in this project. Data analysis and presentation is complete and writing of the manuscript is underway. On completion, the following manuscript will be submitted to the journal *Fisheries Oceanography*: "Linkages between Gulf of Alaska Ichthyoplankton and Physics at the Local and Basin Scales". On April 12th 2006, this work was presented at the Alaska Fisheries Science Center as part of the Fisheries Oceanography Coordinated Investigations (FOCI) Seminar Series. An oral presentation on this work was also given at the PICES/GLOBEC Symposium "Climate Variability and Ecosystem Impacts on the North Pacific: a Basin-Scale Synthesis", April 19-21, 2006, Honolulu, USA.

2. This study is evolving from an initial focus on six species, chosen for their dominance in our ichthyoplankton collections, to a broad range of species that are abundant and ecologically important in the Gulf of Alaska ecosystem. Much of the information has been compiled on the individual species, and additional information from the ichthyoplankton data base and component 1 of this study is being reviewed. A poster entitled "Life History Strategies of Selected Gulf of Alaska Fish Species with Reference to Recruitment Vulnerability under Fluctuating Environmental Conditions" was presented at the 29th Annual Larval Fish Conference (American Fisheries Society, Early Life History Section) in Barcelona, Spain, July 11-14, 2005. A poster of the same title was also presented at the PICES Fourteenth Annual Meeting in Vladivostok, Russia, October 3-9, 2005, in a special session titled "The comparative response of differing life history strategists to climate shifts." The manuscript in preparation will be submitted to *Marine Ecology Progress Series*.

3. Temporal patterns in the early life history of Pacific sandlance in the Gulf of Alaska have been documented and analyzed, and the investigation of spatial patterns is underway. A manuscript is in preparation for submission to *Canadian Journal of Fisheries and Aquatic Science*.

Project:
1. Spring Gulf of Alaska Ichthyoplankton Inter-annual Trends Study.

2. Comparative response of selected Fish Species Early Life History Strategies to fluctuating environmental conditions in the Gulf of Alaska.

3. Early Life History of Pacific Sandlance in the Gulf of Alaska.

PI:
UW - Miriam Doyle (supervised by N. Bond)

Other Personnel:
UW - Mick Spillane
NOAA - Susan Picquelle, Kathryn Mier, Ann Matarese, Morgan Busby, Deborah Blood

NOAA Primary Contact:
NMFS/AFSC

NOAA Goal:
1) Protect, Restore and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management.

Task: II

Objectives:

1. To elucidate the potential links between fluctuating ocean conditions and the early life history dynamics of fish species in the northwest Gulf of Alaska. A time-series of Gulf of Alaska spring ichthyoplankton data, 1981-2003, has been examined for inter-annual trends in abundance, distribution and larval size of numerically dominant ichthyoplankton species, in the vicinity of Kodiak Island and Shelikof Strait. Local physical oceanographic data and model output, along with basin-scale climate/ocean indices were utilized to investigate trends in the ichthyoplankton in relation to inter-annual trends in ocean temperature, circulation, and production in this region.

2. To compare the response of selected fish species' early life history strategies, to fluctuating environmental conditions in the Gulf of Alaska. Six species were chosen for their dominance in our ichthyoplankton collections and their ecological significance in the Gulf of Alaska ecosystem.

Capelin (*Mallotus villosus*), Pacific sandlance (*Ammodytes hexapterus*), and northern lampfish (*Stenobrachius leucopsarus*) are ecologically important forage fish, and Pacific cod (*Gadus macrocephalus)*, arrowtooth flounder (*Atheresthes stomias*), and starry flounder (*Platichthys stellatus*) are important components of the groundfish resources in the Gulf of Alaska. These species represent a diversity of life history strategies. This study reviews details of the biology, life history traits and ecology of these six species, and evaluates their individual adaptation and vulnerability to, prevailing and fluctuating oceanographic conditions in the Gulf of Alaska.

3. To understand the biology and ecology of this key forage species and to investigate the potential

stability or vulnerability of their populations in the Gulf of Alaska oceanographic environment.

Sandlance (*Ammodytes hexapterus*) larvae are the most ubiquitous species in the Gulf of Alaska ichthyoplankton collections, and are second in abundance only to walleye Pollock larvae. The species is an important forage fish in this ecosystem and contributes significantly to the diet of many species of fish, birds and marine mammals. As a key forage species, it is important to understand its biology and ecology, and to investigate the potential stability or vulnerability of Pacific sandlance populations in the Gulf of Alaska oceanographic environment.

Accomplishments:

1. For the time-series, unique patterns of periodicity and amplitude of variation in abundance are apparent among species. Some commonality is observed, especially for the deepwater spawners (northern lampfish, arrowtooth flounder and Pacific halibut) that display a decadal trend of enhanced abundance during the 1990s. Species-specific seasonality is apparent in the associations between late spring larval abundance and environmental variables. There is, however, a general trend indicating that basin-scale environmental conditions in February through April, and local-scale conditions in late-March through early-April, are most influential in terms of prevalence of larvae in late spring. Observed species-specific patterns of association between late spring larval abundance and environmental variables seem to reflect geographic distribution and early life history patterns among species. Further work continues at the individual species early life history level, to investigate potential mechanisms underlying the observed links between species and environmental variables. This type of ichthyoplankton time-series study shows good potential for identifying levels of resilience or vulnerability of individual species' early life history patterns to fluctuating oceanographic conditions. A manuscript is being prepared for submission to the journal *Fisheries Oceanography* by the end of 2005.

2. A manuscript is being prepared for submission to an international marine science journal.

3. A manuscript is being prepared for submission to an international marine science journal during 2006. Results will also be presented at the Annual Larval Fish Conference of the American Fisheries Society in 2006 or another appropriate meeting.

CLIMATE

Project: Center for Science in the Earth System (CSES).

Name of PI:
UW - Edward Sarachik, Climate Dynamics Group, Edward Miles, Climate Impacts Group

Other Personnel:
UW -

Battisti, David	Mantua, Nate
Canning, Doug	Mitchell, Todd
Cuo, Lan	Moore, Stephanie
Essington, Tim	Mote, Philip
Fluharty, David	Norheim, Robert
Francis, Robert	Palmer, Richard
Hamlet, Alan	Petersen, Alexander (Sascha)
Harrison, D. Edmund	Peterson, David L.
Hoskins, Richard	Reading, Don
Kamenkovich, Igor	Salathé, Eric
Karpov, Adrienne	Slaughter, Richard
Kimball, Ann Marie	Snover, Amy
Lettenmaier, Dennis	Trask, Blake
Leung, Ruby	Wallace, J. Michael
Levy, Zenobia	Whitely Binder, Lara
Littell, Jeremy	Wiley, Matt
McKenzie, Don	Zahn, Patrick

NOAA Primary Contact:
OGP/ CDEP

NOAA Goals:
1) Protect, Restore and Manage the Use of Coastal and Ocean Through Ecosystem-based Management.

2) Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond.

3) Serve Society's Needs for Weather and Water Information.

Task: III

Description:

The Center for Science in the Earth System (CSES) performs integrated research on the impacts of climate on the U.S. Pacific Northwest (PNW) by combining and integrating expertise in climate dynamics, ecological dynamics, hydrologic dynamics, and institutional and policy analysis. The CSES also researches the application of climate information in regional decision-making processes in support of the regional aspects of an eventual Climate Service. CSES is comprised of two groups: the Climate Dynamics Group (CDG) and the Climate Impacts Group (CIG).

Objective:

Enhance global understanding of climate dynamics.

Accomplishments:

- ENSO and tropical zonal-mean pressure decadal variability. Analyzed Tahiti and Darwin pressures to discriminate between ENSO and tropical mean pressure variations.
- ENSO: Mechanisms and Predictability. A book by Mark Cane and Ed Sarachik entitled "The El Nino-Southern Oscillation: Mechanisms and Predictability" is in the final stages. It will be published by Cambridge University press in 2007.
- Thermohaline circulation. Continued research examining the general question of thermohaline circulation under climate change, the role of intermediate water in setting the North Atlantic density gradient, and the general role of intermediate water and its correct representation in climate models.

Objective:

Enhance understanding of the role of climate in the functioning and management of coastal and ocean resources.

Accomplishments:

- Effects of climate and land surface changes on fresh water inputs to Puget Sound. This project uses fine scale hydrologic models to explore the implications of climate variations and change, coupled with land surface changes associated with urbanization or other human activities, on the fresh water inputs to Puget Sound. Extension of driving data resources and calibration of existing DHSVM models is in progress.

- Spatial scale of water temperature fluctuations affecting Fraser River Salmon. Analyzed ocean surface temperatures and salinity from British Columbia lighthouse records to characterize the extent to which basin scale temperature variability (Pacific Decadal Oscillation) influences Fraser River temperatures, and could explain the exceptionally warm 2004 summer temperatures.

- Failure of the 2005 Spring Oregon and Washington coast upwelling. Analyzed ocean temperatures, wind, and atmospheric pressures to document climate variability associated with variations in Springtime coastal upwelling.

- Salmon modeling for conservation planning. Secured two years of funding for a multi-investigator multi-institution research project titled "Salmon Modeling Studies for Conservation Planning" from the Gordon and Betty Moore Foundation.

- Climate change and harmful algal blooms (HABs). Secured funding for a collaboration with the Northwest Fisheries Science Center of NOAA Fisheries to study climate impacts on HABs in the PNW; hired post-doctoral fellow for this project. Project examines the role of climate variation in HABs and the predictability of HAB events.

- Climate impacts on Columbia River basin salmon. Secured funding for a collaboration with the NOAA Fisheries Northwest Fisheries Science Center to study climate impacts on Columbia River basin salmon.

Objective:

Enhance the region's capacity to plan for and respond to climate impacts by evaluating climate impacts on Pacific Northwest resources and institutional arrangements, and supporting use of climate information in decision-making processes.

Accomplishments:

- 20th century trends in snowpack, runoff, and soil moisture in the western U.S. In a collaborative effort with Western Water Assessment/Cooperative Institute for Research in Environmental Sciences, CSES completed research examining 20th century trends in climatic and hydrologic variables over the western U.S. Four journal articles have resulted (Hamlet et al., in review; Hamlet et al., 2005; Mote et al. 2005a). The temperature and precipitation records and VIC

simulations have been used in several adjunct studies as well (Andreadis and Lettenmaier 2006).

- Changes in 20th century flood and drought risks. Completed research quantifying systematic changes in flood and drought risks over the 20th century using temperature data that have been "detrended" to remove strong temperature trends in 20th century climate records (Hamlet and Lettenmaier, in review).

- Droughts of 2001, 2003 and 2005. Compared the causes and consequences of three recent droughts in the PNW. Manuscript in preparation.

- Climate-driven variability and trends in mountain snowpack. Continued research documenting the sensitivity of snowpack to temperature and precipitation along a transect of the mountain ranges in British Columbia to Southern California, which resulted in a paper accepted by *Journal of Climate* (Mote, in press).

- Climate impacts on water use and allocation in Idaho. Continued work on developing an "end-to-end" impact analysis for the Snake River basin in Idaho that considers the impacts of climate variability and change on water allocation in the basin and the economic changes resulting from those changes in allocation (model nearing completion).

- Climate impacts on energy production. Continued effort to evaluate the impacts of climate change on hydropower production at the Hells Canyon complex in Idaho (manuscript in preparation). Continued an energy forum with major Puget Sound utilities to regularly meet and discuss climate, climate forecasts, and implications for energy production and fish flows. Continued investigating how the researchers can improve winter and spring/summer forecasts of natural flow at Ross Dam (Seattle City Light). Advised two energy utilities on matters related to climate change.

- Hydropower reconstructions and forecasts for the Columbia, Sacramento/San Joaquin, and Colorado River basins. In partnership with Scripps Institute of Oceanography, CSES is reconstructing hydropower variability for a current level of development for the three major hydropower systems in the western U.S., and develops long-range forecasts of hydropower production by developing linkages between the West Wide Hydrologic Forecasting System's long-range streamflow forecasts and reservoir operations models. This project is ongoing from previous research reported by Voisin et al. 2006.

- A climate vulnerability foundation document for the U.S. Army Corps of Engineers (USACE). The USACE is responsible for a large number of water resources projects of various kinds in the West. Many of the planning and management activities associated with these projects are believed to be sensitive to climate variability and warming. Using interviews and short summary reports from USACE practitioners throughout the West, the project will synthesize a foundation document summarizing the impacts of climate variability and warming on various USACE missions (such as flood control, water supply, hydropower production, coastal protection, etc.), identifying important pilot planning projects that are sensitive to climate variability and change, and leading to the establishment of appropriate methods and procedures for improved planning studies designed to address these issues within the USACE. A draft foundation document is in preparation, and two conference presentations have been given (Vaddey et al.

2006; White et al. 2006).

- Optimized flood control operations in the Columbia River basin in response to climate variability and regional warming. This project employs optimization models of the Columbia River reservoir system to rebalance flood control and refill objectives in the basin in response to changes in climate (ENSO and warming). Collaborative effort with Carolyn Fitzgerald at the U.S. Army Corps of Engineers Seattle District office is extending these methods to daily time step assessments. Two journal articles are currently in preparation, and a conference proceedings paper has been submitted (Lee et al. 2006).

- Characterizating weather and climate variability that influences runoff for the Ross Hydroelectric Dam. In collaboration with Seattle City Light, related Ross Dam Spring runoff and Fall flooding episodes to weather and climate data to develop statistical forecast models.

- Effects of regional warming on juvenile salmon survival in the Salmon River basin in Idaho. This project explores the effects of PNW regional warming scenarios, and related streamflow timing shifts and increases in water temperature, on juvenile salmon survival in the Salmon River basin. A paper is in preparation.

- Climate impacts on forests and forest productivity. Continued research on the response of Douglas-fir, an ecologically and economically important timber species in the PNW, to climate variability. One paper (Littell and Peterson 2005) and one dissertation chapter (Littell 2006) are published from this work. Continued work with the Western Mountain Initiative program, specifically investigating how climate variability affects a wide range of terrestrial and aquatic resources in western U.S. mountain systems.

- Climate variability and forest fires. Developed predictive models for how regional climate patterns from 1916-2003 affected the annual fire burn area in ecoprovinces of the western U.S. One dissertation chapter is published (Littell 2006) and two journal articles will be submitted in Fall 2006. Continued research quantifying how climate variability and topographic constraints affected fire occurrence at different spatial scales over the past 400 years in the Okanogan, Wenatchee, and Colville National Forests in Washington State. Two papers are to be published this year (McKenzie et al. 2006; Hessl et al., in press). Produced a book chapter on fire at the urban-wildland interface (Keeton et al., in press).

- Climate variability, fire, and air quality. Continued research on the effects of climatic change on regional haze produced from wildfire, both across the western U.S. and in the PNW. Continued development of an integrated modeling system to predict regional haze from future wildfires. Four papers were published (McKenzie et al. 2006 a,b,c; and Wiedinmyer et al. 2006).

- Preliminary assessment of climate change impacts on Puget Sound. Completed a preliminary examination of the implications of climate change for Puget Sound. Combining a review of current scientific literature and new research, the report provides a detailed assessment of how climate change has affected - and will continue to affect - the Puget Sound environment. Specific areas of focus include changes in regional climate, snowpack, streamflow, sea level rise, water quality, nearshore habitat, and salmon. The importance of planning for climate change is also discussed. The report was commissioned by the Puget Sound Action Team in the

Washington State Office of the Governor. Two reports were prepared, an overview report for policy makers (Snover et al. 2005) and a technical report (Mote et al. 2005). Press coverage of the report reached around the globe.

- Climate change and PNW ski areas. Building on past simulation efforts to provide a more accurate assessment of impacts on the PNW ski industry associated with climate variability and warming, and assess the feasibility of potential adaptive responses such as the use of snowmaking equipment. Currently collecting additional observed data needed to facilitate precipitation adjustments and updated snow simulations for PNW ski areas.

- Climate impacts on extreme events and water demand. Initiated work with King County, Washington, on the impacts of climate change on regional water demand, base wastewater flows, and flood events within urban areas.

- Climate impact studies on metropolitan water supplies. Continued evaluating the potential impacts of climate change on water supplies for the City of Seattle, the Cascade Water Alliance (representing eight municipalities and districts in the greater Seattle area), and the City of Tacoma. Details on the studies are available at http://www.tag.washington.edu/projects.html.

- Snohomish basin salmon habitat improvements plan. Continued research exploring the potential impacts of climate change on Chinook salmon recovery plan alternatives for the Snohomish River Basin in Washington State.

- Modeling climate impacts on stream temperature. Began effort to develop tools for assessing the impacts of climate change on glacial extent in the Cascades range and impacts on streamflows.

- Assessing institutional capacity to adapt to climate impacts. Completed a comparison of water institutions on the Snake River (Idaho) and Klamath River (Oregon) for capacity to adapt to climate change in the context of changing social preferences (Slaughter et al. 2006, in press [JAWRA]). Initiated a study of institutional underpinnings of water markets and the relationship of markets to legal structure (manuscript in preparation). Completed an analysis of water markets in Idaho (Reading 2006, in review).

- GIS-based decision support tool for evaluating fine-scale climate impacts. Developed prototype online GIS-based climate mapping service that allows users to see how climate has varied temporally and spatially across the PNW. The current implementation allows the user to view maps of historical climate, for temperature, precipitation, snowpack, and soil moisture. The maps show anomalies of how these climate parameters vary from the historical average for warm and cool periods of both ENSO and PDO, and combinations of these two cycles. Next stages will include maps of 20th Century trends in climate and hydrological parameters, followed by maps of future climate change, allowing users to compare how effects of warming compare to historic variability.

- Consultations with regional decision makers on using climate information in decision-making processes. Continued conversations, briefings, and strategizing sessions with regional decision makers in city, county, state, and federal government agencies as well as public and private utilities to help them develop an understanding of the potential utility of using climate

information in planning and decision making and to develop a plan for using that information to improve planning.

- Guidebook for local governments on adapting to climate change. In partnership with King County, Washington and ICLEI – Local Governments for Sustainability, CSES began writing a guidebook for local governments on adapting to climate change. The guidebook will help local governments better understand what adapting to climate change means, identifies resources for information on climate change science and adaptation, and maps out a suggested approach to adapting to climate change (e.g., creating a climate change adaptation team; identifying sectors of concern; assessing sensitivity, exposure, adaptability, and vulnerability; selecting adaptation options). The guidebook will be published by ICLEI – Local Governments for Sustainability and will be the center piece of ICLEI's NOAA-funded Climate Safe Communities Program.

- Stakeholder meetings on climate and water resource management. Conducted annual fall climate and water resource forecast meetings in Seattle, Washington and Boise, Idaho. Details on the meetings are available at: http://www.cses.washington.edu/cig/outreach/workshops.shtml

- Washington State climate change conference. CSES played an integral role in a Washington State conference on planning for climate change, held October 27, 2005. "The Future Ain't What It Used to Be: Planning for Climate Disruption" brought 675 participants from government, business, tribes, non-profits, and the community-at-large together to discuss the projected impacts of climate change in the PNW and how the region (in particular, Washington State) can prepare to adapt to those impacts. The concept for the meeting was developed by King County, Washington, as an outgrowth of the research conducted by the CSES. The CSES prepared a diverse set of presentations and printed materials for the meeting at the request of King County. This includes new climate change scenarios for the PNW, a White Paper on climate change impacts, sector-based fact sheets for the breakout sections, and primers on climate change science and policy. All of these materials are available on the CSES web site at: http://www.cses.washington.edu/cig/outreach/workshops/kc2005.shtml

- Integrated climate change risk and vulnerability assessment proposal. At the request of the Washington State Department of Ecology, CSES and The Water Center at the University of Washington developed and submitted a proposal to conduct an integrated climate change risk and vulnerability assessment for the State of Washington. The assessment would identify the risks posed by climate change for water resources, forest ecosystems, fisheries, coastal areas, agriculture, human health, and urban areas, and identify strategies for managing those risks.

Objective:

Support climate impact studies for the Pacific Northwest.

Accomplishments:

- New climate change scenarios. Produced 20 scenarios of 21st century climate change from state-of-the-science climate models, produced in association with the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. This project included an evaluation of model performance at simulating 20th century PNW climate. Information on the new scenarios

is available at: http://www.cses.washington.edu/cig/fpt/ccscenarios.shtml.

- Development of statistical downscaling methods and products. Continued development of statistical downscaling methods tailored to the PNW and used these methods to downscale several global climate change simulations distributed by the Intergovernmental Panel on Climate Change. The downscaled data have been applied to hydrologic modeling and can be used ultimately to illustrate important differences among the ability of global models to simulate large-scale patterns controlling PNW climate (Salathé, in review; Salathé, 2005).

- Development of Regional Climate Model. The team has developed a regional climate model based on the MM5 modeling system to produce climate scenarios at 15-km resolution over the PNW. The model simulates the full climate system including land-surface processes. Compared to statistical downscaling, the regional model simulates mesoscale climate processes that are not represented in the global model and the output applicable to a much broader range of impacts studies.

- Climate Change and Air Quality. In collaboration with Washington State University and USDA Forest Service, we have performed a detailed study of the interactions of regional climate change, forest fires, and air quality. The CSES PNW regional climate model was used to produce the climate simulations used in the study (Avise, in review).

- Ongoing hydrologic studies for climate change assessments. Continued developing new data processing techniques to produce hydrologic climate change scenarios at weekly and daily time scales.

- Climatic and hydrologic data resources. Continued adding climate records for the western U.S. and some derived records (e.g., spring snowpack for the PNW) to the CSES website. The climate data is available at ftp://ftp.hydro.washington.edu/pub/hamleaf/vic_met_data/. The snow archive is available at ftp://ftp.hydro.washington.edu/pub/hamleaf/snow_archive/. Additional resources are available on the Office of Washington State Climatologist web site, www.climate.washington.edu.

Objective:

Support NOAA and climate research committees.

Accomplishments:

- Data management. Update online data holdings, including rewriting gridded data into a common data format, and providing email assistance in data set selection and use.

- Involvement in international climate science committees. Ed Sarachik serves as head of the IRI International Science and Technology Advisory Committee. Nate Mantua served on the U.S. CLIVAR Predictability, Predictions & Applications Interface Panel and the Study of Environmental Arctic Change (SEARCH) Responding to Change Panel. Philip Mote is participating in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change as a lead author for the chapter on observed changes in snow, ice, and frozen ground. Philip Mote also serves on the American Meteorological Society (AMS) Committee on Climate Variability and Change and

on the program committee for the 87th annual meeting of the AMS in January, 2007. Finally, Philip Mote and Amy Snover served on the organizing committee of the Third International Conference on Climate Impacts Assessments in July 2006 in Cairns, Australia.

- ICLEI Climate Safe Communities Program. CSES is co-authoring a guidebook for local governments on adapting to climate change (see entry in "Enhancing regional capacity…") that will be the center piece of the NOAA-funded Climate Safe Communities Program (developed by ICLEI – Local Governments for Sustainability). This guidebook will form the foundation for ICLEI's program of training local governments on preparing for and adapting to climate change.

- Foundations for a National Climate Service. Developed and presented a conceptual framework for a regionally-distributed National Climate Service based on the lessons learned from the RISA experience. Began drafting a manuscript for publication in the *Proceedings of the National Academy of Sciences*.

Project:
Development of Hydrologic Nowcast and Forecast Products Using Land Data Assimilation.

PI:
UW - Dennis P. Lettenmaier

NOAA Primary Contact:
CPO/Climate Prediction Program for the Americas

NOAA Goals:
2) Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond.

3) Serve Society's Needs for Weather and Water Information.

Task: III

Description:

The Global Energy and Water Cycle Experiment (GEWEX) is designed in part to improve the ability to predict the hydrological cycle and energy fluxes at the land surface. While water resources applications have been identified as a priority area for GEWEX, progress in this area has been slow, in part because of the mismatch in construct and spatial scales between land hydrology models and the Soil-Vegetation-Atmosphere Transfer Schemes (SVATS) used by weather prediction and climate models to represent the land surface. Over the last decade, the capability of land surface schemes developed under GEWEX/GCIP support, like the Variable Infiltration Capacity (VIC) model developed by the PI's group, has improved to the point that their hydrologic functionality approaches that of the more highly calibrated operational hydrologic models. The GCIP-funded Land Data Assimilation System (LDAS), in particular, has facilitated implementation of land surface schemes in real-time, including VIC. The NOAA investment in LDAS facilitates the development of hydrologic nowcast and forecast products over the continental U.S., which this project has undertaken.

Objectives:

1. Identify target areas for LDAS-derived nowcast and forecast products, including soil moisture and snow water equivalent, over the continental U.S. portion of the LDAS domain.

2. Develop and test methods for production of hydrologic forecast products (primarily streamflow), for lead times from two weeks to one year.

3. Evaluate the nowcast and forecast products, through the use of point observations of soil moisture and snow, station and remote sensing-based estimates of snow extent, and streamflow.

4. Coordinate new product development with operational agencies responsible for streamflow forecasting in the western U.S., including the NWS River Forecast Centers and the Natural Resources Conservation Service.

Accomplishments:

- An experimental real-time seasonal streamflow forecast system for the western U.S. which uses climate information from sources including NOAA/CPC "official" forecasts, output from two climate models run to six month lead times, and several resampling schemes have been implemented. www.hydro.washington.edu/forecast/westwide.

- Forecasts have been made via the UW web site, and during the snowmelt season conference calls with NRCS National Water and Climate Center staff are scheduled each month in advance of the release of their forecasts. UW seasonal forecasts were especially useful during the exceptionally high snowfall winter of 2005 in the southwestern U.S., where record snowmelt runoff was experienced.

- A BAMS article describing the system is in press.

Project
Simulation of the ARGO Observing System.

PI:
UW - Igor Kamenkovich, E.S. Sarachik

Other Personnel:
UW - Wei Cheng; NOAA - D.E. Harrison

NOAA Primary contact:
CPO/Office of Climate Observation

NOAA Goal:
2) Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond.

Task: II

Description:

The main goal of this study is to examine how well the ARGO observing system determines the state of the global upper ocean. The scientists sample and reconstruct oceanic fields from ocean general circulation models (GCMs), in gradually more realistic sequence of simulations. By quantifying errors in the reconstructed fields, they estimate accuracy of the ARGO observing system, and therefore directly address NOAA's Program Plan for Building a Sustained Ocean Observing System for Climate.

Objectives:

- To evaluate a performance of simulated ARGO system in a coarse resolution model, and quantify the influence of the spatial distribution of floats and large-scale oceanic advection.
- To estimate the influence of the high-frequency mesoscale variability on the performance of the ARGO observing system in a higher resolution model that realistically simulates spatial and temporal variability in these regions.

Accomplishments:

The team has been looking at the expected performance of the ARGO observing system for the ocean. They have started with a coarse resolution global ocean GCM in order to

(i) train themselves for higher resolution models and

(ii) see if there is anything in the coarse resolution model the ARGO system could *not* resolve, in order to identify direct limitations of the system.

They began by analyzing how the spatial distribution of the floats affects the performance of the ARGO observing system. They, therefore, accomplished the first major objective of their study: to analyze performance of the simulated ARGO observing system in a coarse resolution model. The group looked at three simple sampling considerations:

(i) “standard case” with the floats being advected by GCM-simulated currents;

(ii) “parked-float case”, in which the float locations are fixed in time;

(iii) “random-sampling case”, in which the floats are randomly re-distributed every time sampling takes place.

In reality, the ARGO floats are advected with both the steady large-scale currents and high-frequency mesoscale eddies, and the most realistic scenario is expected to be in between cases (ii) and (iii). To simulate the actual ARGO sampling procedure, they sample simulated temperature and salinity every 10 days, and up to the 1500 meter depth. From the resulting “measurements”, temperature and salinity of the ocean is reconstructed using objective analysis.

Overall performance of the simulated observing system is good, and the reconstructed climatology of the temperature and salinity are very close to the actual GCM-simulated values. However, all three cases exhibit similarly significant differences between the reconstructed and actual fields within western boundary systems, such as the Gulf Stream and Kuroshio, and the Antarctic Circumpolar Current (ACC). These differences are smaller in the random-sampling case, due to a greater overall spatial sampling coverage. Since these regions are characterized by swift oceanic currents and sharp spatial gradients whose intensity is underestimated by our coarse-resolution GCM, the deviations of the reconstructed fields from the actual values are expected to be even greater in reality than in our simulations. This result emphasizes the need for additional, dense spatial sampling in the vicinity of the western oceanic boundaries and in the ACC. The standard case also exhibits large errors near shallow points due to the “loss” of floats.

Results from this study were presented at the NOAA Climate Observation Program 4th Annual

System Review (May 10-12, 2006, Silver Spring, MD).

Project:
Tropical Pacific and Atlantic Ocean Circulation Program.

PI:
UW - Dongxiao Zhang

Other Personnel:
UW - Wei Cheng
NOAA - Michael J. McPhaden, Regina R. Rodrigues

NOAA Primary Contact:
CPO

NOAA Goal:
2) Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond.

Task: III

Objective:

It is well documented that the decadal variability in the tropical Sea Surface Temperature (SST) has substantial effects on marine ecosystems, the carbon cycle, and climate variations world wide. The mechanisms of the decadal SST variability however are less clear. The role of tropical oceans in the long-term climate change remains controversial. The sensitivity of tropical Pacific to the anthropogenic forcing varies largely in climate models. All of these limit the predictability of the climate system. Fluctuations in ocean circulation, the Subtropical Cell (STC) that connects the tropical upwelling and extra-tropical subduction, have been proposed as a key element of tropical SST variability on decadal and longer time scales. The purpose of this study is to better understand the role of this circulation on climate variability.

Accomplishments:

In the past year, the team used NOAA/PMEL Tropical Atmosphere and Ocean (TAO) moored array measurements, historical hydrographic data, numerical modeling, and data assimilation products to investigate:

- How the tropical upwelling and SST are regulated by the STC;
- What is the amplitude of decadal variability and linear trend of the STC and tropical Pacific SST over the past half century;
- How well the state-of-the-art climate models used for the Intergovernmental Panel on Climate Change 4th Assessment (IPCC AR4) simulate the trend and variability of the ocean circulation and SST over the past 50 years;
- The relation between the decadal changes in ocean circulation, dissolved oxygen and apparent oxygen utilization in the north Pacific;
- The decadal changes of the Atlantic STCs and their relation to the modes of tropical Atlantic SST variability.

The results were reported in a number of presentations at the CLIVAR Tropical Atlantic Ocean Circulation Workshop in Venice, Italy, the AGU Ocean Science Meeting in Honolulu, and the seminars at University of Washington and University of Paris. A number of peer-reviewed journal articles were written or in preparation.

Project:
Tropical Atmosphere-Ocean Interaction.

PI:
NOAA - Michael McPhaden

Other Personnel:
UW - Patrick A'Hearn, Dan Dougherty, Curran Fey, Sookmi Moon, Sonya Noor, Regina Rodrigues, Linda Stratton, Dongxiao Zhang, David Zimmerman, Xuebin Zhang, Natalia Stefanova

NOAA Primary Contact:
CPO

NOAA Goal:
2) Understanding Climate Variability and Change to Enhance Society's Ability to Plan and Respond.

Task: II

Description:

JISAO research on tropical atmosphere-ocean interaction 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. NOAA and JISAO scientists at PMEL maintain the TAO array. In combination with the TRITON array maintained by Japanese scientists in the western Pacific, it 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 ENSO forecasting and a variety of oceanographic and climate research studies. The array provides long-term, large-scale context for process oriented field studies such as the Eastern Pacific Investigation of Climate (EPIC). It supports carbon cycle studies in the Pacific, by providing access to ship and buoy platforms and by providing a physical oceanographic and meteorological context in which to interpret chemical measurements. Ships servicing the TAO array also provide a platform for the regular launch of ARGO floats.

Complementing the TAO array in the tropical Pacific is the Pilot Research Moored Array in the Tropical Atlantic (PIRATA), maintained by NOAA and JISAO scientists at PMEL in collaboration with institutions in Brazil and France. This array provides data to advance our understanding and ability to predict intraseasonal-to-decadal variations in the climate of the Atlantic sector. Together, TAO and PIRATA are managed through the TAO Project Office at PMEL. Research related to several aspects of ocean-atmosphere interaction and the role of the ocean in climate is conducted within this programmatic framework.

Objectives:

1. To ensure high quality and timely access to moored time series-data for climate research.

2. To contribute to the global understanding of the ENSO cycle.

3. To advance the understanding of decadal variability in the tropical Pacific and Atlantic.

4. To understand the relationship between local wind-stress forcing in the eastern equatorial Pacific and sea surface temperature variability associated with ENSO.

5. To establish an initial moored buoy array in the Indian Ocean for climate studies.

6. To expand and enhance PIRATA.

Accomplishments:

1. Providing TAO data to the scientific community via the internet. Research carried out at JISAO and elsewhere using data from the TAO/TRITON and PIRATA arrays depends critically on the collection, quality control, archival, and web-based display and dissemination of mooring data sets. At JISAO, considerable effort is devoted to providing easy access to high quality multi-variate time-series through the TAO web page (http://www.pmel.noaa.gov/tao/). Between July, 2005 and June, 2006, TAO web pages received more than 22 million hits and delivered more than 190,000 mooring data files to the international community.

2. Year-to-year variability associated with the El Niño/Southern Oscillation (ENSO) is governed by large-scale ocean dynamics and coupled ocean-atmosphere interactions. However, the cycle between warm and cold phase ENSO conditions exhibits considerable irregularity in terms of amplitude, duration, and spatial and temporal patterns of development. One factor contributing to this irregularity is stochastic forcing in the form of weather noise, a prominent source of which is the Madden-Julian Oscillation (MJO). A simple two-predictor regression model was developed to estimate the relative influence of large-scale low frequency deterministic ocean-atmosphere dynamics and stochastic forcing on peak sea surface temperature (SST) anomalies associated with ENSO for the period 1980-2005. One predictor is equatorial warm water volume, which is an index for the role that upper ocean heat content plays in regulating ENSO variability. The other predictor characterizes stochastic forcing in the western Pacific in the form of an MJO activity index. The two-predictor model accounts for about 65% of peak Nino3.4 SST anomaly variance at 2-3 season lead times and suggests about equal influence (on average) of stochastic and deterministic processes affecting peak ENSO SST anomalies over the past 25 years.

3. (a) The most prominent mode of decadal variability in the tropical Atlantic is the inter-hemispheric sea surface temperature (SST) gradient mode, which affects the climate over South America and Africa. It also affects sea surface temperature variability in the main development region for hurricanes between 10-20°N. The role of horizontal oceanic heat advection in the generation of tropical North and South Atlantic SST anomalies was investigated through an analysis of the oceanic mixed layer heat balance. The team found that SST anomalies poleward of 10° are driven primarily by a combination of wind-induced latent heat loss and shortwave radiation. Away from the eastern boundary, horizontal advection damps surface flux-forced SST anomalies due to a combination of mean meridional Ekman currents acting on anomalous meridional SST gradients, and anomalous meridional currents acting on the mean meridional SST gradient. In addition to the damping effect of horizontal advection in these latitude bands, we find evidence for coupled wind-SST feedbacks, with anomalous equatorward (poleward) SST gradients contributing to enhanced (reduced) westward surface winds and an equatorward propagation of SST anomalies.

(b) The group have investigated the decadal variability of the shallow overturning cells and its effects

on the equatorial sea surface temperature (SST) variability in the Atlantic and Pacific oceans, using the Simple Ocean Data Assimilation (SODA) reanalysis data set from 1958 to 2001. Their analysis are focused on the variability of the pycnocline transports in the interior ocean and western boundary across 10°N and 10°S in the Atlantic and 9°N and 9°S in the Pacific. Comparing with observations, the SODA data reproduce reasonably well the mean and decadal variability of the pycnocline transports. The results reveal that there is a small area between 3°N-3°S and 20°W-5°W where changes in SST are coherent with changes in the pycnocline convergence in the interior ocean. This is an important result since this cold tongue region has been reported as having complex dynamics and also been poorly simulated by atmosphere-ocean coupled models. In the Pacific, the extent of the area where SST anomalies co-vary with the interior convergence is much larger. Higher decadal variability of equatorial SST in the Pacific is primarily due to larger changes in the pycnocline transport and larger spatial extent of its effects. In the Atlantic, the overall impact on equatorial SST is much smaller, mainly due to smaller decadal variability of the pycnocline meridional transports with low signal to noise ratio.

4. Vertical advection of temperature is the primary mechanism by which ENSO time scale SST anomalies are generated in the eastern equatorial Pacific. Variations in vertical advection are mediated primarily by remote wind-forced thermocline displacements, which control the temperature of water upwelled to the surface. However, during some ENSO events, large wind stress variations occur in the eastern Pacific that in principle should affect local upwelling rates, the depth of the thermocline, and SST. The impact of these wind-stress variations on the eastern equatorial Pacific has been addressed using multiple linear regression analysis and a linear equatorial wave model, results of which were published in the *Journal of Climate* in early 2006. This work has been extended to examine relevant processes in a wind forced ocean general circulation model for the period 1980-2005. Sensitivity studies are being conducted to isolate the effect of wind-stress forcing in the eastern Pacific and budget analyses are being conducted to quantify terms in the surface layer heat balance.

5. JISAO and NOAA/PMEL scientists, together with a group of international climate scientists, have developed a plan for systematic, sustained, and comprehensive *in situ* observations in the Indian Ocean to complement both present and planned space-based satellite measurements. The plan includes a strategy for the establishment of a moored buoy array, which in essence represents an expansion of the TAO array into the Indian Ocean. The first NOAA supported moorings of this array were deployed on the Indian research vessel Sagar Kanya in October-November 2004. Data are being transmitted in real-time to shore via Service Argos and analyzed to improve our understanding of ocean-atmosphere interactions in the region. Intraseasonal fluctuations in winds, currents, SST, mixed-layer depth and rainfall are very prominent in the time series. An interesting feature to emerge from the analysis was the effects of a thick barrier layer on inhibiting the vertical mixing of temperature during an especially rainy period of several weeks in late 2004. A first presentation of results on the surface layer heat balance was made at the Ocean Sciences Meeting in Honolulu in February, 2006.

Plans are under way to deploy several additional moorings in the coming year using Indian, French, Indonesian and possibly Chinese vessels.

6. JISAO personnel have contributed to further expansion and enhancement of the PIRATA array in the tropical Atlantic. In addition to the core array of 10 moorings, 3 additional moorings were deployed in the southwest tropical Atlantic in August, 2005 and 3 more in June, 2006 (2 in the Northeast tropical Atlantic and 1 in the Southeast). The array at present thus consists of 16 moorings, with two more planned in mid-2007 in the Northeast. In addition, current meters, additional temperature/salinity sensors and meteorological sensors were added to several moorings to enhance their capability to measure air-sea fluxes of heat, moisture and momentum.

Project:
Wind stress variations and inter-annual sea surface temperature anomalies in the eastern equatorial Pacific.

PI :
NOAA - Michael J. McPhaden

Other Personnel:
UW - Xuebin Zhang

NOAA Primary Contact:
CPO/Office of Climate Observation

NOAA Goal:
2) Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond.

Task: II

Description:

This is a study designed to diagnose the mechanisms responsible for SST variability in the eastern equatorial Pacific Ocean using data sets and numerical model simulations. The study is consistent with JISAO's climate theme and addresses NOAA's goal to understand climate variability and change to enhance society's ability to plan and respond.

Objectives:

1. To document changes in winds, SST, thermocline depth, and precipitation in the eastern Pacific on ENSO time scales.

2. To separate out remote vs. local influences on SST variability.

3. To describe how local ocean-atmospheric feedbacks in the eastern Pacific can affect the evolution of ENSO events.

Accomplishments:

In the past year, the team published a paper in the *Journal of Climate* (Zhang and McPhaden, 2006) demonstrating that, while remote forcing is the major control over eastern and central Pacific SST anomalies during ENSO warm and cold events, local zonal wind forcing east of 170W can significantly affect the temporal evolution and spatial structure of interannual SST anomalies. For large events in particular, e.g. 1997-98, local forcing can account for up to 1/3 the magnitude of the SST anomaly in the Nino3 region.

With the publication of the above empirical analysis, the group has advanced to running an ocean general circulation model to simulate variability from 1979 to 2005. Numerical sensitivity studies and heat balance diagnostics are planned using the model output. Several simulations have been run, and several more are planned.

Project:
Thermal Modeling and Prediction (TMAP).

PI:
UW - J. Callahan
NOAA - S. Hankin

NOAA Goals:
1) Protect, Restore and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management.

2) Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond.

NOAA Primary Contact:
PMEL

Task: II

Objectives:

1. To provide software solutions that integrate and disseminate data and data products via the internet.

2. To provide support for sites utilizing LAS for data access.

3. To develop data management solutions that makes large volumes of oceanographic data accessible to users on demand in real-time.

Accomplishments:

1. i) The Live Access Server (LAS). The Live Access Server is currently installed at approximately 50 institutes worldwide and provides access to terabytes of ocean, atmosphere and climate data. The Live Access Server is being rewritten from the ground up in the Java language in order to implement a web services architecture, and to take advantage of improvements in various Java-based software libraries for data access and user interface development.

ii) Observing System Monitoring Center (OSMC) at NOAA Office of Global Programs. The OSMC database and interface are being continually updated to improve the quantity and quality of data available as well as to provide new visualizations for the end-user. This interface provides an instantaneous overview of the state of the global ocean monitoring system. Users can query a database for actual observations or investigate gridded summaries of the data.

2. HYCOM Data Assimilation Experiment. A new LAS is being designed for the intercomparison of different data assimilation models being run at the University of Miami. This new system adds additional user interface tools for model comparison to the new Java-based LAS product server.

3. i) Carbon Data Management. TMAP is working with the Carbon Dioxide Information Analysis Center at Oak Ridge National Lab to design a data management system that will provide real-time access to a unique collection of ocean carbon measurements including 'underway' data, profiles and time series. Underway data from NOAA's Pacific Marine Environmental Lab and the Atlantic Oceanographic Marine

Lab have been run through QA/QC software and ingested into a database. This database will connect with a new LAS user interface to provide easy access to these data.

ii) Pacific Region Integrated Data Enterprise (PRIDE). This project integrates the current state-of-the-art data assimilation model outputs for the Pacific Islands regions, together with real-time and historical observations served from many distributed sources, and provides access to them through a simple Web browser interface for Pacific Island end-users and researchers. The PRIDE server is currently operational and will be enhanced with improvements to the user interface and additional datasets.

Project:
Oceanic Observations of Climate Change in the Arctic Sub Polar Zone.

PI:
UW - P.B. Rhines

NOAA Primary Contact:
ARO

NOAA Goal:
2) Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond.

Task: III

Objectives:

1. To support the deployment of an acoustic-Doppler current profiler in Barrow Strait, as part of the International Arctic-Subarctic Ocean Flux (ASOF) monitoring of Arctic outflows.

2. To support hydrographic and biological observations in the Labrador Sea, making use of autonomous undersea vehicles known as Seagliders.

Accomplishments:

1. In Barrow Strait, in the Canadian Arctic Archipelago, NOAA supported instrumentation is providing 3 years' observations of the ocean flow from Arctic to Atlantic Oceans, a key part of the global climate system. Dr. Prinsenberg of Bedford Institute of Oceanography, Canada, has successfully deployed the newly conceived 'Icycler', a profiling moored ctd/current sensor in this program.

Yearlong moorings since August 1998 from Lancaster Sound in the Canadian Arctic Archipelago are providing oceanographic data sets to capture decadal variability of the freshwater and heat fluxes passing through the CAA to the North Atlantic Ocean. The project is part of the international effort (ASOF – Arctic Sub-Arctic Ocean Flux Program) to monitor and simulate the fluxes leaving the Arctic and affecting the vertical mixing of the North and Atlantic and thus the Global Ocean Conveyor Belt circulation. Moorings from Lancaster Sound for the 2004-05 and 2005-06 periods were successfully retrieved and redeployed for the 2006-07 period. Moorings have been in place since August 1998 and the plan is to extend the mooring work through August 2010 in cooperation with the Canadian IPY programs. The moorings provide salinity and temperature fields, ocean currents, and ice draft and ice drift data. ASL Env. Sciences Inc. (Victoria, BC) is processing the Upward looking Sonar mooring data for ice draft and ice drift starting with the 2003-04 deployment. The new bottom mounted under-ice profilers (ICYCLERs) have been successfully recovered, #1 for Aug. 2003- Aug. 2004 and #2 for Aug. 2004 – Aug. 2006 and data are being analyzed and will be published as part of the data report series. A third ICYCLER for deeper surface layer profiles (200m) is being designed as part of an effort by BIO, a U.K. and U.S. consortium to build real-time deep ocean profilers to monitor carbon fluxes.

2. Two Seagliders were launched west of Greenland in September 2004, and a third in April 2005. This provided a second winter of successful hydrographic surveying of the Labrador Sea by these

autonomous undersea vehicles (AUVs). The first two AUVs set new records for distance and duration, collecting 2500 hydrographic profiles. A total of roughly 7000km of sections were collected in these three missions.

The Seagliders have documented the source of the low-salinity layer that dominates the near-surface Labrador Sea and controls deep convection and water-mass creation in this important source of the global meridional overturning circulation. By sampling the uv-fluorescence of the upper ocean they also established the origin of the major spring plankton bloom, which is clearly identified with this same offshore flow of shelf waters from west Greenland. The low-salinity buoyancy in the upper layer promotes an exceptionally strong region of springtime biological productivity. The Seagliders have also made repeated sections of the intense boundary currents that form the Atlantic sub polar gyre. The Davis Strait sections are the most detailed surveys of this important exchange flow ever made. A poster describing the 2003-04 Seaglider expedition can be viewed at http://www.ocean.washington.edu/research/gfd/Seaglider-poster-iva.pdf

Project:
US-GLOBEC NEP Phase IIIa-CCS: Latitudinal variations of upwelling, retention, nutrient supply and freshwater effects in the California Current System.

PI:
UW - Dr. Barbara M. Hickey

Other Personnel:
NOAA - Dr. Elizabeth Turner

NOAA Primary Contact:
PMEL

NOAA Goal:
1) Protect, Restore and Manage Use of Coastal and Ocean Resources Through Ecosystem-based Management.

Task III

Description:

This project focuses primarily on datasets from two moored sensor arrays deployed in the California Current System (CCS) from 1997/98-2003. The moorings were deployed on the shelf near Grays Harbor, Washington and near Coos Bay, Oregon. Work is collaborative, in particular, using similar data acquired by other PIs at 2 other sites in the CCS (Newport, OR, [Kosro, PI] and Rogue River, OR, [Ramp PI]. The project is also collaborative with other CCS PIs, using data acquired on survey and process cruises as well as model output.

Objectives:

1. Alongshore variability of water properties and circulation in the California Current System.

2. Inter-annual variability in water properties and circulation.

3. Relationship of such variability to higher trophic levels.

Accomplishments:

Monthly mean variability. In this project year the team first acquired datasets from their Co-PIs. Next, these data were combined and analyzed for variability as described in objectives (1) and (2) and presented as a poster at the Ocean Sciences meeting in Hawaii. A paper on these results is in preparation.

Their results showed that upwelling-favorable wind stress varied by more than a factor of three over the latitudinal range of the data obtained, decreasing to the north. In spite of these latitudinal differences, seasonal cycles as well as year-to-year differences in water properties were remarkably similar at all sites, although south to north lags generally occur. The overall conclusion is that large scale processes overwhelm local spatial scale differences on these time scales. The results reaffirm the importance of remote forcing in the CCS on seasonal to interannual scales. Specific conclusions include

the following:

1. Year-to-year differences in seasonal water properties are very large scale (>500 km along the shelf) and affect the whole shelf water column; differences in the magnitude of the seasonal coastal jet have significantly shorter alongshelf structure.

2. Water property differences from year-to-year are much more variable in winter (low S, high T) than in summer (high S, low T).

3. A south to north lag of 1-3 months usually occurs in summer properties (T, S, V), with greater alongshelf lags in maximum coastal jet velocity.

4. Maximum alongshelf velocity (V) precedes S, T and maximum local alongshelf wind stress at each location, with a greater lead in winter than in summer.

5. Year-to-year differences in the speed of the summertime coastal jet are not related to the strength of the local upwelling-favorable wind stress.

6. Year to year water property differences (both maxima and minima) are strongly related to alongshelf wind stress in winter but not in summer.

7. Year to year winter time whole water column salinity differences are not related to regional freshwater input.

8. Year to year water property differences are strongly related to alongshore wind stress in winter, but not in summer.

The 2005 warm anomaly. A paper on the anomalous coastal conditions in 2005 (Hickey et al., 2006) was prepared by Dr. Hickey for publication in a special volume of *Geophysical Research Letters*. The spring onset of persistent upwelling-favorable winds was later than usual in the northern California Current system in 2005, resulting in delayed provision of inorganic nutrients to the upper waters of the coastal ocean. This paper uses water column measurements to illustrate the evolution of temperature, salinity, nitrate and chlorophyll *a,* prior to and after the onset of persistent local upwelling-favorable winds, including recovery to "typical" conditions. The team shows that warm, nutrient- and chlorophyll-depleted surface conditions similar to those in an El Niño were observed from Vancouver Island to central Oregon, and extended to depths greater than 500 m. Return to typical conditions was more rapid than suggested by time-integrated local wind stress but consistent in timing with "remote" forcing of water properties in this region by upwelling-favorable winds off northern California. It is likely that alongshore advection also contributed to the observed recovery, but was much less effective than upwelling. Dr. Hickey was co-author on a second paper in this *GRL* volume (Kosro et al., 2006).

Data-Model comparison. Dr. Hickey performed detailed comparisons between GLOBEC numerical model output in the CCS and moored sensor velocity and water property time series. Results indicated very poor skill in the model over the Oregon and Washington shelves. The skill of the Kindle Navy Research model was much better than that of the GLOBEC NEP model.

Project:
Argo: A Global Array of Profiling Floats.

PI:
UW - Stephen C. Riser

Other Personnel:
UW - Kurt Heinze, Dale Ripley, Dana Swift

NOAA Primary contact:
OAR

NOAA Goal:
2) Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond.

Task: II

Objective:

To continue participation 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 U.S. is committed to providing about half of these floats. For the past several years the U.S. has been providing about 300 floats per year, split among 4 institutions (SIO, WHOI, PMEL, and UW). In the past year funds were received to build and deploy 125 floats. The UW floats were deployed in the Indian Ocean, the Antarctic, and the Pacific. Most continue to operate as designed for at least 3 years. At the present time the data are being used to examine the state of the Indian Ocean Dipole, the Pacific Decadal Oscillation in the North Pacific and long-term (decade to century) scale of variability of salinity in the North Pacific.

Accomplishments:

In 2006, the most critical region for deploying floats continues to be the South Pacific where the coverage remains thin due to the difficulty in finding suitable means (i.e., ships or aircraft) to deploy the floats. To remedy this situation, funds were received from NOAA through JISAO to charter a vessel for several months that could deploy Argo floats in the tropical and subtropical South Pacific. A small research vessel, has been chartered, R/V *Kaharoa*, based in Wellington, New Zealand, operated by the National Institute of Water and Atmospheric Research of New Zealand. Since 2004, this vessel has deployed nearly 400 floats provided by UW and Scripps. The deployment of these floats has greatly increased the available database for the South Pacific, and the data from these are already being assimilated into climate models. In the coming year, the charter vessel will be used to deploy Argo floats in the South Indian Ocean.

Project:
Analyzing Tropospheric Temperature Trends Using MSU Observations.

PI:
UW - Qiang Fu

Other Personnel:
UW - Celeste M. Johanson

NOAA Primary Contact :
OAR

NOAA Goal:
2) Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond.

Task: III

Description:

In year one, the group has been concentrating on:

1. Investigating the MSU tropospheric temperature trends in the tropical region where large trend differences exist between Spencer and Christy's MSU channel-2 angular scanning retrieval (i.e., T_{2LT} for the low-middle troposphere) and the tropical tropospheric temperature derived from MSU T_2 and T_4 following Fu et al. (2004).

2. Evaluating the sensitivity of the weights of the two channels in the Fu et al. retrieval algorithm for the tropospheric temperatures to the atmospheric stationarity and to the choice of training dataset. In addition the team has been providing MSU-derived product to the NOAA NCDC's Climate Monitoring Branch on the 8th of each month for the period of record updated from 1979 to the most recent month for its monthly State of the Climate reporting. The MSU-derived data from this project have also been used in the fourth assessment report of the IPCC which is now in draft form.

Objectives:

The overall objective of this NOAA-funded research project is to evaluate and improve the MSU tropospheric temperature retrieval method, develop a high quality MSU tropospheric temperature dataset for climate research, and understand the tropospheric temperature trends.

Accomplishments:

1. Tropical atmospheric temperatures in different tropospheric layers are retrieved using satellite-borne Microwave Sounding Unit (MSU) observations. The team found that tropospheric temperature trends in the tropics are greater than the surface warming and increase with height. The analysis indicates that the near-zero trend from Spencer and Christy's MSU channel-2 angular scanning retrieval for the tropical low-middle troposphere (T_{2LT}) is inconsistent with tropical tropospheric warming derived from their MSU T_2 and T_4 data. The team shows that the T_{2LT} trend bias can be largely attributed to the periods when the satellites had large local equator crossing time drifts that cause large changes

in calibration target temperatures and large diurnal drifts. These findings are reported in Fu and Johanson (2005) which is featured prominently in the fourth assessment report of the IPCC. This work also lays a foundation for a later paper where Fu is a co-author (Santer et al. 2005, *Science*).

2. Tropospheric temperature trends based on the Microwave Sounding Unit (MSU) channel-2 data are susceptible to contamination from strong stratospheric cooling. Fu et al. (2004) devised a method of removing the stratospheric contamination by linearly combining data from MSU channels 2 and 4. In this study the scientists examine the sensitivity of the weights of the two channels in the retrieval algorithm for the tropospheric temperatures to the choice of period of record used in the analysis and to the choice of training dataset. They find that the weights derived using monthly temperature anomalies are within about 10% of those obtained by Fu et al. irrespective of the choice of analysis period or training dataset. The trend errors in the retrieved global mean tropospheric temperatures tested using two independent radiosonde datasets are less than about 0.01 K/decade for all time periods of 25 years or longer with different starting and ending years during 1958-2004. It is found that the retrievals are more robust if they are interpreted in terms of the layer-mean temperature for the entire troposphere, rather than the mean of the 850-300 hPa layer. The team shows that because large spurious jumps remain in the reanalyses, especially prior to 1979, one should be cautious when using them as training datasets and in testing the trend errors. This work is reported in Johanson and Fu (2005).

3. The group has started to carry out the comparison between the MSU data and radiosonde observations and the comparison between the new T_{2LT} from both RSS and UAH groups and the tropospheric temperatures retrieved following Fu et al. Their initial results show that since the significant information of T_{2LT} is from the surface, especially over land, the diurnal adjustment over land could still be an issue. It is also noted that because the tropospheric temperatures retrieved from T_2 and T_4 are for the entire troposphere while the T_{2LT} are for the lower troposphere, therefore these two tropospheric temperature products could potentially provide unique information on the vertical structure of tropospheric temperature trends, especially in the tropical region.

Project:
Low-Latitude Cloud Feedbacks on Climate Sensitivity.

PI:
UW - C. S. Bretherton

Other Personnel:
UW - M. Wyant

NOAA Primary Contact:
OGP

NOAA Goals:
2) Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond.

Task: III

Objectives:

1. To contribute to the coordination of Cloud Process Team (CPT) activities.

2. To compare simulations of tropical clouds in different climate models.

Accomplishments:

1. Coordinated a third CPT group meeting in Seattle on 29-30 November, 2005, at GFDL, with approximately 35 participants including all the funded CPT investigators, some of the advisory group members, several other GFDL scientists, and guest observers Warren Wiscombe (ARM chief scientist) and Amy Clement (U. Miami). The meeting presentations summarized the CPT progress so far, highlighting two group projects initiated in the spring of 2005, both of which have promising preliminary results. These were a single-column climate sensitivity simulation framework (led by Minghua Zhang) and an aquaplanet climate sensitivity (led by Bjorn Stevens). There were also presentations of the first climate sensitivity study of a superparameterized GCM (a UW/CSU collaboration) and of diagnosis of boundary layer clouds in the NCAR/GFDL climate models run in weather forecast mode (an NCAR/GFDL/CAPT/UW collaboration).

2. Wyant and Bretherton collaborated with CSU CPT scientist Marat Khairoutdinov to carry out and publish the first climate sensitivity study of a superparameterized GCM, the CAM3-SP, using a Cess framework based on the change in top-of-atmosphere radiation balance with a uniform imposed 2K SST increase. Since superparameterization permits simulations between clouds and cumulus convection that are much more realistic than in a conventional GCM, one might regard the CAM3-SP as giving a more meaningful estimate of cloud feedbacks on climate sensitivity. The team found that the CAM3-SP had a climate sensitivity that was lower than almost all current GCMs. This was found to mainly stem from increased boundary-layer cloud cover simulated at all latitudes in a warmer climate, which reflects more sunlight back to space. Unfortunately, the simulation of boundary layer clouds in the CAM3-SP is only marginally more realistic than in a conventional AGCM because the vertical and horizontal grid spacing in the cloud-resolving models at each grid column of the CAM3-SP is too large to accurately simulate boundary-layer turbulent eddies and clouds.

3. Bretherton, together with graduate student Peter Caldwell, investigated the climate sensitivity of a subtropical cloud-topped mixed layer model, using this to help design the CPT single-column framework. Their model was framed in terms of the response of the cloud-topped mixed layer to a specified local and warm pool SST. The warm pool SST determines the free-tropospheric temperature, moisture and mean subsidence rate. They found that if the local and warm pool SSTs were increased by the same amount (corresponding to a standard 'Cess' test of climate sensitivity), the stratocumulus cloud thickens due to deepening of the boundary layer, but if the local SST is determined by ocean energy balance, it increases less than the warm pool SST and the cloud thickness remains essentially constant. Thus the cloud feedbacks on climate are rather different in these two cases. A manuscript describing this work is nearly ready for submission to *J. Climate*.

4. Bretherton, together with CPT liaison C. Hannay of NCAR, tested the performance of the NCAR CAM GCM in forecast mode vs. a six-day period of shipboard observations from the SE Pacific stratocumulus region. The performance of the default CAM3 was compared with a version with UW parameterizations for moist turbulence and shallow cumulus convection. The UW parameterizations slightly improved the model performance and had a much more realistic partitioning of the heat and moisture budgets between the parameterized physical processes. This is a groundbreaking example of how this type of forecast-mode analysis allows field measurements of marine boundary layer clouds to be more effectively used to test and improve parameterization approaches. Hannay is preparing this work for publication.

5. Wyant led the analysis of the latest single-column intercomparison case of the GEWEX Cloud System Study Boundary Layer Cloud Working Group (GCSS-BLCWG). This case involved simulation of a drizzling nocturnal stratocumulus boundary layer. It showed that for these thin cloud layers, GCM microphysical parameterizations do not all produce realistic rainfall rates for a given cloud thickness. Most models tend to underestimate how much of the drizzle evaporates before reaching the ground. So-called 'two-moment' schemes for describing the rain process may help address this bias. Wyant is in an advanced stage of writing this case up for publication.

Talks and outreach activities:

The PI gave presentations about the CPT activities (below) at the Atmospheric Radiation Measurement (ARM) meeting in Albuquerque and at the CCSM Atmospheric Model Working Group meeting, both in March, 2005. Parts of this work were presented in seminars and posters, including at the CCSM annual meetings in June 2005 and 2006, the AMDS Boundary Layers and Turbulence meeting in May 2006, U. Chile in Oct. 2005, and at UW in January, 2006.

Project:
Regional Weather Analysis & Predictions.

PI:
UW - Clifford Mass and Greg Hakim

Other Personnel:
UW - Phil Regulski

NOAA Primary Contact:
NWH

NOAA Goal:
3) Serve Society's Needs for Weather and Water Information.

Task: III

Description:

This project is directed towards improving weather forecasting over the mountainous western U.S. by developing and operationally testing improved analysis and numerical weather prediction approaches. The proposed effort builds on a long history of applied cooperative research between the National Weather Service and the University of Washington, with many of the expected advances applicable to other regions of the country.

The first task will be to evaluate the potential of very high-resolution numerical weather prediction over the Northwest using the Penn. State/NCAR (MM5) and Weather Research and Forecasting (WRF) numerical models at grid spacing down to 1.3 km. Running these models in real-time over an extended period of time, the team will comprehensively verify the model forecasts and test a range of improvements in their moist and boundary layer parameterizations. The new WRF modeling system will be appraised relative to the MM5, and should lead to a switch to WRF by the Northwest modeling effort during the proposal period. As has been the case for the past five years, these model forecasts will be available in real-time to regional NWS offices for use in both graphic and gridded formats.

Objectives:

To improve NOAA's ensemble data assimilation and forecasting systems, with emphasis on performance in regions of complex terrain.

Accomplishments:

During the past year there has been considerable progress on several of the project goals. A grid-based bias correction scheme has been developed and tested. Currently, minor improvements to this scheme are being made and during the next month bias-corrected grids will be provided to the Northwest NWS offices in a real-time mode. Under the project there has been continued progress in improving and evaluating the regional ensemble prediction system, with a recent extension to 72-h. Also under this project, a new quality control system suitable for complex terrain was developed and tested, and new verification methods for high-resolution predictions have been evaluated. The University of Washington's research-grade ensemble Kalman filter was released as a real-time operational ensemble data assimilation and forecasting system on 23 December, 2004. This functioning system realizes a major goal of the UW CST AR proposal, and is in fact the first such system in the world. Graduate student Ryan Torn is largely responsible for creating and maintaining the system.

Project:
Monitoring the Eurasian Basin of the Arctic Ocean.

PI:
UW - Ignatius Rigor

Other Personnel:
UW - Mark Ortmeyer

NOAA Primary Contact:
ARO

NOAA Goal:
3) Serve Society's Needs for Weather and Water Information.

Task: III

Description:

Dramatic changes in Arctic climate have been noted during the past two decades. Observations from the International Arctic Buoy Programme (IABP) have played a significant role in the detection of this change. For example, using IABP data, Walsh et al. (1996) showed that sea level pressure (SLP) has decreased; Rigor et al. (2000) showed that surface air temperature (SAT) has increased; and in concert, the circulation of sea ice and the ocean have changed so as to flow less clockwise (Steele and Boyd, 1998; Kwok, 2000; and Rigor et al. 2002). In addition to studies of Arctic climate and climate change, observations from the IABP are also used to validate satellites, for forcing, validation and assimilation into numerical climate models, and for forecasting weather and ice conditions.

The observational array of the IABP is maintained by the 20 Institutions from 10 different countries, and supports the World Climate Research Programme (WCRP), the World Meteorological Organization (WMO) World Weather Watch (WWW) Programme. The IABP is an Action Group of the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM).

Objectives:

The scientists propose to deploy enhanced buoys in the Eurasian Basin of the Arctic Ocean, which will monitor the mass balance of sea ice, and will complement the observations collected by the International Arctic Buoy Programme (IABP, http://iabp.apl.washington.edu). Establishing a record of climate-induced changes in the thickness of the sea ice cover is essential to understanding the role of the sea ice cover in the global climate system, and to the application of the sea ice cover as an early indicator of global climate change.

Accomplishments:

Buoy Deployments.
1. WHITE TRIDENT Flight: 3 of 7 Meteorological buoys air deployed by the U.S. Naval Oceanographic Office, WHITE TRIDENT flights were purchased using funds from this grant.

2. Healy Cruise, Sept 2005: 3 of 5 Ice Mass Balance buoys deployed by the *USCG Ice Breaker Healy* were purchased using funds from this grant.

Project:
Forecasting the Condition of Arctic Sea Ice on Weekly to Seasonal Time Scales.

PI:
UW - Ignatius Rigor

Other Personnel:
UW - Mark Ortmeyer, Mark Wensnahan

NOAA Primary contact:
TRACS (Transitions of Research Applications to Climate Services)

NOAA Goal:
2) Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond.

Task: III

Description:

The Arctic has long been considered a harbinger of global climate change, as numerical simulations of global climate change predict that if the concentration of CO2 in the atmosphere doubles, the greenhouse warming signal will be much greater at high latitudes. This "polar amplification" of the global warming is attributed to changes in sea ice and snow (ice-snow albedo feedback). Indeed, many studies of the observational records show polar amplification of the warming trends, and four of the last seven summers have set record minima for Arctic sea ice extent. Could the scientists have predicted these past minima? Through this project, the team plans to answer this question, and hope to improve their operational capability to predict the conditions of Arctic sea ice, so they can forecast future minima with demonstrable skill.

Objectives:

1. Analyze new observations from Ice Mass Balance buoys, and other sources of *in situ* sea ice thickness observations, to validate the National/Naval Ice Center's current prediction models; and.

2. Exploit the significant lag correlations between variations in atmospheric circulation and sea ice extent to produce long-range forecasts of Arctic sea ice conditions.

Accomplishments:

Outreach: The team has been meeting with and giving presentations to potential users of their sea ice forecasts such as the US Coast Guard, Alaska Fisheries Science Center, the JISAO Climate Impacts Group, and at the Marine Science of Alaska Symposium.

Analysis:
1. The team has begun validation of the NIC Gerson and Perchal Ice Growth model using air temperature and ice growth data from the Ice Mass Balance buoys deployed by CRREL, PMEL, PSC, & NIC.

2. Estimates of the age of sea ice have been updated through 2005. They have shown that the age of sea ice has explained most of the variance in summer sea ice extent, and they have begun cross-validation studies to determine the skill of using age as a predictor of summer sea ice conditions. The age of sea ice over the Arctic Ocean will also be shown in the NOAA State of the Ocean Report for 2005.

3. The group is also working with the Arctic Submarine Lab to obtain submarine ice draft observations from cruises in 2005 to validate both the ice growth model and age of ice estimates. Submarine ice draft data from earlier cruises has already been collected and analyzed by PSC.

Project:
Monitoring Ice Thickness in the Western Arctic.

PI:
UW - R. W. Lindsay

NOAA Primary Contact:
ARO

NOAA Goals:
2) Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond.

Task: III

Objective:

Determine how data from the Ice Mass Balance Buoys (IMBs) deployed over the last several years by PMEL and the Cold Regions Research and Engineering Laboratory can be most effectively used to improve model simulations of the ice pack. The data from the buoys regarding the ice growth rates and ocean heat flux will be compared to model output and, if appropriate, methods of assimilating the data into the model will be devised.

Accomplishments:

Most of the last year has been dedicated to reformulating the coupled ice-ocean model to a new higher-resolution curvilinear grid, formulating open boundary conditions for the POP ocean model, and tuning the model parameters to use forcing from the ERA-40 Reanalysis. The team has changed the forcing fields from the NCEP Reanalysis to the ERA-40 Reanalysis, primarily because the clouds and downwelling radiative fluxes in the ERA-40 products are much superior to those from NCAR. Indeed, the NCEP radiative flux estimates are much worse than simple climatological estimates. The new model simulations that include assimilation of ice concentration, wet-ocean SST, and ice velocity are currently being run. Progress in relating the IMB data to the model runs has been delayed while these model-development steps have been taken under NASA support. The scientists have now determined how to extract model estimates of the ice growth rates and the ocean heat flux for specific ice thickness bins and are in the process of extracting these estimates for the times and locations of the IMB data. Estimates of these parameters are available from CRREL for some of the IMBs and they will need to make the parameters by themselves for some of the others.

Assimilating the ice mass balance data from the buoys will not be straightforward. The team first needs to look carefully at the data and the model and see what is most useful. Can the model or model parameters be adjusted to remove any bias in the model results? (Call this zeroth-order data assimilation, probably the MOST important step, not the least). This can be done profitably even with limited amounts of data. With abundant data the group can imagine assimilating some of the observations with an optimal-interpolation approach. Ocean heat flux might be a good candidate for assimilation, since it may not be tied so tightly to one thickness class. The model represents the ice thickness distribution with eight thickness classes, while the IMB data is from but one thickness (that of the buoy location).

Project:
Correction of Systematic Error in the TOVS Radiance.

PI:
Axel Schweiger

NOAA Primary Contact:
ARO

NOAA Goal:
2) Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond.

Task: III

Objectives:

1. To identify, quantify, and mitigate errors in TOVS radiances caused by changes to satellite orbits, instruments, and/or calibration method. The plan is to produce a 22-year (or more) record of TOVS radiances and retrieved products that are as error-free as is practicable, given available information and resources. Many of the known errors should be regionally and seasonally independent, but it is suspected that some may be peculiar to or exacerbated by Arctic conditions. Thus while the efforts will be global, the focus will be primarily Arctic. The expected product of this investigation will be a data set of tremendous value both for geophysical retrievals with sufficient accuracy to identify changes since 1979, as well as for direct assimilation by numerical atmospheric models. The database of high-latitude rawinsondes, many of which have not been incorporated into the operational Global Telecommunications System or assimilated by reanalyses, together with collocated satellite radiances, will also be of great value for further studies.

Accomplishments:

1. Expansion of collocation data set to include:

- Cloud observations from the EECRA data set.
- Cloud observation from RADAR/LIDAR from SHEBA and the Barrow and SGP ARM sites.
- NSIDC weekly snow and ice charts provide information on the surface type.
- A filtering and interpolation scheme for radiosonde observations has been implemented.
- Initial radiance bias computations have been performed.
- Numerous pieces of legacy code have been rewritten and documented.

2. Improvements of cloud detection algorithm:

Using the collocation data set, the team has updated the cloud detection algorithm used by the Path-P retrieval scheme. Significant improvements in cloud detection accuracy have been made by incorporating an additional test including the 7.2 micron channel and updating cloud detection thresholds in the algorithm resulting in an improvement in cloud detection accuracy from 64% to 88%. Most improvements affect night-time cloud detection.

The project has been slowed somewhat by difficulties at our NOAA-NESDIS collaborators to provide elements of the collocation data set. These problems have now been resolved. A no cost extension through July, 2007 has been filed.

ENVIRONMENTAL CHEMISTRY

Project: Ocean Carbon and Climate Change Program (OCCCP).

PI:
NOAA - Richard A. Feely and Christopher L. Sabine

Other Personnel:
UW - Paul Covert, Katie Fagan

NOAA Primary Contact:
CPO

NOAA Goal:
2) Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond.

Task: II

Description:

The PMEL/JISAO Ocean Carbon and Climate Change Program (OCCCP) conducts research on the sources and sinks and biogeochemical impacts of carbon dioxide in the oceans (Feely et al., 2005, Sabine, Feely and Wanninkhof, 2006). Atmospheric and oceanic carbon dioxide data are collected on cruises onboard 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.

Objectives:

1. To contribute to the scientific understanding of carbon sources and sinks in the oceans.

2. To foster the use of chemical and hydrographic data information for modeling efforts.

3. To contribute to graduate education at the University of Washington.

Accomplishments:

1. Determining the effects of the Pacific Decadal Oscillation on seawater pCO2 in the equatorial Pacific. The equatorial Pacific Ocean is one of the most important yet highly variable oceanic source areas for atmospheric carbon dioxide (CO2). The group used the partial pressure of CO2 (PCO2), measured in surface waters from 1979 through early 2004, to examine the effect of the Pacific Decadal Oscillation phase shifts, which occurred in 1889-90 and 1997-98, on the equatorial Pacific CO2 chemistry. As part of their continuing effort to understand decadal changes in the carbon fluxes of the equatorial Pacific, they developed seasonal and inter-annual fCO2-SST relationships from shipboard data that were applied to high-resolution temperature fields deduced from satellite data to obtain high-resolution large-scale estimates of the regional fluxes. The data were gathered on board research ships from November 1981 through June 2004. The results indicated a strong inter-annual (ENSO) and weaker seasonal variability. There is also a slight increase (~27%) in the out-gassing flux of CO2 after the 1997–1998 PDO mode shift (Feely et al., 2006). Most of this increase is due to increase in wind speeds after the spring of 1998 and is coincident with the recent rebound of the shallow water meridional overturning circulation in the tropical and subtropical Pacific after the PDO shift.

2. Distributing ocean carbon data to the oceanographic community. The OCCCP group has developed a WWW-based access for hydrographic and carbon data. This resource has been used by the modeling community to verify their carbon system biogeochemical process models for the oceans. The WWW site is supported by a live access server that provides both data access and graphical outputs. All the data and graphics can be found at the following WWW site:
http://www.pmel.noaa.gov/co2/co2-home.html

The OCCCP group completed a workshop report entitled, "Impacts on Ocean Acidification on Coral Reefs and Other Marine Calcifiers".

Project:
Chlorofluorocarbon Tracer Program.

PI:
NOAA - John Bullister

Other Personnel:
UW - Rolf Sonnerup, Frederick Menzia

NOAA Primary Contact:
PMEL

NOAA Goals:
2) Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond.

Task: II

Description:

Chlorofluorocarbons (CFCs) along with other anthropogenic tracers have proven to be useful in the study of a variety of oceanic processes. CFCs have well characterized atmospheric histories and their equilibrium concentrations in the surface ocean can be modeled globally as functions of location and time. Sensitive analytical techniques have been developed to measure CFC concentrations in seawater and these measurements have been included in a number of recent hydrographic surveys. The data collected have been used to provide information on rates and pathways of ocean circulation and mixing processes, water mass formation rates, and to evaluate Ocean General Circulation Models. CFCs have also been used directly to estimate the global uptake of anthropogenic CO2 in the ocean (McNeil et al., 2003) and as a component of the ΔC* technique (Sabine et al., 2004).

In recent years, the growth rates of CFCs in the atmosphere have slowed, increasing uncertainties in water 'ages' calculated from CFC concentrations. The scientists are working on methods for utilizing other tracers (including sulfur hexafluoride-SF6) to supplement the CFCs in ocean studies.

Objectives:

1. To monitor the uptake of anthropogenic chlorofluorocarbons (CFCs) and sulfur hexafluoride (SF6) into the ocean on decadal timescales and to use this information to estimate the rates and pathways of ocean ventilation processes.

2. To use observed tracer fields to help evaluate global ocean model simulations and to estimate the oceanic uptake of other tracer gases, including carbon dioxide.

Accomplishments:

1. The team completed CFC measurements on the P16N CLIVAR Repeat Hydrographic/CO2/Tracer expeditions in the Pacific Ocean (from Tahiti to Kodiak in Feb-March, 2006) repeating sections occupied a decade earlier. A coarse spatial resolution SF6 section was made as part of the CLIVAR

repeat hydrography section, demonstrating the potential for including these measurements more routinely on future hydrographic sections. This program is part of a systematic and global re-occupation of select hydrographic sections to quantify changes in storage and transport of heat, fresh water, CO2, CFCs and related parameters. Changes in observed CFC fields are being used to estimate water mass formation rates and to evaluate the importance of physical vs. biological processes in observed subsurface dissolved oxygen changes. Combining SF6 and CFC-12 age data will allow improved estimates to be made of ideal ages and of the oceanic uptake of anthropogenic CO2 in this region. Preliminary results are presented in Bullister et al., (submitted).

2. The group has developed analytical methods for ultra-trace level measurements of SF6 in seawater. This anthropogenic compound is rapidly increasing in the atmosphere and has the potential to provide valuable information on the rate of uptake of gases in the ocean and for estimating water mass ventilation rates. These methods have been tested on visits to Hawaii Ocean Time-Series (HOT) monitoring site.

3. Project personnel have worked with carbon investigators to utilize CFCs to estimate the global oceanic uptake of anthropogenic carbon dioxide.

Project:
Surface Ocean ^{13}C / ^{12}C Measurements: a tracer of anthropogenic CO_2 uptake.

PI:
UW - Paul Quay

Other Personnel:
UW - Jennifer Maurer, Jackie Lee, Aileen Li, Cynthia Peacock

NOAA Primary Contact:
OGP

NOAA Goal:
2) Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond.

Task: III

Objective:

Measure the change in the ^{13}C / ^{12}C of dissolved inorganic carbon (DIC) in the surface ocean in order to determine the rate of oceanic uptake of anthropogenic CO_2 using, first, atmospheric CO_2 and $^{13}CO_2$ budgets and, second, ocean models of CO_2 and $^{13}CO_2$ uptake.

Accomplishments:

1. Sample Collection. The group's approach to obtain the greatest spatial and temporal coverage of the $\delta^{13}C$ change in the surface ocean is to use Volunteer Observing Ships (VOSs) for sample collection. Seawater samples for the analysis of the ^{13}C / ^{12}C of the DIC can be collected while underway using the ship's seawater intake line. These samples can be preserved for several years if the sample is poisoned and sealed against air. During the past year, they have collected $\delta^{13}C$-DIC samples on several ships including the *Polar Sea* Coast Guard ice breaker between Seattle and McMurdo, Antarctica, the *Polarstern* a German research vessel between Bremen, Germany and Cape Town, S. Africa, *Waikato Columbus* a container ship between Seattle and Auckland, NZ, (three times), the *Atlantic Meridional Transect* (AMT) cruises between England and S. Africa, the *FICARAM* cruises between Spain and Argentina, the *L.M. Gould* cruises between Punta Arenas and Antarctica, the *Astrolabe* cruises between Tasmania and Antarctica. They collected a total of ~1000 samples for $\delta^{13}C$ analysis on these cruises over the last year.

2. $\delta^{13}C$ Measurements. To date project staff have measured the $\delta^{13}C$-DIC on ~1300 samples collected on these VOSs. There are two notable outcomes of the $\delta^{13}C$-DIC samples measured to date. First, there has been the significant $\delta^{13}C$ decrease in the surface waters of the North Atlantic Ocean over the last decade at an average basin-wide rate of –0.17 ‰ per decade. The largest $\delta^{13}C$ decreases occur in the subtropics and the smallest decreases occur south of 60ºS. The deepest $\delta^{13}C$-DIC changes occur in the subarctic N. Atlantic, and the shallowest changes occur in the equatorial Atlantic, when compared to $\delta^{13}C$-DIC measurements from 1993 and 1981. Second, the group now has measured the $\delta^{13}C$ of

DIC on seven *Waikato Columbus* container ship cruises between 2004 and 2005. There is a remarkably consistent spatial (meridional) pattern, which shows little seasonality. These data are being used to estimate the export rate of organic carbon from the surface layer for the subtropical N. and S. Pacific Ocean.

3. GCM Simulations. The group has compared the observed δ^{13}C-DIC changes in the surface layer of the Atlantic Ocean with those predicted in Princeton's GCM (MOM). Although MOM substantially overestimates the surface δ^{13}C-DIC on average by 0.4 ‰ (by up to 1 ‰ south of 50°S), MOM predicts an anthropogenic surface ocean δ^{13}C-DIC decrease of –0.19 ‰ per decade that agrees well with our observations. The group thinks that MOM's overestimation is the result of overestimations of the deep water δ^{13}C-DIC, which in turn, is the result of overestimated δ^{13}C in the surface waters of the Southern Ocean.

4. Air-sea δ^{13}C disequilibrium. The δ^{13}C-DIC measurements for the surface waters of the Atlantic Ocean (~1000) yield a mean air-sea δ^{13}C disequilibrium of ~ 0.7 ‰. Interestingly, the observed depth integrated δ^{13}C change (-30 ‰ mols/m2/yr) was twice the air-sea $^{13}CO_2$ flux of –14 ‰ mols/m2/yr [i.e., gross gas exchange rate (20 mols/m2/yr) times the air-sea δ^{13}C disequilibrium of –0.7 ‰]. This implies that half the observed DIC13 inventory change is the result of processes other than air-sea exchange, i.e., northward advection of anthropogenic CO_2 laden surface waters.

Project:
PMEL-JISAO Atmospheric Chemistry - Aerosol Program.

PI:
NOAA - Tim Bates

Other Personnel:
UW - Dave Covert, Sarah Doherty, Drew Hamilton, James Johnson, Catherine Keil
NOAA - Patricia Quinn, Derek Coffman, K. Schulz

NOAA Primary Contact:
OGP/Health of the Atmosphere Program

NOAA Goals:
2) Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond.

3) Serve Society's Needs for Weather and Water Information.

Task: II

Description:

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 3 objectives:

Objectives:

1. To assess the regional climate and air quality impacts of atmospheric aerosol particles through measurements of their chemical and radiative properties.

2. To quantify the oceanic source of atmospheric sulfur.

3. To improve our capability to observe, understand, predict, and protect the quality of the atmosphere through national and international partnerships.

Accomplishments:

1. Aerosols directly affect climate and air quality through the scattering and absorption of incoming solar radiation. Measurements of aerosol properties during integrated field campaigns provides 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 allows for the linking of aerosol sources to climate and air quality impacts. The overall payoff is a reduction in the uncertainty associated with estimates of aerosol direct radiative forcing (climate) and aerosol haze plumes (air quality).

During the past year the PMEL-JISAO Atmospheric Chemistry – Aerosol Group analyzed data from the International Consortium for Atmospheric Research on Transport and Transformation (ICARTT) field experiment in the Gulf of Maine. Measurements in the marine boundary layer over the Gulf of Maine were used to study the evolution of aerosols as they were transported away from the continental source regions. As distance from the source region increased, the aerosol measured in the marine boundary layer became more acidic, had a lower particulate organic matter (POM) mass fraction, and the POM became more oxidized. The relative humidity dependence of light extinction reflected the change in aerosol composition being lower for the near-source aerosol and higher for the more processed aerosol. The aerosol light absorption to extinction ratio also changed with distance from the sources. The increase in the single scattering albedo with increasing distance from the continent was attributed to condensation of non-absorbing mass and mixing with other air masses.

The PMEL-JISAO Atmospheric Chemistry – Aerosol Group led a major study during the past year which focused on three regions downwind of major urban/population centers [(North Indian Ocean (NIO) during INDOEX, the Northwest Pacific Ocean (NWP) during ACE-Asia, and the Northwest Atlantic Ocean (NWA) during ICARTT)]. The study incorporated understanding gained from field observations of aerosol distributions and properties into calculations of perturbations in radiative fluxes due to these aerosols. The study evaluated the current state of observations and of two chemical transport models (STEM and MOZART). Measurements of burdens, extinction optical depth (AOD), and direct radiative effect of aerosols (DRE - change in radiative flux due to total aerosols) were used as measurement-model check points to assess uncertainties. *In situ* measured and remotely sensed aerosol properties for each region (mixing state, mass scattering efficiency, single scattering albedo, and angular scattering properties and their dependences on relative humidity) were used as input parameters to two radiative transfer models (GFDL and University of Michigan) to constrain estimates of aerosol radiative effects, with uncertainties in each step propagated through the analysis. Constraining the radiative transfer calculations by observational inputs increased the clear-sky, 24-hour averaged AOD (34±8%), top of atmosphere (TOA) DRE (32±12%), and TOA direct climate forcing of aerosols (DCF – change in radiative flux due to anthropogenic aerosols) (37±7%) relative to values obtained with "a priori" parameterizations of aerosol loadings and properties (GFDL RTM). The resulting constrained clear-sky TOA DCF was -3.3±0.47, -14±2.6, -6.4±2.1 W m-2 for the NIO, NWP, and NWA, respectively. With the use of constrained quantities (extensive and intensive parameters) the calculated uncertainty in DCF was 25% less than the "structural uncertainties" used in the IPCC-2001 global estimates of clear-sky aerosol climate forcing. Such comparisons with observations and resultant reductions in uncertainties are essential for improving and developing confidence in climate model calculations incorporating aerosol forcing.

2. DMS (dimethylsulfide) is biologically produced in the surface ocean and is the major natural source of sulfur to the atmosphere. In the atmosphere, DMS is transformed into sulfate aerosol particles, which scatter solar radiation back to space and alter the properties and lifetimes of clouds. The concentration of DMS in surface seawater and thus its flux to the atmosphere vary spatially and temporally as a result of the physical, biological and chemical properties of seawater.

A database of seawater DMS concentrations is essential for global chemical transport and climate models to accurately predict climate change scenarios. PMEL-JISAO scientists have developed and are currently maintaining 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. The database (http://saga.pmel.noaa.gov/dms/) now contains over 30,000 seawater DMS measurements.

DMS is also a major night-time sink of the nitrate radical downwind of continents. Simultaneous, *in situ* measurements of atmospheric dimethylsulfide (DMS) and nitrate radical (NO3) from the NOAA research vessel *Ronald H. Brown* off the New England Coast during the summer of 2002 show a clear anticorrelation between these compounds. Calculations suggest that between 65 and 90% of the DMS oxidation was due to NO3, depending on NO3 mixing ratios. The area over which DMS oxidation by NO3 is at least as strong as by OH can extend as far as 3000 km over the ocean surface.

3. PMEL/JISAO hosts 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. Dr. Sarah Doherty, JISAO Research Scientist, is the Executive Officer (http://www.igac.noaa.gov/). Funding for the core project office (NOAA, NSF, NASA) was renewed in 2006 for an additional 3 years (through June 2009). During the past year IGAC organized 4 international specialty workshops and initiated 2 new international research projects.

Project:
NOAA-VENTS Hydrothermal Research Group.

PIs:
UW - David A. Butterfield and Joseph A. Resing

Other Personnel:
UW - Kevin K. Roe, Geoffrey Lebon, Nathaniel J. Buck, Andrew Opatkiewicz, Marvin D. Lilley, John Baross, Eric Olson, Sheryl Bolton
NOAA - Stephen Hammond, Ed Baker, Robert Embley, William Lavelle, John Lupton, Sharon Walker

NOAA Goal:
1) Protect, Restore and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management.

NOAA Primary Contact:
PMEL

Task: II

Description:

Mid-ocean ridge hydrothermal systems have been studied intensively since the late 1970s, but there are still many geologic environments on the seafloor that have not been investigated, and recent discoveries remind us that there is still much that we have not seen on the seafloor. Microbial diversity in hydrothermal ecosystems is not well understood, but significant strides are being made. At present, the classic mid-ocean ridge (or divergent plate margin) environment is relatively well documented, but volcanic arcs (convergent plate margin) and off-axis environments are not.

Objectives:

1. To explore the ocean to locate and characterize neovolcanic areas, to study their associated hydrothermal ecosystems, and to assess their impact on the oceans.

2. To understand how submarine hydrothermal systems evolve over time and how they respond to local and regional tectonic or volcanic events.

3. To understand the link between the chemical environment and microbial communities in hydrothermal vents.

Accomplishments in Exploration:

1. i) Mid-Atlantic Ridge. K. Roe collected vent fluids from a newly discovered hydrothermal system near Jan Mayen Island north of Iceland in June, 2006. JISAO scientists played important roles in the exploration and sampling of an off-axis, non-volcanic hydrothermal system where seawater reacts with rocks exposed from the earth's mantle. Under NSF support, in 2003 a large number of samples were

obtained from the off-axis hot spring site near the Mid-Atlantic Ridge, the Lost City hydrothermal field. In July, 2005, the Lost City site was the target of a unique study (funded by NOAA Ocean Exploration) using a broadband connection to the *Hercules* ROV on the NOAA ship *Ron Brown* to allow scientists on shore to participate in research more than 4000 miles away (http://www.oceanexplorer.noaa.gov/explorations/05lostcity/welcome.html). This was the first expedition of its kind, where the scientific direction was located at the University of Washington by way of real-time video, audio and data links to the ship and the remotely operated vehicle working in the mid-Atlantic.

ii) Western Pacific. JISAO scientists (Butterfield, Resing, Lebon, Roe, and Buck) have been key participants in a multi-year project funded by NOAA Ocean Exploration to study volcanic arcs in the western Pacific, an area of the ocean that has been virtually unknown to science. The team has had at least one major water column and/or submersible expedition in the western Pacific since 2003.

March 2003, Mariana volcanic arc, high-resolution bathymetric mapping and water-column surveys of hydrothermal signals (shipboard participants: Resing and Lebon).

March/April 2004, Mariana volcanic arc, exploration and sampling of seafloor volcanic and hydrothermal features on six submarine volcanoes using *ROPOS* ROV (shipboard participants: Butterfield, Roe, Lebon). http://oceanexplorer.noaa.gov/explorations/04fire/

April/May 2004, Lau Back Arc Basin along the East Lau Spreading Center (ELSC), water column and mapping survey to locate hydrothermal activity, in an area with the most striking and pronounced gradients in fundamental geophysical properties of any similar length of spreading axis on the globe. (Shipboard: Resing).

April/May 2005, Tonga-Kermadec volcanic arc, exploration and sampling seafloor volcanic and hydrothermal features on six submarine volcanoes using the manned submersible *Pisces V* (shipboard: Butterfield and Roe) http://www.oceanexplorer.noaa.gov/explorations/05fire/welcome.html

November 2005, Mariana volcanic arc, return visit to NW Rota-1, NW Eifuku, and Daikoku volcanoes, exploration and sampling with Japanese ROV *Hyper-Dolphin* (shipboard: Roe)

April 2006, Mariana volcanic arc, exploration and sampling with ROV *Jason II* of 4 new volcanoes, and return to NW Eifuku, Daikoku, and actively erupting NW Rota-1 (shipboard: Butterfield, Resing, Buck).

Discoveries: First direct observation of lava eruption in the deep sea; overlapping hydrothermal and photosynthetic ecosystems; venting of liquid carbon dioxide; active molten sulphur lakes and flows; extreme acid alteration of volcanic rocks; volcanic gas emission in the upper ocean; novel and varied ecosystems.

2. Very little is known about how hydrothermal systems change when they are perturbed by geological events, and the prospect of recording data and collecting samples immediately after an event promises to yield new insight into the workings of hydrothermal systems. Volcanic events have been seen to give rise to microbial blooms, but the chemical conditions that lead to increased biomass in vent fluids have not been measured.

Accomplishments:

i) JISAO scientists (Butterfield, Roe) are 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 and the Nootka fault zone adjacent to Vancouver Island. Many different instruments are deployed at the same time in an inter-disciplinary approach to understand the links between physical, chemical, and biological processes in hydrothermal systems. This work, which is supported for 5 years (2001-2006) by the W. M. Keck Foundation, involves instrument development and experiments in the field. The JISAO component is focused on time-series samplers for chemistry and microbiology that have been deployed and recovered at approximately year-long intervals to create weekly time-series extending from 2003 through 2006. The 2005/06 sampling has shown a response in a hydrothermal vent that is strongly correlated with earthquakes in February 2005. Resing participated in a rapid response cruise that mobilized within one week of this seismic event and searched for enhanced hydrothermal signals in the water column.

ii) JISAO scientists have pioneered the use of acoustic/satellite systems to enable two-way data transmission between the seafloor and shore-based laboratories. The NeMO-Net project is the first to return data via acoustic modem and satellite from a deep-sea site. This system has been working since 1999, and data are displayed in near real-time on the internet (http://www.pmel.noaa.gov/vents/nemo/realtime/index.html). Two-way communication allows direct modification of a seafloor sensing and sampling instrument, so that the sampling rate can be changed, special routines initiated, or immediate return of sensor data requested. Sensors include temperature and pH, with the addition in 2004 of a redox (Eh) sensor. Recovered filters and water samples allow extensive chemical analysis to detect changes related to volcanic activity or long-term evolution. In 2005, the interactive sampler was recovered, leaving only a bottom pressure recorder to detect inflation or deflation of this active volcano. Time-series sampling will be resumed in August, 2006. This work is funded by the NOAA-PMEL VENTS program, with additional funding from NOAA West Coast and Polar Regions Undersea Research Center.

iii) An *in situ* technique capable of measuring Fe at the very low levels typically found in the surface ocean and the high levels found near shallow volcanoes along the Mariana arc. This project has been funded by the FOCI program. The test bed for this instrument is the Gulf of Alaska, where the instrument was deployed in August 2005, and recovered three weeks later. It is currently thought that iron might regulate plankton growth in the Gulf of Alaska, and thus is an important cog in the Alaskan fishery ecosystem. Real- time measurements will allow us to better understand these ecosystems. In addition, this instrument will allow us to monitor iron in plumes at submarine volcanoes.

3. Hydrothermal ecosystems are highly diverse and complex. Our understanding of hydrothermal ecology is in its infancy, and new data are required to advance knowledge in this area. We are in a period of explosive growth in knowledge of microbial ecology, and the work being done by JISAO scientists and their colleagues in microbiology is at the forefront of work in submarine microbial ecology.

Accomplishments:

A unique sampling tool (Hydrothermal Fluid and Particle Sampler or HFPS) has been developed by JISAO scientist D. Butterfield that can take clean water samples and concentrate microbes on filters from the same location, while recording the temperature of the vent fluid in order to control sample quality. This sampler has been used extensively since 1998 to collect an unprecedented suite of samples that are being analyzed for their chemical and microbial content. Results have been published in a series of papers that describe microbial populations and their relationship to changing chemical conditions. HFPS has been used in support of this research goal throughout the NE Pacific and in global exploration of volcanic arcs. Research activities to support this goal have been sponsored by the PMEL VENTS Program, Washington Sea Grant, NOAA West Coast and Polar Regions Undersea Research Center, the W.M. Keck Foundation, and the National Science Foundation. UW Oceanography graduate student, Andrew Opatkiewicz (co-supervised by J. Baross and D. Butterfield) is applying innovative methods of DNA analysis to samples collected from volcanic arcs and the Juan de Fuca ridge. Post-doctoral researcher Julie Huber (Marine Biological Laboratory at Woods Hole) is conducting state-of-the-art cloning and sequencing on samples collected by HFPS, and is a co-author on an important new paper using these samples [Mitchell L. Sogin, H.G. Morrison, Julie A. Huber, D.M. Welch, S.M. Huse, P.R. Neal, J.M. Arrieta and G.J. Herndl (2006): Microbial diversity in the deep sea and the under explored "rare biosphere". *Proceedings of National Academy of Sciences*, 133:32, 12115-12120.]

Project:
Enhancing Exploration Efficiency with Specific Application to Exploration of the Galapagos.

PI:
UW - Joseph Resing

NOAA Primary Contact:
Office of Ocean Exploration

Related NOAA Goal:
1) Protect, Restore and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management.

Task: II

Objectives:

The overall goal of the proposed research was to improve the utility of the DSL-120 side scan sonar instrument for exploration purposes. The team proposed to make ancillary data available in real-time during DSL-120 sonar surveys. Secondly, they proposed to make improvements to the auxiliary sensors that they were to place on the DSL-120 sonar system.

The funding was made available less than two months before the cruise, making full implementation of the proposed work not possible. However, for some of the work the team had advance contracts set up and were able to execute the work to improve the capabilities of using auxiliary sensors during DSL-120 sonar surveys.

Accomplishments:

1. Data handling software was rewritten and data handling was greatly simplified using the new software.

2. Software was successfully written to merge vehicle navigation with sensor data. This significant improvement allowed data to be viewed more readily in a geographical context.

3. Dedicated computers were purchased to log the data, thereby allowing them to be dedicated to the mi sion.

4. Data was written to allow real-time logging of the chemical analyzer data shipboard, and hardware improvements greatly increased data reliability.

Unmet goals:

1. Additional memory could not be added to the chemical analyzer. However, accomplishment #4 above, allowed shipboard logging, thus making this redundancy non-critical.

2. Real-time navigation was not merged with the chemical analyzer data stream. Although more steps were required to view the data, accomplishment #2 above allowed us to cut and paste navigation data from sensor files directly to chemical analyzer files.

3. The pump for the CTD sensors was not connected to DSL-120 power as proposed.

The balance of funding could be used to accomplish the unmet goals, however we will negotiate with Ocean Exploration to broaden the goals of the project to include general improvements in chemical sensing for towed instruments.

Project:
Exploring for Seafloor Eruption.

PI:
UW - Joseph Resing
NOAA - Edward Baker;

NOAA Primary Contact:
Office of Ocean Exploration

NOAA Goal:
1) Protect, Restore and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management.

Task: II

Description:

A field program was developed on short notice to respond to seismic activity about 34 km north-northeast of the Main Endeavour Vent Field on the Endeavour Segment of the Juan de Fuca ridge. This project received funding from NOAA's Ocean Exploration Program for 3 days of ship time to explore the area for effects on the water column from the suspected volcanic activity. The earthquakes were detected in real-time by an array of hydrophones monitored by the NOAA-PMEL VENTS Program. The intensity of the earthquake activity (to >60 earthquakes per hour) and pattern of activity indicated the seismic swarm was caused by a magmatic event with the possibility of a seafloor eruption. The location of such an eruption could be identified by conducting hydrographic surveys in the region of greatest seismic activity.

Objectives:

The decision to respond rapidly to this seismic event was based on the combined seismological and geological data indicating the likelihood that this event was a magmatic event with the possibility of a seafloor eruption and/or development of significant hydrothermal venting, including possible event plume(s). The objective of the resulting response cruise was to investigate the possibility that this presumed magmatic event expressed itself at the seafloor (new lava flows or active venting) and/or within the water column (significant 'event' plumes or altered venting intensity or fluid chemistry of known vent sites). The team was particularly interested in finding any large "event" plumes, that could be associated with either an extrusive or an intrusive magmatic event, and which not only retain a signature of the sub-seafloor geochemical/thermal conditions from the time of their formation, but also have been found to provide windows into the sub-seafloor biosphere by way of unusual extremophilic microorganisms.

Accomplishments:

A cruise was conducted aboard the University of Washington's R/V *Thomas G. Thompson*. The cruise was designed to conduct hydrographic, multibeam mapping, and photographic surveys of the effected area. Hydrographic operations were conducted using a SeaBird 911+ CTD with a 21 bottle rosette for water sampling. In addition to the standard hydrographic sensors, the package also measured light backscattering, relative Eh (redox), and particle size using a laser scatterometer (LISST). The team

conducted the following operations: a 13-km-long hydrographic tow on the eastern edge of the earthquake swarm, an 18-km-long tow-yo on the western edge of the swarm, and a 32-km-long tow that passed through the center of the earthquake swarm and continued south, paralleling and ~3 km west of the Endeavour segment axis. The group found no evidence of hydrothermal plumes on any of these tows. As a result they conducted three vertical casts west and south of the swarm cluster, hoping to find plumes that might have been advected out of the survey area before our arrival. No hydrothermal indications were found on these casts. Finally, they conducted four casts over the known vent sites along the crest of the Endeavour Ridge segment.

Discrete water samples were collected on each cast. A total of 1001 sub-samples were drawn from the seven casts, for both ship-board and shore-based analyses. While at sea, samples were collected for total dissolvable metals (107), dissolved metals (26), particulate matter composition including (34), particle morphology (18), pH (166), and Total CO_2 (51). (J. Resing, M. Stephens, G. Lebon, K. Kaiser, W. Thompson, D. Kadko). Water samples were collected for a suite of gases including $^4He/^3He$, methane, hydrogen, ammonia, and radon (E. Olson, M. Stephens, J.Haxel, M. Lilley, D. Kadko, J. Cowen, P. Lamm, and J. Lupton). Most of these were analyzed on shore. However, samples collected for methane and hydrogen were determined on board ship. A phylogenetic survey (J. Jacobs, S. Giovannoni) of microbial diversity was made with LH-PCR. Sub-samples (64) from the CTD tow-yo and vertical casts were taken for extremophile culturing and DNA sequencing (Julie Huber and John Baross).

In addition to hydrographic work, a multibeam sonar survey (B. Chadwick, M. Swartz, R. Waller, D. Glickson, and S. Ristau) of the area was accomplished, and a camera tow (Dan Fornari) 5-10 km north of the Endeavour hydrothermal vent fields along the ridge axis acquired over 1800 pictures in 7 hours on the bottom.

Results:

It appears unlikely that this February/March 2005 earthquake swarm resulted in an eruption of a lava flow or in the expulsion of large volumes of hydrothermal fluid into the water column. The *in situ* and ship-board physical and chemical data from the 3 long tow-yo casts and 7 vertical casts revealed no water column signal that can be clearly associated with the recent earthquake swarm, whether magmatic or tectonic. The areas of major tectonic activity showed little to no change in pH in the water column, indicating no major injections of magmatic CO_2. Initial calculation of methane to hydrogen ratios from Main Endeavour Field, Mothra, High Rise, or Salty Dawg is comparable to historic (2003) values from vent fluids. No evidence of any temperature or optical anomalies were seen in the near-bottom camera tow data (CTD or MAPR) overlying a weak axial magma chamber reflector, close to the region of the Feb/March swarm. Camera images of the seafloor revealed no fresh basalt; rather, the entire camera tow track showed moderately to heavily sediment-covered lavas. Finally, the team searched for evidence of new lava flows in the earthquake area by comparing high-resolution multibeam bathymetry data with the historic SeaBeam data. No bathymetric anomalies were detected.

COASTAL OCEANOGRAPHY

Project: Estuaries Research Program.

PI:
UW - Vasily Titov;
NOAA - Frank Gonzalez, Hal Mofjeld

Other Personnel:
UW - Paul Sorvik, Diego Arcas, Kevin McHugh, Chris Chamberlin, Angie J. Venturato, Donald W. Denbo, Mick Spillane, Nazila Merati, Elena Tolkova, Robert Weiss, Liujuan Tang, David Burwell, Arun Chawla, Christopher Moore, John Osborne, Jean C Newman;
NOAA - Eddie Bernard, Marie Eble, Hal Mofjeld, Mike Hopkins

NOAA Primary Contact:
PMEL

NOAA Goals:
3) Serve Society's Needs for Weather and Water Information.

4) Support the Nation's Commerce with Information for Safe, Efficient and Environmentally Sound Transportation.

Task: II

Description:

The Estuaries Research Program works with NOAA's National Center for Tsunami Research (NCTR) which is focused on improving the understanding of tsunami dynamics and the development of applications that will reduce the loss of life and property. Currently, the primary goals of NCTR are in direct support of a major expansion and acceleration of the NOAA Tsunami Program, in the wake of the 26 December, 2004, Indian Ocean tsunami disaster. Shortly after this catastrophic event, President Bush called for action "... to improve tsunami protection for the United States ... " by expanding U.S. capabilities in " ... emergency warning systems ...". In response, NCTR is accelerating research and development of the operational NOAA Tsunami Forecast System and expanding the geographical coverage of this forecast system to include the development of site-specific forecast models for 74 major U.S. population centers along Pacific, Caribbean, Atlantic and Gulf coasts.

In a broader context, NOAA bears national responsibility to address issues of public safety and economic cost associated with extreme weather and ocean hazards, including tsunamis, as reflected in the NOAA Mission Goals and Objectives outlined in *New Priorities for the 21st Century: NOAA's Strategic Plan* (http://www.spo.noaa.gov/). NOAA thus organized and leads the U.S. National Tsunami Hazard Mitigation Program (NTHMP), a Federal/State collaborative partnership of NOAA, USGS, FEMA, NSF and the Emergency Management and Geotechnical Agencies of U.S. coastal states. NCTR research and development is aimed at achieving tsunami-related goals of NOAA, including the specific objective to "Increase Lead Time and Accuracy for Weather and Water Forecasts." The PMEL/JISAO Estuaries Program works with NCTR to accomplish the following objectives:

Objectives:

1. To improve tsunami forecasts and warnings. The NCTR has developed and is implementing tsunami-forecasting tools for NOAA Tsunami Warning Centers (TWC). The methodology integrates two PMEL technologies – tsunami modeling and tsunameter measurements - to provide real-time forecasts for warning guidance. This ongoing R&D in Tsunami Forecasting is being expanded and accelerated.

2. To improve tsunami hazard assessment methodology. R&D conducted by the NCTR to improve our understanding of tsunami dynamics is exploited to improve development of community-specific inundation maps that describe the potential hazard. These maps are essential tools for State Emergency Management and Geotechnical officials responsible for hazard mitigation, education, and disaster planning and response. The Federal Emergency Management Agency (FEMA) requires a probabilistic version of inundation mapping technology for development of Federal Rate Insurance Maps (FIRMs), used for actuarial purposes. Such probabilistic products would, of course, be of great value for Emergency Management purposes, as well.

3. To help developing Tsunami Warning System for the Indian Ocean, working with the UNESCO-organized Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning System (ICG/IOTWS). As part of NOAA's international commitment, NCTR is involved in the capacity building efforts to establish tsunami community modeling activity for the Indian Ocean nations.

Accomplishments

1. In response to the NOAA's objectives, the NOAA Center for Tsunami Research (NCTR) was established at PMEL in October, 2005, to lead the tsunami research and development efforts for the improved Tsunami Warning System (TWS). An international team of 22 researchers was assembled from PMEL staff and outside talents (6 new researchers have been hired) to form a diverse group of experts (arguably, the best tsunami research group in the world) to tackle the challenges of TWS development. The Center is focused on developing forecast models for population centers along the U.S. coastlines, as well as on creating a more effective and efficient forecast system for the two U.S. warning centers. The first products of NCTR research are now being installed and tested by the Pacific Tsunami Warning Center in Honolulu and by the West Coast and Alaska Tsunami Warning Center in Fairbanks, AK.

Specifically, the NCTR has developed an implementation plan that is being used as a template for NOAA's "Research to Operation" strategy. The first components of the new model forecast system (known as SIFT – Short-term Inundation Forecast for Tsunamis) was installed at the warning centers. As a part of the Forecast System, NCTR has developed 8 high-resolution tsunami forecast models, which will be used by TWCs for accurate real-time tsunami hazard assessment for the respective communities. In addition, the plan calls for development of high-resolution tsunami forecast models for an additional 75 coastal communities in the U.S. by FY13.

2. Another objective accomplished this year included inundation mapping studies for 3 locations in Washington State. Results of the tsunami modeling studies for Tacoma, Long Beach and Ocean Shores, WA have been provided to the state.

The NCTR also completed a pilot project which enables inclusion of tsunami inundation boundaries on FEMA flood maps. The pilot study resulted in a complete probabilistic tsunami hazard assessment for Seaside, OR which will now serve as a template for similar studies for other coastal locations. The study has generated wide interest among state hazard managers (even though the final publication has not yet been published) and it will serve as a template for other U.S. tsunami hazard assessment studies and products, including the Nuclear Regulatory Commission's tsunami studies.

Also as a part of its FY06 objectives, the NCTR completed a tsunami hazard assessment of the proposed new site for the NOAA/Pacific Region Center facility (which includes the Pacific Tsunami

Warning Center) at Ford Island in Pearl Harbor, Oahu. One issue considered in evaluating the new site was the likelihood of tsunami inundation. To address this issue, the NCTR completed a detailed tsunami modeling study for the entire Oahu region. The study focused on the distant tsunami hazard because historical data do not indicate that there is a local tsunami hazard over the expected life of the NOAA building (60 years). The study was based on information on past distant tsunamis striking Pearl Harbor, as well as scenarios of tele-tsunamis generated along major subduction zones throughout the Pacific Region.

3. NCTR developed Tsunami Community Model (TCM) interface for Indian Ocean. USAID and NOAA funded NCTR to develop a principal design and working prototype for the Internet-enabled tsunami community model facility based on previous and current modeling efforts of the NCTR. The facility will provide access to NOAA's tsunami forecast model (MOST) for training, tsunami inundation mapping, and real-time tsunami forecast applications. NCTR presented the prototype tools to the UNESCO Working Group at the beginning of August as planned. The prototype development was completed in September.

Project:
Confidence Intervals for the Near Real-time Estimates of Tsunami Amplitudes.

PI:
UW - Donald B. Percival

NOAA Primary Contact:
PMEL

NOAA GOAL:
3) Serve Society's Need for Weather and Water Information.

Task: III

Description:

NOAA has deployed a series of DART buoys (primarily in the Pacific Ocean) for the purpose of directly measuring the start of a tsunami event, with the idea of using these measurements to predict the impact of a tsunami along U.S. coastal communities. These buoys are designed to measure tsunamis that are generated by earthquakes along known fault lines. While very large earthquakes will lead to an immediate evacuation order, there is a need to assess the impact of moderate-sized earthquakes and to judiciously issue evacuation orders, with the realization that false alarms carry a cost to society. Since it is not possible to predict the impact of a tsunami perfectly, it is necessary to use statistical methods for determining the possible impact of a tsunami. The most relevant statistical measure is a confidence interval that quantifies how large a tsunami event is likely to be when it reaches a coastal community.

Objectives:

The goal of this project is to produce confidence intervals (CIs) for the amplitudes of tsunamis along U.S. coastal communities. These CIs must not only be reliable, but also use methods that allow them to be computed as rapidly as possible. The CIs are to be based upon an assimilation of data collected in real-time by DART buoys and a database of amplitudes precomputed by computer models.

Accomplishments:

The team has developed an analytical procedure and computer code in the language R for fitting data from DART buoys to precomputed model wave heights using constrained nonlinear least squares. The procedure determines the tsunami amplitudes by allowing for a time stretching of the model heights, along with a possible shift in time. Confidence intervals for the unknown tsunami amplitudes were derived based upon standard expressions for an asymptotic covariance matrix in the statistical literature. Monte Carlo methods were used to verify that the asymptotic expressions are remarkably accurate when the errors are uncorrelated even for sample sizes as small as 20 points. The procedure is computationally much faster than the exhaustive grid search method currently used by NOAA. The procedure is also flexible in that it can handle data from multiple DART buoys with either coupled or uncoupled stretching and/or time shifts. The procedure has been tested on a suite of simulated tsunami-like events and also on a limited amount of actual tsunami data with encouraging results.

APPENDICES

APPENDIX 1

JISAO Senior Fellows

University of Washington

Aagaard, Knut, Professor, Oceanography, Principal Oceanographer, Applied Physics Lab (APL)
Battisti, David S., Professor, Atmospheric Sciences, Asst. Vice Provost and Director, Earth Initiative
Bretherton, Chris, Professor, Atmospheric Sciences and Applied Mathematics
Cannon, Glenn A., Affiliate Professor, Oceanography
Charlson, Robert J, Professor Emeritus, Atmospheric Sciences
Covert, David S., Research Professor, Atmospheric Sciences
Emerson, Steven R., Professor, Oceanography
Eriksen, Charles C., Professor, Oceanography
Fleagle, Robert G., Professor Emeritus, Atmospheric Sciences
Fu, Qiang, Associate Professor, Atmospheric Sciences
Gammon, Richard H., Professor, Oceanography and Chemistry
Hartmann, Dennis L, Professor and Chair, Atmospheric Sciences
Jaegle, Lyatt, (JISAO Fellow), Assistant Professor, Atmospheric Sciences
Jaffe, Dan, Professor, Interdisciplinary Arts & Sciences, Adjunct Professor, Atmospheric Sciences
Lettenmaier, Dennis P., Professor, Civil and Environmental Engineering
McDuff, Russell, Director and Professor, Oceanography
Miles, Edward L., Professor, School of Marine Affairs, Director, CIG
Murray, James W., Professor/Adjunct Professor of Chemistry, Oceanography
Quay, Paul D., Professor, Oceanography
Rhines, Peter B., Professor, Oceanography
Thompson, LuAnne, Associate Professor, Oceanography
Untersteiner, Norbert, Professor Emeritus, Atmospheric Sciences
Wallace, John M., Professor, Atmospheric Sciences, Director, JISAO

NOAA Pacific Marine Environmental Lab (PMEL)

Baker, Edward, Supervisory Oceanographer, Ocean Environment Research Division, Affiliate Associate Professor, Oceanography
Bates, Timothy S., Research Chemist, Ocean Climate Research Division, Affiliate Assistant Professor, Atmospheric Sciences
Bullister, John, (JISAO Fellow) Oceanographer, Ocean Climate Research Division, Affiliate Associate Professor, Oceanography
Cronin, Meghan, Oceanographer, Ocean Climate Research Division, Affiliate Associate Professor, Oceanography
Feely, Richard A., Supervisory Oceanographer, Ocean Climate Research Division, Affiliate Professor, Oceanography
Harrison, D.E., Oceanographer, Ocean Climate Research Division, Affiliate Professor, Oceanography and Atmospheric Sciences
Johnson, Gregory C., Oceanographer, Ocean Climate Research Division, Affiliate Associate Professor, Oceanography
Kessler, William S., Oceanographer, Ocean Climate Research Division, Affiliate Professor,

Oceanography
McPhaden, Michael J., Senior Research Scientist, Ocean Climate Research Division, Affiliate Professor, Oceanography
Mofjeld, Harold O., Oceanographer, Ocean Environment Research Division, Affiliate Professor, Oceanography
Moore, Dennis W., Leader, Ocean Climate Research Division, Affiliate Professor, Oceanography
Overland, James E., Division Leader, Coastal and Arctic Research Division, Affiliate Professor, Atmospheric Sciences
Quinn, Patricia K., Research Chemist, Ocean Climate Research Division
Sabine, Christopher, Oceanographer, Ocean Climate Research Division, Affiliate Assistant Professor, Oceanography
Stabeno, Phyllis, Supervisory Oceanographer, Ocean Climate Research Division

APPENDIX 2

Task 1 2005-2006 Visiting Scientists

July 1-30, 2005
Yolande Serra, Research Scientist, Department of Atmospheric Science, University of Arizona. "Horizontal and Vertical Structure of Synoptic Disturbances in the Tropical East Pacific."

August 9, 2005
Clara Deser, Senior Scientist, NCAR/Climate and Global Dynamics Division. "Simulation of ENSO in the Community Climate System Model Version 3."

August 19, 2005
Ileana Blade, Professor, University of Barcelona. "Impact of Global Coupling on Variability and Predictability Related to ENSO."

September 2, 2005
Ming Cai, Associate Professor, Department of Meteorology, Florida State University. "Dynamic Amplification of Polar Warming."

September 8, 2005
James Renwick, Research Scientist, National Institute of Water & Atmosphere Research, Wellington, New Zealand. "Southern Hemisphere Circulation, ENSO and SAM."

October 13, 2005
Grant Branstator, Research Scientist, National Center for Atmospheric Research (NCAR). "The Circumglobal Waveguide Pattern of Interannual Variability."

October 25, 2005
Gavin Schmidt, Research Scientist, NASA/GODDARD Institute for Space Sciences. "Consistent Multi-proxy Modeling of the 8.2 kyr Rapid Climate Change Event."

October 27, 2005
William Hsieh, Professor, Department of Earth & Ocean Sciences ,University of British Columbia, Canada. "Nonlinear Atmospheric Teleconnections: Their Properties."

November 1, 2004- October 31, 2007
Sandy Tudhope, Senior Lecturer, University of Edinburgh, Scotland. Visiting Scientist for three years.

November 3, 2005
Brian F. Farrell, Professor of Meteorology, Harvard University, Cambridge, MA. "The Mechanism of Jet Vacillation."

November 17, 2005
Reto Knutti, Postdoctoral Research Associate, National Center for Atmospheric Research, Boulder, CO. "Uncertainties in Projections of Future Global Temperature."

December 1, 2005
Michela Biasutti, Postdoctoral Research Associate, Lamont-Doherty Earth Observatory, Columbia University, NY. "Understanding African Climate Variability: Progress and Challenges."

December 15, 2005
Christian Reuten, Postdoctoral Research Associate, Earth and Ocean Sciences, University of British Columbia, Canada. "Similarity Violation of Upslope Flow Velocities in Atmosphere and Water Tank."

January 19, 2006
Panagiotis Athanasiadis, JISAO Postdoctoral Research Associate candidate, University of Reading, UK. "Teleconnections and Transient Eddies, Examining the PV Isentropic Balance."

February 17, 2006
Graham Feingold, Research Scientist, NOAA Earth System Research Laboratory, Chemical Sciences Division, Boulder, CO . "Aerosol-Cloud Interactions in Boundary Layer Clouds."

May 3, 2006
Matthieu Carre, JISAO Postdoctoral Research Associate candidate, University of Montpellier, France. "ENSO and Seasonality Changes During the Holocene: Mollusk Records in the Eastern Pacific."

May 5, 2006
Tapio Schneider, Assistant Professor, California Institute of Technology, Pasadena, CA. "Scaling Laws and Regime Transitions of the General Circulation of the Atmosphere."

May 19, 2006
Thomas Gorgues, JISAO Postdoctoral Research Associate candidate, University Pierre and Marie Curie, Paris, France. "Biogeochemical Impact of Tropical Instability Waves in Pacific Ocean."

APPENDIX 3

JISAO Employees Supported By Task II Projects

NAME	TITLE
A'Hearn, Patrick N.	Research Consultant
Alvarez-Flores, Carlos	Research Associate
Arcas, Diego Rodriguez	Research Scientist
Bahl, Kimberly Y.	Research Consultant
Belgrano, Andrea	Visiting Scientist
Bond, Nicholas A	Research Scientist
Buck, Nathaniel	Project Appointment
Burwell, David	Research Scientist
Butterfield, David A.	Research Scientist
Callahan, Jonathan S.	Research Scientist
Chamberlin, Christopher D	Research Scientist
Chawla, Arun	Research Scientist
Childs, Carl R	Research Scientist
Covert, Paul A.	Research Scientist
Denbo, Donald W.	Research Scientist
Dobbins, Elizabeth L	Research Scientist
Doherty, Sarah J.	Research Scientist
Dougherty, Daniel M	Research Consultant
Doyle, Miriam	Research Scientist
Evans, Mary B.	Research Scientist
Fey, Curran W.	Research Consultant
Gica, Edison	Research Scientist
Hamilton, Drew C.	Research Scientist
Hermann, Albert J	Research Scientist
Jenkins, Antonio	Research Scientist
Kachel, Nancy B	Research Scientist
Keil, Catherine A.	Research Scientist
Ladd, Carol A	Research Scientist
Lebon, Geoffrey T.	Research Scientist
Mazur, Michael M.	Research Associate
Mc Clurg, Dai C.	Research Scientist
Mchugh, Kevin Thomas	Research Scientist
Mcleod, Toby E.	Students Assistant
Menzia, Frederick	Research Scientist
Merati, Nazila	Research Scientist
Moon, Sookmi	Research Scientist
Moore, Christopher W.	Research Scientist
Mordy, Calvin W	Research Scientist
Mueter, Franz J.	Research Associate
Newman, Jean	Research Scientist
Noor, Sonya M.	Research Consultant

O'brien, Kevin	Research Scientist
Parada Veliz, Carolina E.	Research Associate
Perez, Renellys	Limited Term Appointment
Proctor, Peter D.	Research Scientist
Resing, Joseph A.	Research Scientist
Righi, Dylan D.	Research Scientist
Rodionov, Sergei	Research Scientist
Rodrigues, Regina	Research Associate
Roe, Kevin K	Research Scientist
Schulz, Kristen	Research Scientist
Sonnerup, Rolf E	Research Scientist
Sorvik, Paul	Research Scientist
Spillane, Michael C	Research Scientist
Steele, T	Students Assistant
Stratton, Linda	Research Scientist
Stumbaugh, Matt R.	Research Scientist
Sullivan, Margaret E.	Research Scientist
Tang, Liujuan	Research Scientist
Titov, Vassilii V	Research Scientist
Tolkova, Elena	Research Scientist
Venturato, Angie J.	Research Scientist
Wang, Muyin	Research Scientist
Weiss, Robert	Visiting Scientist
Wood, Kevin R.	Research Scientist
Zhang, Dongxiao	Research Scientist
Zhu, Hui Willa	Research Consultant
Zimmerman, David K.	Research Scientist

APPENDIX 4

Task III -- UW Principal Investigators and Projects

PI	Academic Unit	Title of Project	Funding
Bretherton	Atmos Sci	Climate Process Team on Low-Latitude Cloud Feedbacks on Climate Sensitivity	$124,565
Gallucci	Fisheries	Atka Mackerel Food Habit Project	$27,524
Fu	Atmos Sci	Analyzing Troposperic Temperature Trends Using the MSU Observations	$66,075
Gunderson	Fisheries	Biology of Skates	$32,442
Gunderson	Fisheries	Support Training of Graduate Student in Habitat Research for Development of Surveys in Untrawable Habitat	$42,282
Hickey	Oceanography	Collaborative: US-GLOBEC NEP Phase IIIa-CCS: Latitudinal variation of upwelling, retention, nutrient supply & freshwater effects in the CA Current System	$131,343
Hilborn	Fisheries	Graduate Student Stipend for Stock Assessment Training and Improvement	$57,440
Horne	Fisheries	Fisheries Acoustic Research	$142,485
Lindsay	APL	Monitoring Ice Thickness in the Western Arctic Ocean	$25,000
Mass	Atmos Sci	Regional Weather Analysis and Prediction	$95,000
Miller	Fisheries	Marine Biological Interactions in the North Pacific Fish Interactions Task	$315,410
Percival	APL	Confidence Intervals for the Near Real-Time Estimates of Tsunami Amplitudes	$35,000
Quay	Oceanography	Surface Ocean 13c/12c Measurements: tracer anthropogenic CO2 uptake	$146,359
Rhines	Oceanography	Oceanic Observations of Climate Change in the Arctic-Subpolar Zone	$339,800
Rigor	APL	Monitoring the Eurasian Basin in the Arctic Ocean	$205,000
Rigor	APL	Forecasting the Condition of Sea Ice on Weekly to Seasonal Time Scales	$80,083
Riser	Oceanography	The Argo Project: Global Observations for Understanding and Prediction of Climate Variability	$2,491,421
Kamenkovich	Atmos Sci	Simulating ARGO Measurements in an Ocean GCM	$60,000
Sarachik	Atmos Sci	CSES Evaluation Component Supplement	$40,000
Sarachik	Atmos Sci	The Center for Science in the Earth System	$1,420,000
Schweiger	APL	Correction of Systemic Errors in TOVS Radiances	$106,000
Stafford	APL	Analysis of Myticete Whale Calls from Beaufort and Chukchi Seas	$30,000
Stafford	APL	Analysis of Mysticete Whale Calls and Detection Distances in the Gulf of Alaska	$50,000

APPENDIX 5

JISAO Projects by Task

Task	PI	Award $	Project Title
I	Wallace	$200,100	JISAO Task I
II	Resing	$70,845	Enhancing Exploration Efficiency with Specific Application to Exploration of the Galapagos
II	Wallace	$74,223	Exploring for Seafloor Eruption
II	Wallace	$98,309	Fisheries Oceanography Coordinated Investigations Research Support
II	Wallace	$7,045	Marine Biological Interactions in the North Pacific Fish-Marine Mammal Interactions
II	Wallace	$1,703,872	Estuaries Research Program: Research Support
II	Wallace	$77,970	Marine Carbon Program
II	Wallace	$37,278	Early Life History of Fish Species in the Gulf of Alaska
II	Wallace	$67,400	Incorporating Climate into Population and Ecosystem Models
II	Wallace	$67,400	Use of Aggregate Indices in Studies of Climate and Ecosystems
II	Wallace	$14,058	A Modeling Study of Stellar Sea Lion-Walleye Pollock Interactions
II	Wallace	$83,477	Walleye Pollock Recruitment and Stock Structurein the Gulf of Alaska
II	Wallace	$27,194	Wind stress variation & interannual sea surface temperature anomolies in the Eastern equatorial Pacific
II	Wallace	$348,064	Observing Systems Research
II	Wallace	$375,000	Fisheries Research Cruise
II	Wallace	$447,660	Submarine Hydrothermal Venting Program
II	Wallace	$405,518	Atmospheric Chemistry Program
II	Wallace	$182,523	Chlorofluorocarbon Tracer Program
II	Wallace	$109,208	Tropical Atlantic and Pacific Ocean Circulation Program
II	Wallace	$766,594	Tropical Ocean Atmosphere Program
II	Wallace	$1,770,563	Fisheries-Oceanography Coordinated Investigations Research Support
II	Wallace	$363,648	VENTS NeMO 2004 Cruise
III	Bretherton	$124,565	Climate Process Team on Low-Latitude Cloud Feedbacks on Climate Sensitivity
III	Gallucci	$27,524	Atka Mackerel Food Habit Project

III	Fu	$66,075	Analyzing Troposperic Temperature Trends Using the MSU Observations
III	Gunderson	$32,442	Biology of Skates
III	Gunderson	$42,282	Support Training of Graduate Student in Habitat Research for Development of Surveys in Untrawable Habitat
III	Hickey	$131,343	Collaborative: US-GLOBEC NEP Phase IIIa-CCS: Latitudinal variation of upwelling, retention, nutrient supply & freshwater effects in the CA Current System
III	Hilborn	$57,440	Graduate Student Stipend for Stock Assessment Training and Improvement
III	Horne	$142,485	Fisheries Acoustic Research
III	Lindsay	$25,000	Monitoring Ice Thickness in the Western Arctic Ocean
III	Mass	$95,000	Regional Weather Analysis and Prediction
III	Miller	$315,410	Marine Biological Interactions in the North Pacific Fish Interactions Task
III	Percival	$35,000	Confidence Intervals for the Near Real-Time Estimates of Tsunami Amplitudes
III	Quay	$146,359	Surface Ocean 13c/12c Measurements: tracer anthropogenic CO2 uptake
III	Rhines	$339,800	Oceanic Observations of Climate Change in the Arctic-Subpolar Zone
III	Rigor	$205,000	Monitoring the Eurasian Basin in the Arctic Ocean
III	Rigor	$80,083	Forecasting the Condition of Sea Ice on Weekly to Seasonal Time Scales
III	Riser	$2,491,421	The Argo Project: Global Observations for Understanding and Prediction of Climate Variability
III	kamenkovich	$60,000	Simulating ARGO Measurements in an Ocean GCM
III	Sarachik	$40,000	CSES Evaluation Component Supplement
III	Sarachik	$1,420,000	The Center for Science in the Earth System
III	Schweiger	$106,000	Correction of Systemic Errors in TOVS Radiances
III	Stafford	$30,000	Analysis of Myticete Whale Calls from Beaufort and Chukchi Seas
III	Stafford	$50,000	Analysis of Mysticete Whale Calls and Detection Distances in the Gulf of Alaska

APPENDIX 6

Publication Count

	JOINT INST LEAD AUTHOR					NOAA LEAD AUTHOR				
	FY 01	FY 02	FY 03	FY 04	FY 05	FY 01	FY 02	FY 03	FY 04	FY 05
PEER REVIEWED	27	43	33	73	99	21	35	61	22	71
NON-PEER REVIEWED	23	30	15	9	19	16	10	21	0	3
TOTALS	50	73	48	82	118	37	45	82	22	74

	OTHER LEAD AUTHOR					
	FY 01	FY 02	FY 03	FY 04	FY 05	**TOTAL**
PEER REVIEWED	*	*	*	90	79	654
NON-PEER REVIEWED	*	*	*	6	5	157
TOTALS	*	*	*	96	84	811

* DATA NOT AVAILABLE

APPENDIX 7

Employee/Personnel count

Category	Number	B.S.	M.S.	Ph.D.
Research Scientist	67	7	14	46
Visiting Scientist	18	0	2	16
Postdoctoral Fellow**	7	0	0	7
Research Support Staff	5	5	0	0
Administrative	0	0	0	0
Total (> or = 50%)	**97**	**12**	**16**	**69**
Undergraduate Students	5			
Graduate Students	24	11	13	0
Employees receiving less than 50% NOAA support	87			
Located at Lab	23			
Obtained NOAA employment within the last year	2			

**3 additional Post-Docs received less than 50% support from JISAO

APPENDIX 8

Graduate Students

GRAD STUDENT NAME	ACADEMIC DEPARTMENT	DEGREE	DEGREE SUPERVISOR
A'MAR, Z TERESA	Quant Ecol Res Management	Ph.D.	Andre Punt
ANCELL, BRIAN C.	Atmospheric Sciences	Ph.D.	Cilff Mass
BURGOS, JULIAN	School of Aquatic & Fisheries Sci	Ph.D.	John Horne
CARSON, MARK L.	Oceanography	M.S.	Ed Harrison
CHIODI, ANDREW M.	Oceanography	Ph.D.	Ed Harrison
DOTSON, BRIGID M.	Atmospheric Sciences	M.S.	Cliff Mass
FAGAN, KATHRYN E.	Oceanography	Ph.D.	Richard Feely
HAYDEN-SPEAR, JESSICA	School of Aquatic & Fisheries Sci	M.S.	Donald Gunderson
HENCE, DEANNA	Atmospheric Sciences	M.S.	Robert Houze
JIANG, CHUAN LI	Oceanography	Ph.D.	Kathie Kelly
JOHANSON, CELESTE M.	Atmospheric Sciences	Ph.D.	Qiang Fu
KOURY, JESSICA LYNN	Atmospheric Sciences	M.S.	Robert Houze
LARSON, BENJAMIN I	Oceanography	Ph.D.	Marv Lilley
LITTELL, JEREMY	College of Forest Resources	Ph.D.	David Peterson
MATTA, MARY E.	School of Aquatic & Fisheries Sci	M.S.	Donald Gunderson
OPATKIEWICZ, ANDREW D.	Oceanography	M.S.	John Baross & David Butterfield
ORTIZ, IVONNE	School of Aquatic & Fisheries Sci	Ph.D.	Bob Francis
RAND, KIMBERLY	School of Aquatic & Fisheries Sci	M.S.	Vincent Gallucci
REN, LI	Oceanography	Ph.D.	Steve Riser
TRASK, RICHARD BLAKE	School of Marine Affairs	M.S.	Ed Miles
WILTON, DARREN	Civil & Environmental Engineering	Ph.D.	Rick Palmer
ZAHN, PATRICK H.	Atmospheric Sciences	M.S.	Cliff Mass
ZELINKA, MARK D.	Atmospheric Sciences	M.S.	Dennis Hartmann
ZHANG, XUEBIN	Oceanography	Ph.D.	Mike McPhaden

APPENDIX 9

Postdoctoral Fellows

ALVAREZ-FLORES, CARLOS**
BOLDT, JENNIFER L.
FUEGLISTALER, STEPHAN
GRIFFITHS, STEPHEN D.**
HASTINGS, MEREDITH
ITO, TAKAMITSU
MAZUR, MICHAEL M.
PARADA VELIZ, CAROLINA
RICE, ANDREW L.**
RODRIGUES, REGINA

**received less than 50% support from JISAO

APPENDIX 10

JISAO Awards and Honors

2006

Baker, Edward, Senior Fellow, received the NOAA Distinguished Career Award for enduring scientific leadership, innovative research into fundamental processes of
Earth-ocean interaction, and visionary expansion of NOAA research to a global scale.

Hermann, Albert, Research Scientist, received fifteen year service recognition.

Houze, Robert, Research Scientist, given the American Meteorological Society's Carl-Gustaf Rossby Research Medal, the highest honor that the Society bestows on an Atmospheric scientist.

McClurg, Dai, Research Scientist**,** received ten year service recognition.

Merati, Nazila, Research Scientist, received five year service recognition.

O'Brien, Kevin, Research Scientist, received fifteen year service recognition.

Noor, Sonya, Research Consultant, received five year service recognition.

Titov, Vasily, Research Scientist, chosen Team Member for the month of April at NOAA PMEL.

Untersteiner, Norbert, Senior Fellow, elected Fellow of AAAS.

Venturato, Angie, Research Scientist, received five year service recognition.

Zhu, Willa, Research Scientist, given the NOAATech 2006 Best Presentation award for her presentation of "Interactive Web Access to Historical Weather Data Archives."

2005

Aagaard, Knut, Senior Fellow, elected Fellow of the American Geophysical Union.

Baker, Edward, Senior Fellow, wrote a paper that was selected by the NOAA Office of Oceanic and Atmospheric Research (OAR) for one of the Outstanding Scientific Paper Awards for 2005: Baker, E.T., and C.R. German (2004), On the global distribution of hydrothermal vent fields, in Mid-Ocean Ridges: Hydrothermal Interactions Between the Lithosphere and Oceans, Geophys. Monogr. Ser., vol. 148, edited by C. R. German, J. Lin, and L.M. Parson, pp. 245-266, AGU, Washington, D. C.

Bond, Nicholas, Meteorologist, received fifteen year service recognition.

Callahan, Jonathan, Research Consultant, received ten year service recognition.

Johnson, Gregory and **William S. Kessler**, Senior Fellows, were presented with a NOAA OAR Outstanding Scientific Paper award for "Direct measurements of upper ocean currents and water properties across the tropical Pacific Ocean during the 1990s". B.M. Sloyan and K.E. McTaggart were co-authors.

Lettenmaier, Dennis P., Senior Fellow, elected Fellow of the American Geophysical Union.

Mantua, Nathan, Research Scientist, received ten year service recognition.

McPhaden, Michael J., Senior Fellow, elected fellow of the Oceanography Society.

McPhaden, Michael J., Senior Fellow, won the Science and Technology Web Award for El Niño Theme Page.

Miles, Edward, Senior Fellow and CIG Director, appointed Fellow of AAAS recognized for "... distinguished contributions to international governance of natural resources and environmental challenges, particularly in the domains of marine and fisheries policy and climate change."

Mofjeld, Harold, Senior Fellow, won the U.S. Department of Commerce Gold Medal Award for 2005 as a member of the NOAA/PMEL Tsunami team. The award was given "for research and development leading to the creation of a tsunami forecasting capability".

Quay, Paul, Senior Fellow, elected Fellow of the American Geophysical Union.

Resing, Joseph, Research Scientist, appointed to the Ridge 2000 Steering Committee.

Sarachik, Edward S., Research Scientist, elected Fellow of the American Geophysical Union.

Snover, Amy, Research Scientist, received five year service recognition.

Sullivan, Margaret, Research Scientist, received ten year service recognition.

Wallace, John M, Senior Fellow and JISAO Director, received the UW 2006 David B. Thorud Leadership Award which honors faculty members "who lead, serve, inspire and collaborate with broad-ranging impact that is beyond their regular responsibilities."

Wang, Muyin, Meteorologist, received five year service recognition.

Zimmerman, David, Research Engineer, received ten year service recognition.

APPENDIX 11

July 2005 - June 2006 - JISAO Publications (Reported as Published)

1. Aguilar-Islas, A.M., J.A. Resing, and K.W. Bruland. 2006. Catalytically enhanced spectrophotometric determination of manganese in seawater by flow-injection analysis with a commercially available resin for on-line preconcentration. *Limnology and Oceanography,* Methods, 4: pp. 105-113.

2. Alfaro, E., D. Pierce, A. C. Steinemann, and A. Gershunov. 2005. Relationships between the irrigation-pumping electrical loads and the local climate in Climate Division 9, Idaho. *Applied Meteorology* 44(12):1972-1978.

3. A'mar, Z.T., A.E. Punt, and M.W. Dorn. 2006. "The Management Strategy Evaluation approach and the Gulf of Alaska walleye pollock fishery". *Proceedings: American Statistical Association Joint Statistical meeting (with IBS, IMS, and SSC) 6 - 10 August 2006*, Seattle, Washington, USA.

4. A'mar, Z.T., A.E. Punt, and M.W. Dorn. 2006. "The Management Strategy Evaluation approach and the Gulf of Alaska walleye pollock fishery". *Proceedings: UW/ NWFSC/ AFSC Quantitative Fisheries Mini-workshop, 17 May 2006,* Seattle, Washington, USA.

5. A'mar, Z.T., A.E. Punt, and M.W. Dorn. 2006. "The Management Strategy Evaluation approach and the Gulf of Alaska walleye pollock fishery". *Proceedings: NOAA Fisheries National Stock Assessment Workshop 9, 18 - 20 April 2006*, San Francisco, California, USA.

6. A'mar, Z.T., A.E. Punt, and M.W. Dorn. 2006. "The Management Strategy Evaluation approach and the Gulf of Alaska walleye pollock fishery". *Proceedings: 14th Western Groundfish Conference, 30 January - 3 February 2006*, Newport, Oregon, USA.

7. A'mar, Z.T. and A.E. Punt. 2005. "Management Strategy Evaluations and the Gulf of Alaska walleye pollock fishery" *Proceedings: North Pacific Fishery Management Council, Groundfish Plan Team meeting, 21 September 2005*, Seattle, Washington, USA

8. Andreadis, K. M., and D. P. Lettenmaier. 2006. Trends in 20th century drought over the continental United States. *Geophysical Research Letters,* 33, L10403, doi:10.1029/2006GL025711.

9. Andreadis, K.M., E.A. Clark, A. W. Wood, A. F. Hamlet, and D. P. Lettenmaier. 2005.

20th century drought in the conterminous United States. *Journal of Hydrometeorology,* Vol. 6 (6):

pp. 985-1001.

10. Arrigo, K., H. Bange, R. Feely, N. Gruber, D. Hansell, G. Herndl, K. Lee, T. Johannessen, K. Johnson, A. Koertzinger, N. Metzl, T. Saino, and B. Stephens. 2006. Joint SOLAS-IMBER Ocean CarbonResearch: Implementation Plan. *IMBER Report No. 1/SOLAS Report, International Council for Science, Scientific Committee on Oceanic Research,* 45 pp.

11. Armstrong, J.L., J.L. Boldt, A.D. Cross, J.H. Moss, N.D. Davis, K.W. Myers, R.V. Walker, D.A. Beauchamp, and L.J. Haldorson. 2005. Distribution, size and interannual, seasonal and diel food habits of northern Gulf of Alaska juvenile pink salmon (Oncorhynchus gorbuscha). *Deep-Sea Research II,* 52: pp. 247-265.

12. Bailey, K.M., L. Ciannelli, N.A. Bond, A. Belgrano and N.C. Stenseth. 2005. Recruitment of walleye pollock in a physically and biologically complex ecosystem: A new perspective. *Progress in Oceanography, 67*: pp. 24–42.

13. Baker, E.T., J.A. Resing, S.L. Walker, F. Martinez, B. Taylor, and K.-I. Nakamura. 2006. Abundant hydrothermal venting along melt-rich and melt-free ridge segments in the Lau back-arc basin. *Geophysical Research Letters*, 33, L07308, doi: 10.1029/2005GL025283.

14. Bates, T.S., P.K. Quinn, D.J. Coffman, D.S. Covert, T.L. Miller, J.E. Johnson, G.R. Carmichael, S.A. Guazzotti, D.A. Sodeman, K.A. Prather, M. Rivera, L.M. Russell, and J.T. Merrill. 2003. Marine boundary layer dust and pollutant transport associated with the passage of a frontal system over eastern Asia. *Journal of Geophysical Research*, 109, D19, doi:10.1029/2003JD004094.

15. Bates, T.S., P.K. Quinn, D.J. Coffman, J.E. Johnson, and A. Middlebrook. 2005. The dominance of organic aerosols over the Gulf of Maine during NEAQS 2002. *Journal of Geophysical Research (Atmospheres)*, vol. 110, D18202, doi:10.1029/2005JD005797.

16. Bates, Timothy S., Patricia K. Quinn, Derek J. Coffman, James E. Johnson, Theresa L. Miller, David S. Covert, Alfred Wiedensohler, Stephan Leinert, Andreas Nowak, and Christian Neus. 2001. Regional Physical and Chemical Properties of the Marine Boundary Layer Aerosol across the Atlantic during Aerosols99: An overview. *Journal of Geophysical Research*, 106(D18) 20, 767-20, 782.

17. Bennett, A.F., B.S. Chua, D.E. Harrison and M.J.McPhaden. 2000. Generalized Inversion of Tropical Atmosphere-Ocean (TAO) data and a coupled model of the Tropical Pacific, II: the 1995-96 La Nina and 1997-98 El Nino. *Journal of Climate*, Vol. 13, No. 15: pp. 2770-2785.

18. Biasutti, M., D.S. Battisti, and E.S. Sarachik. 2005. Terrestrial influence on the annual cycle of the Atlantic ITCZ in an AGCM coupled to a slab ocean. *Journal of Climate*, 18: pp. 211-18.

19. Boldt, J.L. (Ed.). 2005. Ecosystem Considerations for 2006. *North Pacific Fishery Management Council Groundfish Plan Team Document, November 2005*. Dept. of Commerce, NMFS, NOAA, AFSC, 7600 Sand Point Way N.E., Seattle, WA 98115.

20. Bond, N.A., and J.E. Overland. 2005. The importance of episodic weather events to the ecosystem of the Bering Sea shelf. *Fisheries Oceanography,* 14(2): pp. 97–111.

21. Bond, N.A., B.F. Smull, M.T. Stoelinga, C.P. Woods, and A. Haase. 2005. The evolution of a cold front over quasi-2D terrain: Coordinated aircraft observations of 8-9 December 2001 from IMPROVE-2. *Journal of the Atmospheric Sciences*, October 2005, Vol.62, No. 10: pp. 3559-3579.

22. Buck, C. S.,W. M. Landing, J.A. Resing, G. T. Lebon. 2006. Aerosol Iron and Aluminum Solubility in the Northwest Pacific Ocean: Results from the 2002 IOC Cruise. *Geochemistry, Geophysics, Geosystems* 7, No. 4, doi:10.1029/2005GC000977.

23. Burkett, V.R., D.A. Wilcox, R. Stottlemyer, W. Barrow, D. Fagre, J. S. Baron, J. Price, J. L. Nielsen, C.D. Allen, D. L. Peterson, G. Ruggerone, and T. Doyle. 2005. Nonlinear dynamics in ecosystem response to climatic change: Case studies and policy implications. *Ecological Complexity* 2: pp.357–394.

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APPENDIX 12

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JOURNAL OF WATERWAY PORT COASTAL AND OCEAN ENGINEERING-ASCE 124 (4): 157-171 JUL-AUG 1998
Times Cited: 38

APPENDIX 13

JISAO Diversity and Outreach Initiative[1]

In response to NOAA recommendations, JISAO formed a diversity and outreach committee in fall 2005. The committee's first action was to identify short- and long-term goals and to develop the following mission statement:

> "JISAO is committed to building and fostering diversity in our scientific community. We believe that a diverse organization reflects and serves the multidisciplinary and global nature of our research. To create an inclusive community, JISAO collaborates with its partners at NOAA and the University of Washington on such outreach activities as internships, career fairs, summer camps and recruitment programs."

The committee identified four areas of focus: 1) to develop a recruitment and retention policy for staff; 2) to create a JISAO Summer Internship Program for undergraduate students from Minority Serving institutions; 3) to establish K-12 education activities with existing UW and NOAA programs; and, 4) to inform and educate the academic community, JISAO's partnering organizations, funding agencies and the public about JISAO's collaborative research and outreach services. Over the past year JISAO's diversity/outreach committee successfully met several of its goals in partnering with university and NOAA organizations as detailed below. There is now a web link featuring JISAO's participation in these outreach activities.

JISAO expanded participation in NOAA's annual science camp this year and participated in planning meetings and worked with camp coordinator Julie Hahn (of the Washington Sea Grant Program) on community outreach to successfully increase the diversity of this year's camp participants. JISAO funded seven needs-based scholarships enabling more students to participate in this important program. JISAO scientists Nick Bond, Sonya Noor, Mick Spillane and Curran Fey devoted time to NOAA science camp, as they have in past years.

The PMEL/JISAO science sessions were set up on the docks at Lake Washington where kids rotated through two activity stations. One group boarded a NOAA research vessel to collect water, plankton and mud samples for analysis. Niskin bottles were lowered off of the A-frame and water samples were tested for dissolved O2 using Indigo Carmine test ampoules. Kids learned about regional problems such as decreasing O2 levels in Washington's Hood Canal. The other group gathered around a TAO buoy (Tropical Atmosphere Ocean Project) where they learned about weather and atmospheric data collected from instruments mounted on the buoy (anemometer, rain gauge, radiometer, and sea surface temperature module). In a "real-time" experiment demonstrating heat transfer from the ocean to the atmosphere through evaporation, kids downloaded data from the buoy onto a laptop computer and ran a simple calculation of heat flux. Campers learned about El Niño and the relationship between global climate and local weather. They also learned how to deploy and recover a sonobuoy. More information is available at: www.jisao.washington.edu/JISAO_admin/Diversity/ScienceCamp.

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[1] JISAO projects are also involved in community outreach as it relates to public policy and education. The Climate Impacts Group is especially active and their work in this regard is described in the project summary section under the Climate theme.

Our efforts through contact with the Burien Science Center positively increased the diversity of students attending this year's Science Camp. In addition, JISAO funded seven needs-based scholarships enabling more kids to participate in this important science education activity. See the web link at www.jisao.washington.edu/JISAO_admin/Diversity/ScienceCamp for more information.

In further support of its mission to participate in K-12 education activities, JISAO formed a science team with one research scientist, a postdoc and three graduate students to present two afternoon science sessions to middle school kids participating in the UW GEAR UP Summer Institute Project. The Summer Institute brings middle school kids from around Washington State to the UW for a week-long college immersion experience. JISAO's team taught basic weather and climate science concepts and performed several experiments to demonstrate atmospheric pressure. The kids were taken to the rooftop of the Atmospheric Science building to observe weather instruments. They were also shown slides from a recent research expedition to Greenland where postdoc Meredith Hastings and graduate student Justin Wettstein drilled a 100 meter ice core.

Of high priority for the coming year is the design and implementation of a recruitment and retention policy to increase workforce diversity. This past spring committee members met with the director of the Center for Workforce Development (CWD) and outlined a strategy for creating a policy that will meet the institute's needs and goals in this area. Further work needs to be done and will involve consultation with CWD staff to formalize the policy. Additional effort will focus on communicating with JISAO faculty and staff about this effort to gain support and participation from our personnel.

Diversity and outreach work during the next year will concentrate on the JISAO Summer Internship Program and JISAO Recruitment and Retention Policy. In addition, the committee needs to further define its outreach goals and determine how best to continue making JISAO more visible within the greater UW and NOAA science communities. The diversity/outreach committee will continue its partnership with the GEAR UP Summer Institute Project and NOAA Science Camp. Further work needs to be done on the JISAO web site to make these on-going efforts visible and to inform our partner organizations and the public about JISAO's outreach/diversity activities and our scientific research.