Joint Institute for the Study of the Atmosphere and Ocean

JISAO

Annual Report

JISAO

Joint Institute for the Study of the Atmosphere and Ocean

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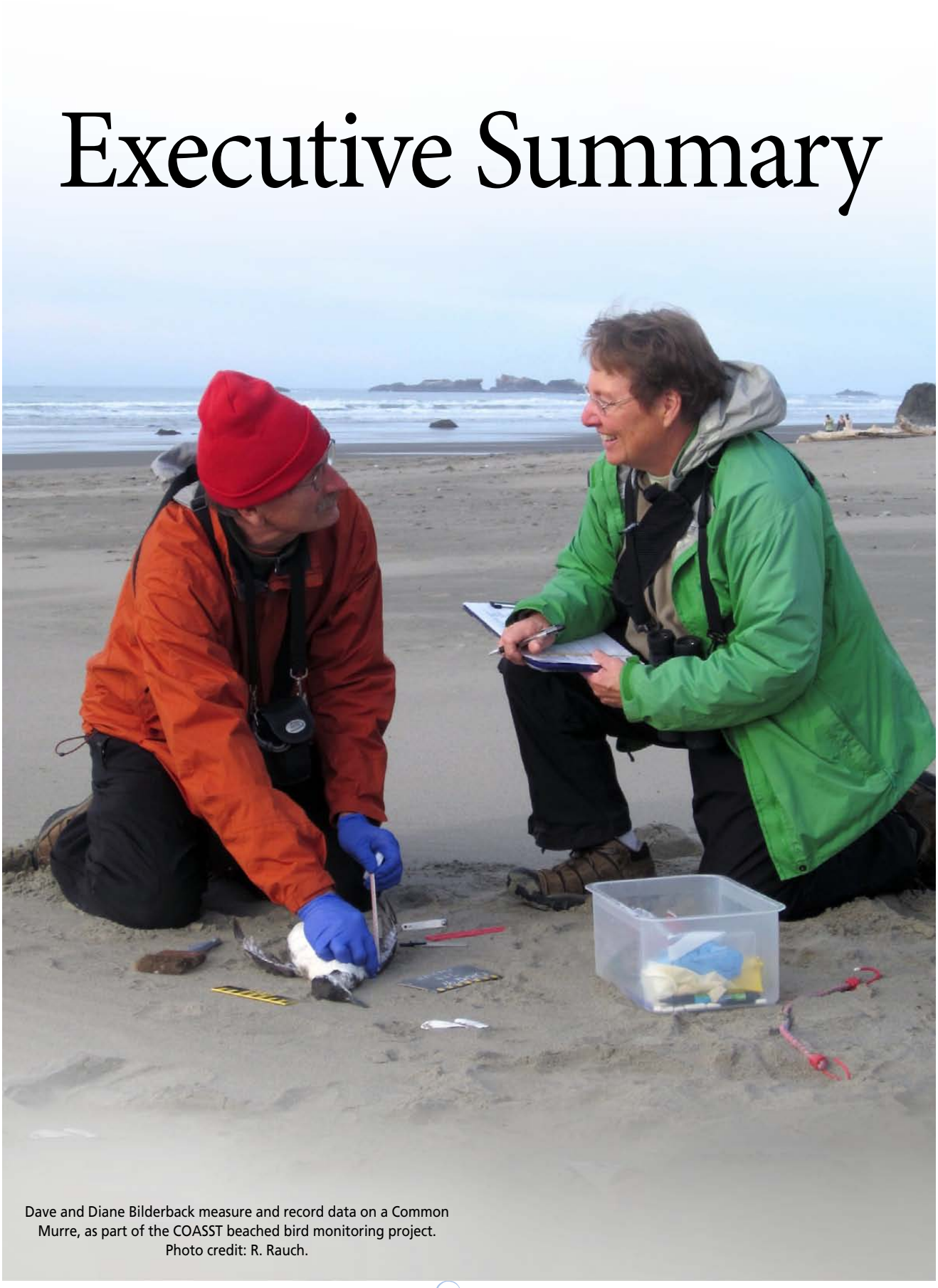
Graphic Design – Robyn Ricks, Washington Sea Grant

Contents

Executive Summary



Dave and Diane Bilderback measure and record data on a Common Murre, as part of the COASST beached bird monitoring project. Photo credit: R. Rauch.

Introduction

As a leader in atmospheric, ocean and fishery sciences, the Joint Institute for the Study of the Atmosphere and Ocean (*JISAO*) at the University of Washington (UW) promotes collaborative, interdisciplinary research between the National Oceanic and Atmospheric Administration (NOAA) and university scientists. These investigations fall within seven major themes:

1. Climate research and impacts
2. Environmental chemistry
3. Marine ecosystems
4. Ocean and coastal observations
5. Protection and restoration of marine resources
6. Seafloor processes
7. Tsunami observations and modeling

Designed to meet NOAA's goals and strategic plan, and encompass the wide range of interests of both UW and NOAA scientists, JISAO's unique collaborative structure provides easy access to exceptional resources. JISAO is located at the UW, one of the oldest public universities on the West Coast, long recognized as a preeminent institution of higher education as well as an outstanding research university. The partnership with JISAO allows NOAA access to the extensive intellectual talent and resources available at the UW in the natural and social sciences. The NOAA Pacific Marine Environmental Laboratory (PMEL) serves as JISAO's host laboratory and is located at the NOAA Western Regional Center, a short distance from the UW campus. JISAO scientists also work with NOAA's Alaska Fisheries Science Center (AKFSC) and the Northwest Fisheries Science Center (NWFSC).

This cutting-edge research is well recognized in the scientific community and covered often in the media. Media coverage is highlighted on JISAO's home page and archived online for easy reference. A few examples of awards and honors bestowed on JISAO personnel over the past year include: Dr. Thomas Ackerman, JISAO's Executive Director, was elected a Fellow of the American Geophysical Union; Dr. Amy Snover, Co-Director of JISAO's Climate Impacts Group, won the Editor's Award from the Bulletin of the American Meteorological Society (BAMS); Dr. Jeremy Littell won a USFS Excellence in Wilderness Stewardship Research Award for the paper he co-wrote titled "Climate Change and Wilderness Fire Regimes;" and Jake Zaragoza, JISAO summer intern in 2011, has been accepted into the SOARS research mentoring program at the National Center for Atmospheric Research (NCAR) in Boulder, CO (see Appendix 6 for a complete list).

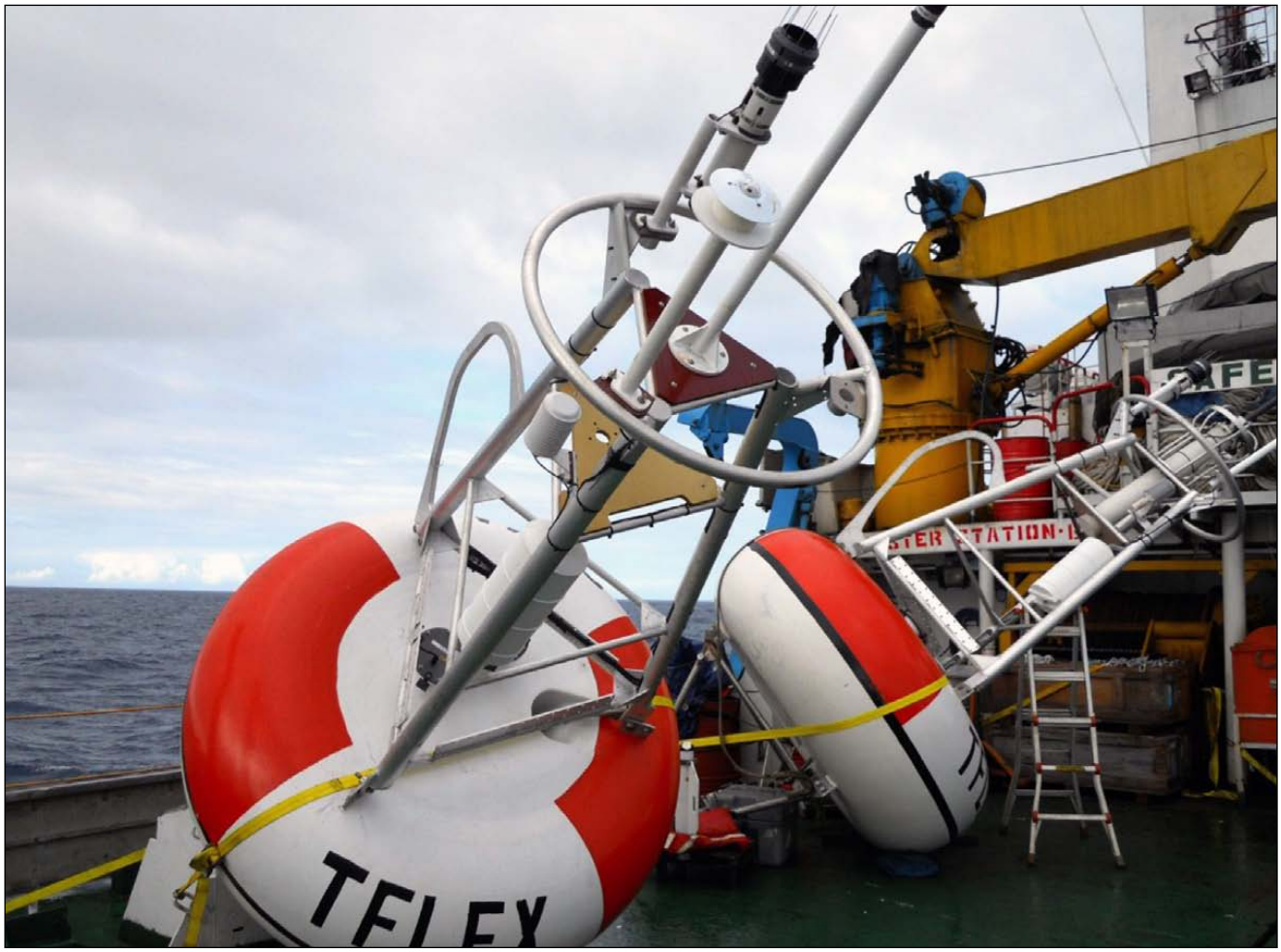
Organizationally, JISAO is a unit under the innovative UW College of the Environment whose mission includes the study of the earth's land, water and atmospheric systems; the development and application of engineering and technological advances; and the impact of policy and human dimensions on the environment and natural resources' management.

In addition to the Science Highlights below, this Executive Summary features a comprehensive look at JISAO's Education and Outreach (E&O) program and an update on financial and administrative information. Beyond this section are individual progress summaries for each project funded by the NOAA Cooperative Agreement in the past year, as well as appendices with additional information as requested by the NOAA Performance Reporting guidance.

Science Highlights

Climate Research & Impacts

The Tropical Atmosphere Ocean (TAO) project is engaged in studies of ocean-atmosphere interactions spanning intraseasonal to centennial time scales throughout the tropics. The scope of activities includes field work in support of climate observing systems for the ocean, data analysis and interpretation, dynamical modeling, and model diagnostics. TAO research features an extensive network of collaborators in the U.S. and abroad who work cooperatively to advance project goals. Highlights from the past year include development of a new deep ocean moored buoy system, continued expansion of the Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA) in the Indian Ocean and several publications in high impact journals.



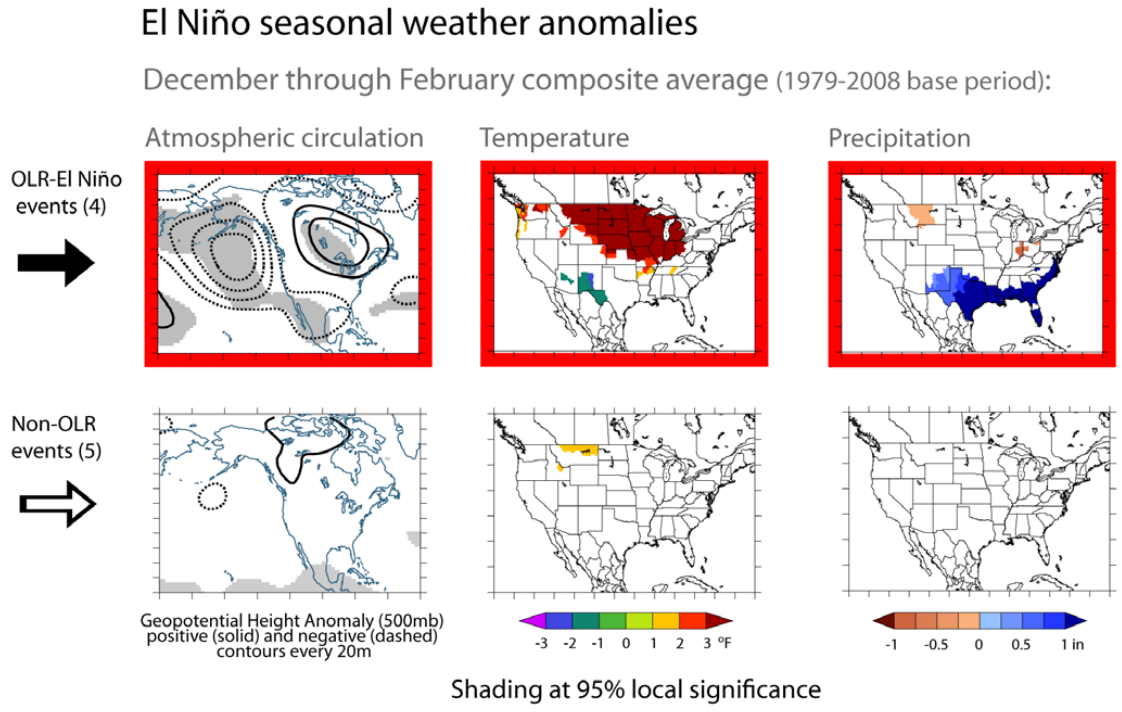
Prototype T-Flex mooring being readied for deployment. Compared to the legacy ATLAS system, T-Flex is comprised of more commercially available instruments, a more reliable sonic anemometer, and higher-bandwidth Iridium telemetry allowing transmission of hourly vs. daily data.

Ocean and Coastal Observations

UW and NOAA researchers with the Ocean Observing System group based at NOAA/PMEL have examined how different types of El Niño events impact US weather. Since 1979 when outgoing longwave radiation (OLR) observations became available, most of the useful US seasonal weather relationship to the impact of El Niño events is associated with the few events identified by the Chiodi and Harrison (2010) OLR El Niño index. These events produce composite seasonal, regional weather anomalies that are 95% statistically significant and robust, in the sense that they are associated with almost all events. This work also shows that there are very few statistically significant seasonal weather anomalies, even at the 80% confidence level, associated with the non-OLR El Niño events. A major enhancement of statistical seasonal forecasting skill over the contiguous US states appears possible by incorporating these results. It is essential to recognize that not all events commonly labeled as El Niño events lead to statistically useful US seasonal forecast skill. This work shows that continuing analysis of historical climate records can produce valuable insights.

Environmental Chemistry

The scientists in the JISAO, NOAA PMEL environmental chemistry group participated in several field experiments aimed at the NOAA goal to understand climate variability and change. The objective of their field experiment work was to measure the physics, chemistry and optical properties of aerosol particles. This was done in collaboration with larger scale observational efforts by US and international research teams in regions around the globe from the Arctic to the tropics, and from the oceans to the continents that have been identified as critical to our understanding of anthropogenic effects on radiation balance and climate. The focus was on major sources of natural and man-made aerosol types that contribute a significant particulate mass or number to the global burden.



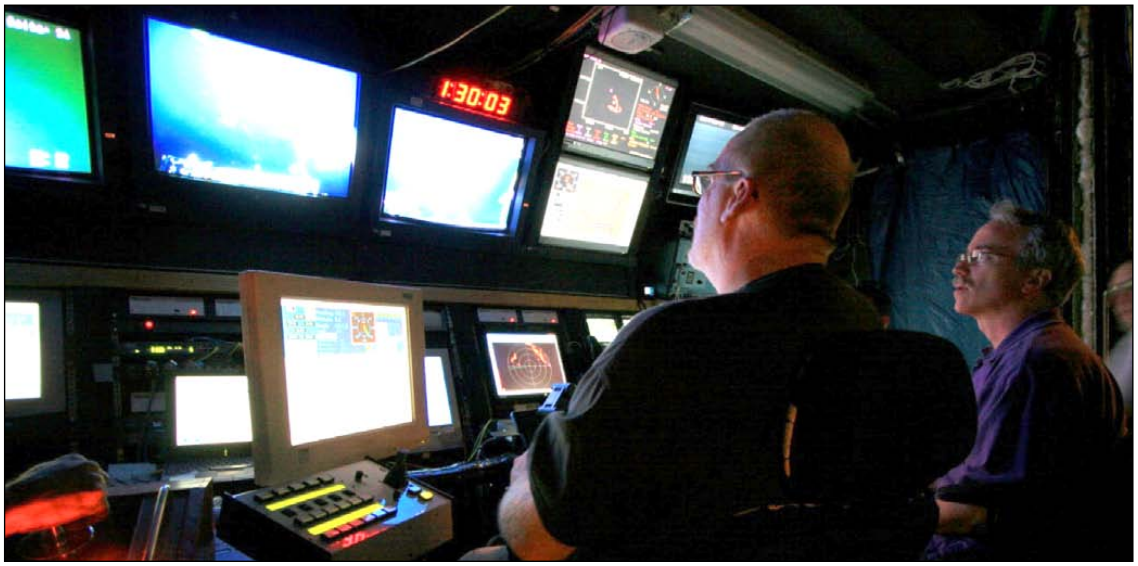
Most of the useful US seasonal weather impact of El Nino is associated with the events identified by the Chiodi and Harrison (2010) OLR-El Nino index

Seafloor Processes

The NOAA/PMEL Hydrothermal Vents research group discovers unique deep-sea habitats and studies biogeochemical processes of global importance that address the NOAA goals of healthy oceans, technology development, and ocean stewardship. The Vents Program discovery of two submarine volcanoes with persistent ongoing eruptions has afforded a spectacular first look at deep ocean volcanic processes, including the first high-definition video of a deep eruption and the first direct sampling of fluids and rocks from an eruptive vent. In 2011, the researchers published a paper describing the eruption at West Mata volcano, the first eruption of the unusual boninite lava ever observed, and another paper on the chemical processes associated with magmatic gases escaping from erupting lava at NW Rota. Erupting and hydrothermally active volcanoes emit large quantities of acid and carbon dioxide, creating conditions of local acidification and adding metals and nutrients to the overlying ocean. Hydrothermal input from shallow submarine volcanoes of the western Pacific arcs has a potential impact on primary productivity in nutrient-starved tropical waters. Vents researchers are developing and deploying new technology on undersea cabled observatories on the Juan de Fuca ridge. This group discovered a large volcanic eruption in 2011 at Axial Seamount and recorded data at the site. Vents research is enhancing our understanding of the complex links between volcanic activity, hydrothermal chemistry, and microbial ecology. Researchers have extracted novel natural products from biological materials collected during Vents cruises and found significant inhibitory activity against the pathogens *Staphylococcus Aureous* and *E. Coli*., highlighting the high potential of hydrothermal research and the importance of Vents within the NOAA use-inspired research portfolio.

Tsunami Observations and Modeling

The fallout from the 2011 Tohoku tsunami continued into 2012, providing multiple opportunities to learn from and improve our response to this type of event. Following the disaster, Yong Wei, a JISAO tsunami scientist, traveled to Japan to join one of the international tsunami survey teams that collected scientific data from the event. The team gathered information about time of wave arrival, maximum height, inland penetration, and sediment deposits. These data were used by Yong Wei and other JISAO tsunami scientists to reconstruct tsunami inundation along the Japanese coast using forecast models similar to those available for US coastal communities. This emphasized the benefits of having such models available for the Japanese coast for future tsunamis. JISAO researchers also emphasized the need for faster assessment of tsunami magnitudes in the near-field, which triggered a JISAO/NOAA effort to build a new generation of tsunami sensors (DARTs). These new sensors will allow for deployment closer to the source and enable the warning centers to generate a rapid forecast for the near-field.



ROV pilot Jim Varnum (left, fore) and David Butterfield, looking at the ROV cameras and other data and discussing the next move during a NeMO cruise.

Marine Ecosystems

Methods and models for assessment of fish stocks and management strategies are being explored by Professor Andre Punt of the UW, and his collaborators and students. The research focuses on the population dynamics, assessment and management of West Coast groundfish. Among other specific topics, this work reveals ways to reduce by-catch and maximize profit in multi-species systems that include the effects of spatial dynamics. A series of regular workshops are held to increase collaboration among NOAA scientists and UW faculty and students working on west coast groundfish issues, and to provide peer-review for ongoing research projects. These workshops are broadcast over the web to ensure broad participation. The work on management strategies features formal accounting for the impacts of uncertainty in the age-structure of fish populations into harvest control rules for groundfish fisheries in Alaskan waters.

A major study of the marine ecosystem of the eastern Bering Sea is underway under the auspices of the National Science Foundation's Bering Ecosystem Study (BEST) Program and the North Pacific Research Board's Bering Sea Integrated Ecosystem Research Program (BSIERP). This effort includes a local and traditional knowledge component. As part of this component, JISAO scientist Nicholas Bond collaborated with other scientists, and notably, George Noongwook, an elder and leading hunter from the community of Savoonga, Alaska, in a project examining the linkages between physical conditions and walrus hunting success from St. Lawrence Island. Previous interviews with local hunters identified the conditions conducive to successful hunts; the present project yielded the quantitative result that ice concentrations and wind speeds and directions account for about 30% of the variance in the day-to-day variability in number of animals harvested. This work has been summarized in a paper that has been submitted to Deep-Sea Research II as part of a special issue from the BEST-BSIERP programs. It will be used to help establish how climate change is liable to impact future hunting of this primary source of subsistence for the St. Lawrence native community.

JISAO Scientist Scott McKeever removes sensitive instruments from the top of the Peggy mooring at site M2 before the mooring can be brought aboard the Oscar Dyson.

Protection and Restorations of Marine Resources

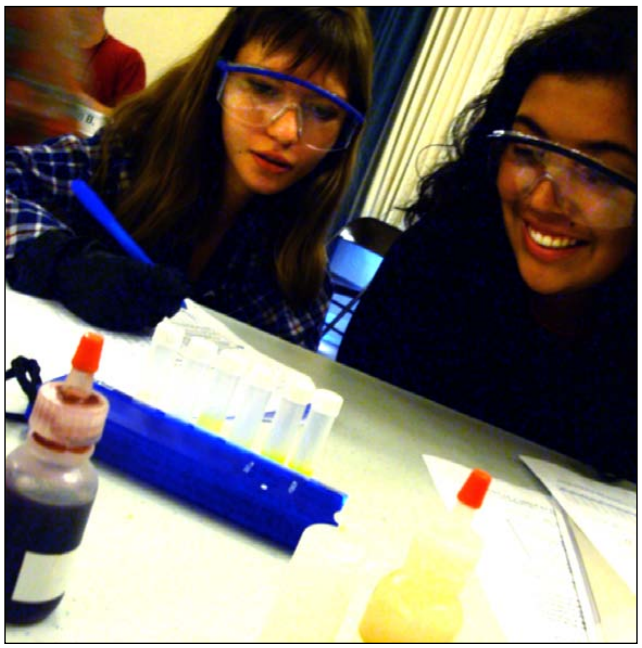
Numerous oil spills routinely occur around the world every year. Most are relatively small, but occasionally there is a catastrophic oil spill, such as the Deep Water Horizon oil spill in the Gulf of Mexico in 2011. NOAA's Emergency Response Division, Office of Response and Restoration (OR&R), located in Seattle, is the primary NOAA agency responsible for predicting the fate and monitoring hazardous spills that occur in coastal marine and estuarine waters of the United States. Dr. Russell Herwig worked with OR&R during the past year to provide expertise in the area of oil spill biodegradation and microbiology. His work provided biodegradation parameters for NOAA models that describe the trajectory and fate of crude oil spills.

Life-cycle assessment (LCA) provides a means for estimating all of the environmental impacts associated with a product or service. Under the auspices of the project Life Cycle Assessments for the Improvement of Aquaculture Systems, Joyce Cooper and other scientists at the UW and at NOAA's Northwest Fisheries Science Center have developed the Montlake Process. The Montlake Process is a modification of current salmon processing intended to reduce the life cycle contribution to climate change through (a) more efficient thermal design, (b) the ability to use fish oil to reduce diesel or electrical inputs, and (c) the use of a waste product in the place of virgin resources. Toward the overarching NOAA goal of demonstrating the value of LCA in informing technology development and dissemination decision-making, data, facility and equipment drawings, and related documents provided by NOAA were compiled to conform to LCA data formats and data were developed to fill gaps, including missing equipment specifications and distances to landings and to the processing plant (for the representation of feedstock transport).

The Coastal Observation and Seabird Survey Team (COASST), is a scientifically rigorous citizen science program which focuses on beach-cast carcasses of marine birds as environmental indicators. This year, over 700 participants from 70 coastal communities (northern California to the Chukchi Sea in Alaska) recorded data on 3,000 beached birds, including incidence of by catch and oiling; changes in mortality patterns of species managed by NOAA's Office of Protected Resources in partnership with the U.S. Fish and Wildlife Service.

Supporting NOAA's Mission of Science Service and Stewardship

The *NOAA Scholar Funding* project supports one student with a disability interested in pursuing post-secondary education and a career in one of the areas of focus of NOAA through three years of the DO-IT (Disabilities, Opportunities, Internetworking, and Technology) Scholars Program. The DO-IT Scholars Program works with high school students with disabilities who have the potential to pursue college studies and careers and develop leadership skills, but face significant challenges because of their disabilities. The 2011 NOAA Scholar was selected in April 2011 and engaged in the first year of Scholar activities including a 10-day residential Phase I Summer Study at the University of Washington. This experience helped the student gain skills in using the Internet, college preparation, career planning, self-determination, and leadership. The Scholar continues to participate in year-round mentoring and networking activities.



Education and Outreach

"My experience as a JISAO intern has played an instrumental role in the development of my academic and professional career. It introduced me to the wonders of scientific research and convinced me to pursue research as a career. The honor associated with conducting research at NOAA through JISAO has led to many significant opportunities for me, such as graduate school."

~Alyssa De La Rosa, 2009 JISAO intern

JISAO's Education and Outreach (E&O) Program has continued to make important contributions to UW College of the Environment *(CoEnv)* and to NOAA's goals of advancing environmental literacy at all levels of society while mentoring the next generation of scientists who reflect the diversity of our nation and are skilled in science and technology. Of the many projects supported by the E&O Program, perhaps most noteworthy is the success of the JISAO Research Experience for Undergrads (REU) Program. The REU program began in 2008 with one student, expanded to four students in summer 2009, seven students in 2010, and six interns from universities across the U.S. and Puerto Rico in 2011. Five of JISAO's former interns are currently in graduate school at Pennsylvania State University, Stanford University, University of California, Davis, and University of Washington (2). In past years JISAO's REU has received funding support from NOAA's Office of Oceanic and Atmospheric Research (OAR) and the NOAA Center for Atmospheric Research (NCAS) at Howard University.

JISAO's presence in the local and national environmental science communities continues to expand. The E&O Program continues to be involved in many successful events and projects as outlined below:

- **Conferences and Career Fairs**
  - Pacific Northwest Climate Science Conference: Organized by JISAO's Climate Impacts Group, the second annual conference consisted of a combination of discussions and poster sessions about the latest PNW climate change and climate impacts research.
  - SACNAS (Society for the Advancement of Chicanos and Native Americans in Science) National Conference in San Jose, CA: Daniel Hernandez, a graduate student in UW Aquatic and Fishery Sciences (and 2009 JISAO summer intern) represented the College of the Environment and distributed applications for JISAO's REU internship program. Seattle will be hosting the SACNAS National Conference in October 2012.
  - Sustainability Summit: JISAO co-sponsored the October 2011 Sustainability Summit at the University of Washington. The event was designed to celebrate the University's leadership and accomplishments in environmental stewardship and sustainability.

- **K-12 Events**
  - ecoFOCI Outreach: Nancy Kachel (JISAO) and Dave Kachel (NOAA) presented ecoFOCI educational materials to middle schoolers at Jane Addams K-8 school as part of the schools 2nd Annual Science Day in November 2011.
  - GirlFest: Nick Bond and Karin Bumbaco had a booth at the Girl Scouts of Western Washington's GirlFest at Century Link Event Center in September 2011. The event celebrated "everything cool about being a girl" so Nick and Karin brought a science experiment encouraging the girls to think about the best places in Washington to place rain gauges.
  - HMS *Plover* High School Project: Kevin Wood is mentoring students who are evaluating air temperature and weather data collected in the 1850s by the British Navy's HMS *Plover*. The research will show how air temperature observations recorded on the *Plover* compare to present day.
  - NOAA Science Camp: JISAO scientists led sessions and participated in the 2011 NOAA Science Camp at the Pacific Marine Environmental Laboratory. This was the sixth year that JISAO funded NOAA Science Camp scholarships for low income and underrepresented students. JISAO is currently working with Science Camp coordinators to establish a second partnership with a community program working with low-income teens in order to provide an opportunity for students to attend who would not normally be able to do so.
  - Orca Bowl: JISAO scientists Fred Menzia and Scott McKeever were judges at the 2012 Orca Bowl presented by Washington Sea Grant. Teams of high school students from around Washington State came to the UW campus to challenge their knowledge of the world's oceans. Top prizes included UW Oceanography scholarships and shipboard science experiences.
  - Yesler Terrace Youth Tutoring Program: JISAO researcher Megan Melamed participated in a panel discussion for a diverse group of middle and high school students. The professionals talked with students about education, goals and careers.

- **Morehouse College Collaboration**
  - JISAO director, Tom Ackerman, plans continued discussions on ways the institute can collaborate with Morehouse to offer more opportunities for student internships in the future.
  - Rahmelle Thompson, Director of the John Hopps Research Scholars Program at Morehouse has talked with JISAO about the possibility of bringing a group of students to UW to tour the campus and explore internship possibilities.

- **NOAA Center for Atmospheric Sciences (NCAS) and Howard University Partnerships**
  - NCAS and JISAO are currently exploring ways to reestablish summer internship collaboration.
  - NCAS and JISAO are planning a more formalized faculty exchange program between the two institutions.
  - JISAO scientist, Dr. Kevin Wood, recently visited NCAS to discuss a possible collaboration involving Howard students in working with weather data from logbooks collected on historical cruises in Alaskan and Arctic waters. These log books are in the National Archives in Washington, DC. The data will be used to better diagnose high-latitude historical climate.

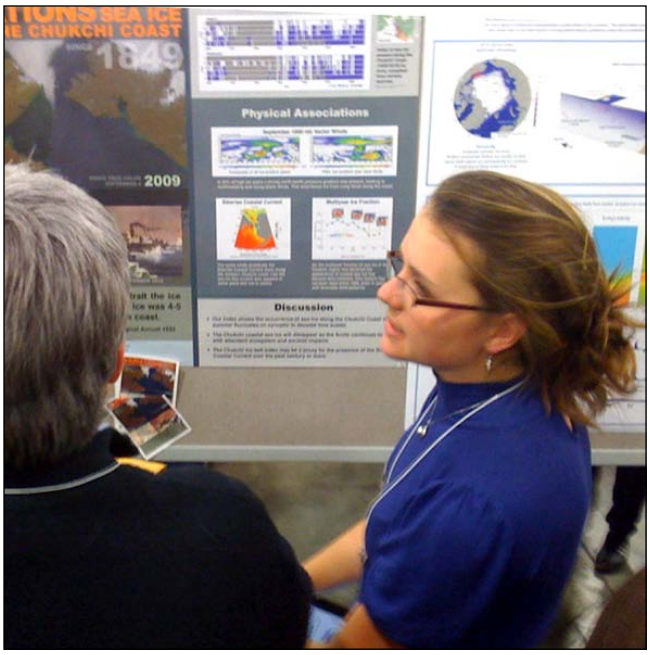
- **Outreach Communication**
  - A new JISAO website debuted in June 2011. It was designed to look similar to other sites within the UW's College of the Environment and it provides a more effective means to communicate institute activities to constituents with its improved design, user-friendly format and organization.
  - *The S Factor* workshop: An episode of JISAO's video program *Science in 180* was selected to be shown during *The S Factor* workshop at the AGU conference in San Francisco. The workshop focused on how to make a successful science video and featured three Hollywood professionals who critiqued ten videos chosen from researchers across the country. JISAO's video about Joe Resing's undersea volcano research was chosen from a pool of 42 submissions. Resing and video creator Jed Thompson both attended the workshop.

- **Pacific Science Center (PSC) Partnership**
  - Paws-On Science Husky Weekend: Seattle families visited Pacific Science Center (PSC) for a weekend of activities, games, and demonstrations designed to show the world-class research and achievements of scientists at the UW. JISAO scientists led activities showing their work on climate change, tsunamis, and underwater volcanoes.
  - Polar Science Weekend: Guests of all ages visited PSC to enjoy four days of demonstrations, activities, and exhibits and to meet and talk with polar researchers. JISAO's Calvin Mordy, Lisa Guy, and Scott McKeever displayed a satellite drifter and demonstrated how it was deployed in the open ocean.
  - Science Communication Fellows: JISAO scientists continue to undergo training as official Science Communication Fellows as part of PSC's Portal to the Public initiative. Science Communication Fellows are professionals who have been certified by PSC as current science ambassadors and excellent communicators.
    - Camille Lique, a JISAO Postdoctoral Associate, participated in a series of professional development workshops and created a hands-on educational activity related to her work in oceanography.

- **Public Outreach**
  - Art Institute of Seattle: Karin Bumbaco was invited to the Art Institute to give a talk called "What is 'normal' climate? Washington climate and climate change."
  - Bering Sea Integrated Ecosystem Research Program (BSIERP) worked with Alaska natives to include local traditional knowledge (LTK) with its scientific research. George Noongwook, a Saboonga elder and hunter, came to Seattle in May 2011 to help summarize how the LTK component of the project is enabling us to better understand factors important to the ecosystem of the Bearing Sea at the 2nd Meeting of the Ecosystem Studies of Sub-Arctic Seas.
  - Climate Lecture Series: Deputy Director Nick Bond gave a series of presentations to the Beach Watchers Lecture Series as well as the Fiero Marine Life Center Lecture Series:
    - Camano Island, WA: "The climate of WA and Camano Island"
    - Anacortes, WA: "Climate change and its implications for the Pacific Northwest"
    - Port Angeles, WA: "Climate change and its implications for the Pacific Northwest"
  - International Arctic Buoy Program: Ignatius Rigor has an outreach program that engages the popular press and shares science with the public. Press interviews he has participated in include:
    - New York Times, Dot Earth Blog: The arctic ice watch
    - New York Times, Dot Earth Blog: A bad bet on Arctic sea ice
    - New York Times, Dot Earth Blog: An ice expert muses on greenhouse heat
    - Earth Times: River water hundreds of miles off course
    - National Public Radio, Race to the Arctic Series: The Arctic's diminishing sea ice
    - Discovery News: A new fisheries frontier in the Arctic
  - Live chat with scientists onboard a research cruise in Antarctica: PolarTREC teacher Juan Botella and scientists, including JISAO's Nancy Williams, onboard the Icebreaker *N.B. Palmer* off the coast of Antarctica hosted a real-time event giving anyone with a computer a chance to chat with scientists about oceanography of the Antarctic.
  - National Weather Service/Emergency Management Weather Workshop: Karin Bumbaco gave a talk at the October 2011 workshop titled "History of back to back La Niña events."
  - Sound Waters 2012: Nick Bond co-taught a class with Dr. Richard Feely of NOAA/PMEL called "Ocean Acidification, Ecosystems, and Climate." The third-annual class was part of the public education efforts by the Island County Beach Watchers. The issues that were addressed involved how climate change affects the Northwest and how citizens can limit their carbon footprint.

- "Time to Act: Adapting to climate change": JISAO Director Tom Ackerman was the keynote speaker at the climate symposium in Bellingham, WA in April 2011. Research Scientist Ingrid Tohver also gave a talk on salmon and river systems.

- **Summer Research Experience for Undergrads (REU)**
  - JISAO welcomed six undergraduate students in summer 2011. Students were matched with mentors at NOAA's Pacific Marine Environmental Laboratory, the Northwest Fisheries Science Center, UW Friday Harbor Laboratories on San Juan Island, the Alaska Salmon Research Program on the Alaska Peninsula, and UW School of Oceanography. Student web pages and videos are displayed in the *Outreach* section on JISAO's website. The interns and their universities are listed below:
    - Theresa Edwards, Willamette University
    - Karissa Lear, Clark University
    - Dennis Negron-Rivera, University of Puerto Rico
    - Rachel Pausch, University of Miami
    - Vivian Underhill, University of Colorado
    - Jake Zaragoza, Gonzaga University
  - Angel Adames-Corraliza, a JISAO undergraduate intern in 2008 and 2010, began graduate school last fall in the UW Department of Atmospheric Sciences.
  - Daniel Hernandez, a JISAO undergraduate intern in 2009, began graduate school last fall in the UW School of Aquatic and Fishery Science.



- **Task III Outreach**
  - DO-IT (Disabilities, Opportunities, Internetworking, and Technology): The DO-IT Scholars Program works with high school students with disabilities who have the potential to pursue college studies in the sciences. During the 10-day summer program at UW students participate in lectures, live in residence halls, engages with staff in a presentation, and practice skills that will help them be successful in college and their careers.
  - Northwest Fisheries Science Center (NWFSC) Undergrad Internship Program: Between five and 12 internships are awarded annually for students to work in NWFSC's research divisions. In collaboration with UW Undergraduate Academic Affairs, the program is designed to engage undergraduates from a range of scientific disciplines with scientists and leaders at the NWFSC to develop their research interests and prepare them for careers in fisheries science research. Nine interns were selected in 2011 and four of them presented their results at the annual UW Undergraduate Research Symposium.

Financial Management and Administration

JISAO's management team, listed below, meets once per week for planning purposes and to discuss issues related to budgets/grants, human resources and daily operations:

- Thomas Ackerman, Executive Director
- Nicholas Bond, Deputy Director (JISAO management representative at NOAA/PMEL)
- Mary Smith, Assistant Director, Finance & Administration
- Fred Averick, Finance Manager
- Collen Marquist, Assistant to Executive Director

JISAO's Executive Council meets when there are agenda items that require higher-level policy reviews and decisions. All-personnel meetings are held at NOAA once per quarter and at UW once/year. These meetings include both UW and NOAA employees and focus on items of mutual interest to both organizations, to recognize outstanding scientific, technical and administrative staff and to share updated operational information. The JISAO Assistant Director holds weekly office hours at NOAA/PMEL to provide both JISAO and NOAA employees with a variety of services related to management of human resources, financial issues and other administrative matters that arise.

JISAO's Cooperative Agreement 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
- Small percentage of administrative support

JISAO provides space, computer access, administrative support, and other services for postdoctoral research associates and visitors supported on Task I. Over the past year, Task I funding provided support for two post docs (Andreas Muhlbauer, Jessica Kleiss) whose appointments ended, and two new post docs, Samantha Siedlecki, from the University of Chicago, and Camille Lique, from Laboratoire de Physique des Océans, Plouzané, France.

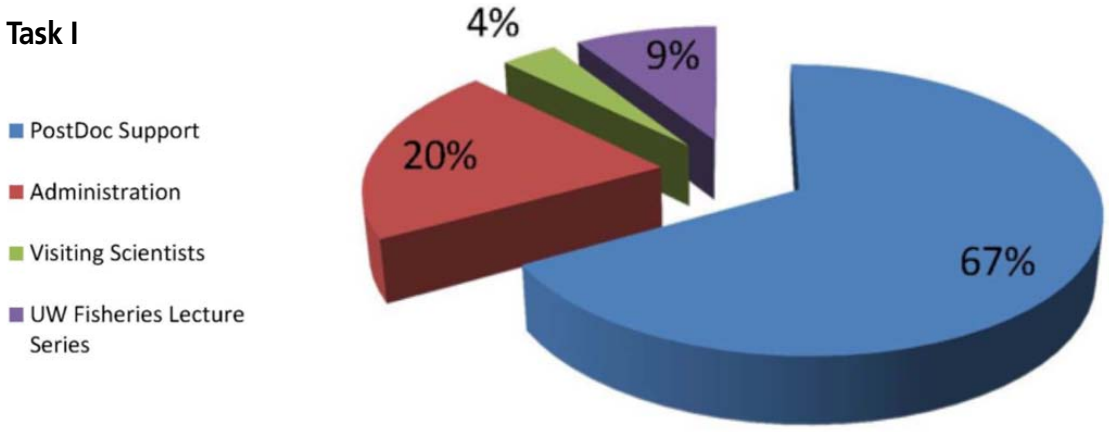
JISAO's education and outreach program activities are supported by a small portion of Task I. Please see the section above for details about this program. Additionally, a small portion supports a fraction of administrative salaries.

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

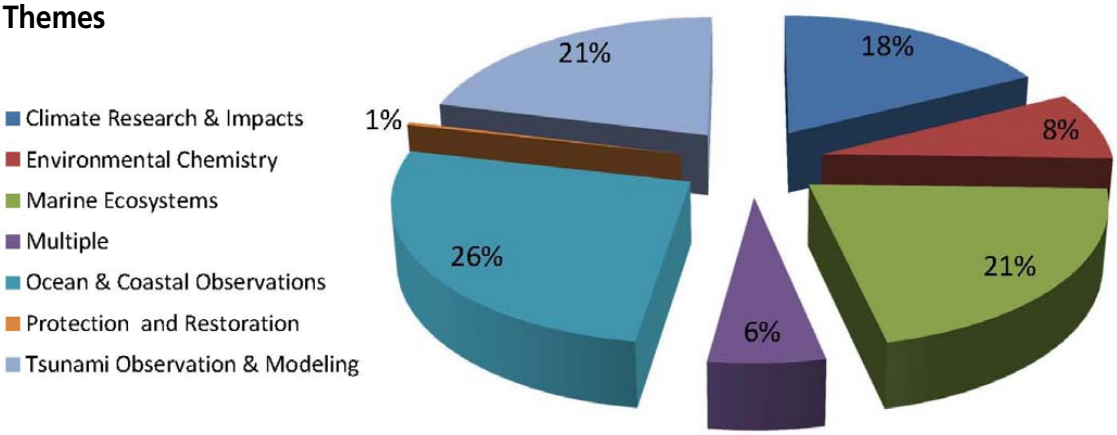
Task III supports University of Washington research in areas compatible with the institute's major research themes. Along with Task II, Task III programs serve as vehicles for funding research scientists (UW faculty and professional staff,) postdoctoral research associates and graduate students through the JISAO Cooperative Agreement. Task III also supports postdoctoral research associates housed at NOAA. University of Washington grants and principal investigators on NOAA grants funded through Task III are listed in Appendix 3.

The JISAO/NOAA Cooperative Agreement funding for the period ending on March 31, 2012 totals $14,137,403. JISAO's funding exclusive of the Cooperative Agreement for the last 12 months amounts to another $3,956,366. The charts below break down Cooperative Agreement funding by tasks and themes.

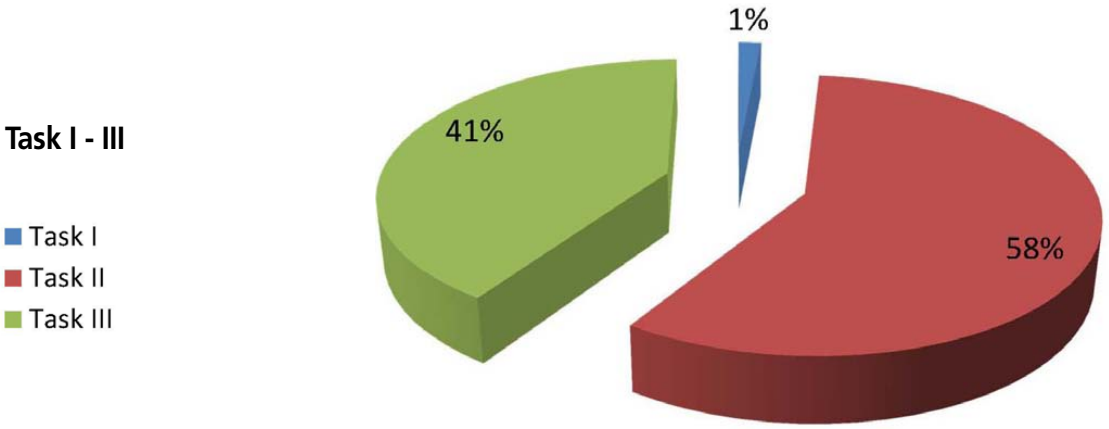
Task I



Themes



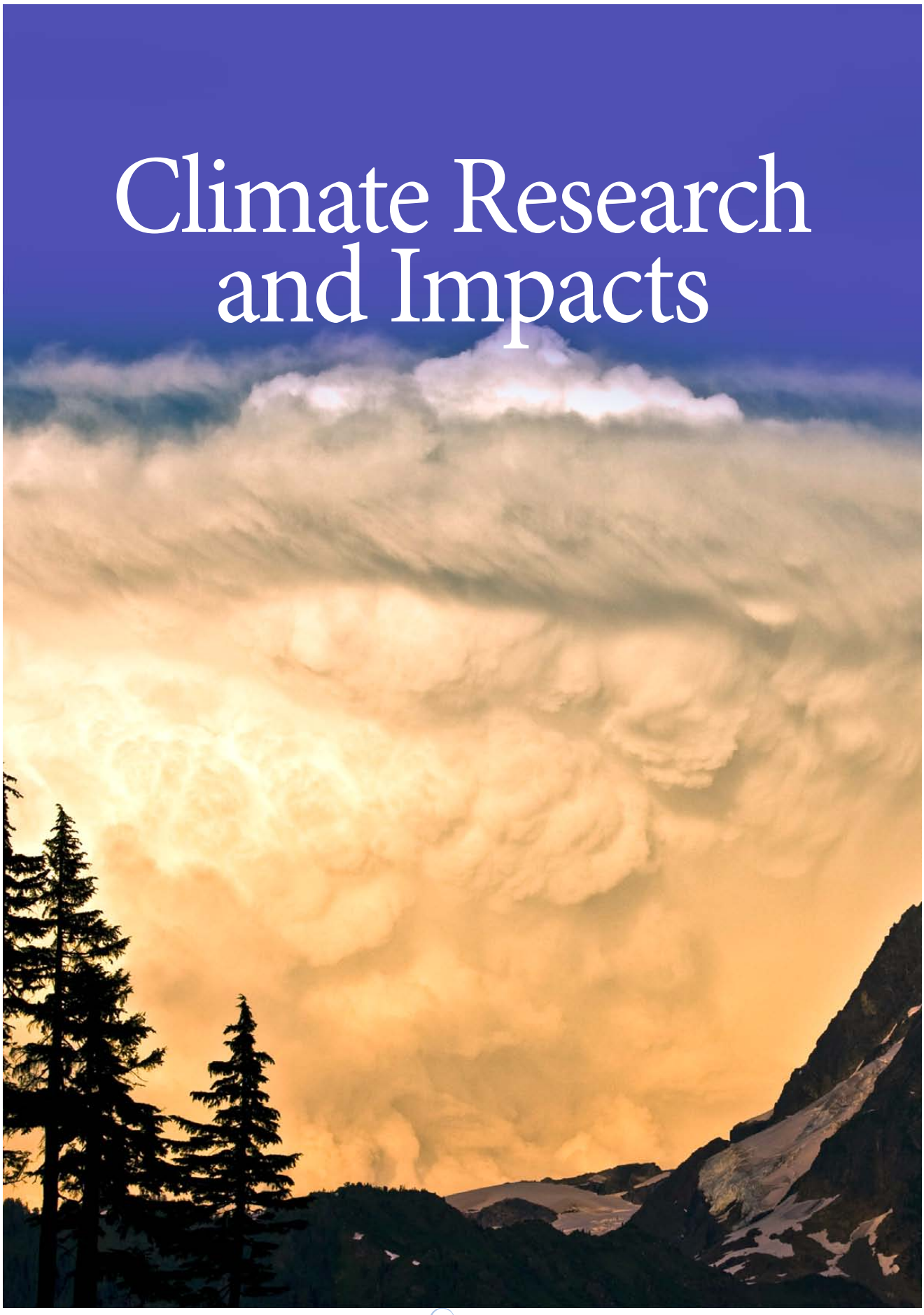
Task I - III



The JISAO administration continued to work on the following initiatives over the past year to improve and strengthen JISAO as an organization:

- **JISAO Staff Recognition Program**
  - Recognized outstanding research, papers, honors and awards on JISAO website.
  - Presented UW service awards to JISAO employees.
- **JISAO Outreach and Education Program**
  - Continued to strengthen and broaden the success of the E&O program (see section above for details of the year's activities)
- **Strengthening Communications**
  - Continued joint quarterly meetings with JISAO and NOAA employees
  - Planned a 5th annual all-staff meeting on UW campus that includes all JISAO employees at UW and those who work at NOAA facilities.
  - JISAO assistant director continued to hold weekly office hours at NOAA/PMEL, improving communications and collaboration between NOAA and UW personnel.
  - Website was re-designed in the Drupal format and now includes updated information such the additional scientific themes as outlined in the recompetition proposal.
  - Developed Science in 180 video series.
  - Participated on both the NOAA and UW CoEnv communications teams to regularly share information and best practices.
  - Continued to develop JISAO's marketing and public relations efforts to communicate research and education goals and activities to partnering organizations as well as local, regional and national communities.
  - Continued social networking via Facebook and YouTube
  - Created better systems to track media coverage and publications of JISAO researchers.
  - Developed additional educational and public relations materials.
- **Improving Organization and Infrastructure**
  - Streamlined staff assignments and are currently working with reduced number of FTEs by not filling 2 vacant positions.
  - Continued to reorganize administrative and supervisory structure, including JISAO scientific and technical staff working at NOAA.
  - Thomas Ackerman, JISAO Executive Director, is a member of the CoEnv Executive Committee and serves the College is various other capacities.
  - Mary Smith, JISAO Assistant Director, participates in both the CoEnv Administrator and Communications Groups.

Climate Research and Impacts



Life Cycle Assessments for the Improvement of Aquaculture Systems

PI
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Other UW Personnel
Steven Diesburg, Mechanical Engineering and the Design for Environment Laboratory

NOAA Personnel
John Colt, Northwest Fisheries Science Center, National Marine Fisheries Service (NMFS), National Oceanic & Atmospheric Administration (NOAA)

Task III

NOAA Contacts
John Colt, Northwest Fisheries Science Center, National Marine Fisheries Service (NMFS), National Oceanic & Atmospheric Administration (NOAA)

NOAA Goal
Climate Adaptation and Mitigation

Description
Montlake Process data, facility and equipment drawings, and related documents provided by NOAA were compiled to conform to LCA data formats. Data were developed to fill gaps, including missing equipment specifications and distances to landings and to the processing plant (for the representation of feedstock transport).

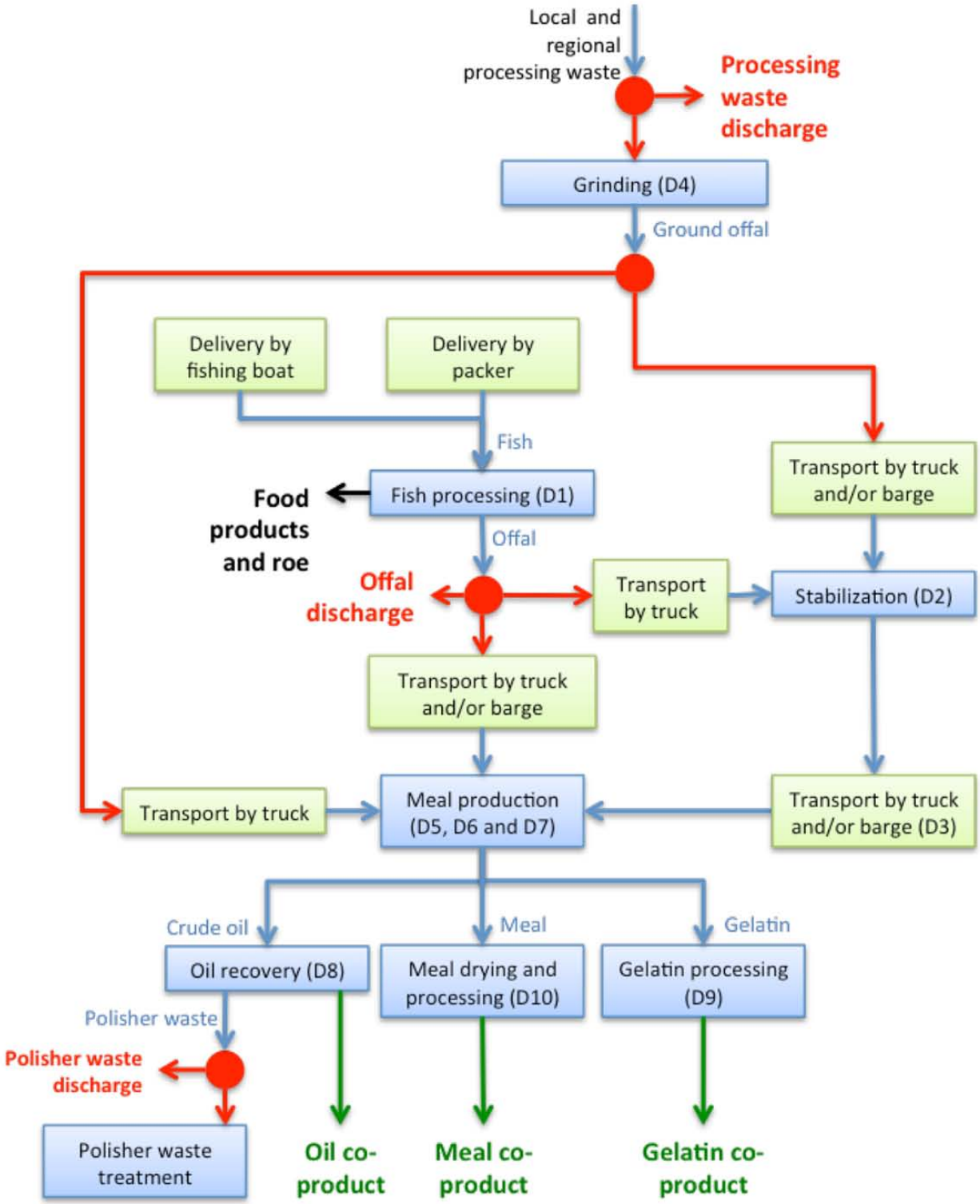
Objectives
1. ***Assess Alaskan Salmon Processing Waste Alternatives:*** The objective is to demonstrate the use of LCA in aquaculture for the development of process improvement and dissemination recommendations. The project will assess the "Montlake Process" described by Nicklason, et al. (Nicklason 2010) as a case study. The Montlake Process is a modification of current salmon processing intended to reduce the life cycle contribution to climate change through (a) more efficient thermal design, (b) the ability to use fish oil to reduce diesel or electrical inputs, and (c) the use of a waste product in the place of virgin resources.
2. ***Assess Alternative Feeds for Aquaculture Systems:*** The objective is to investigate the integration of LCA into feed optimization for aquaculture systems by developing a framework to facilitate optimal feed selection and management on the basis of minimizing life cycle environmental, economic, and social impacts with consideration given to feed formulation, species-specific dietary requirements and the availability of and need for local and global resources.

Accomplishments
Montlake Process data, facility and equipment drawings, and related documents provided by NOAA were compiled to conform to LCA data formats. The data captured 600,000 tons of fish processing wastes in Alaska discharged directly into the ocean, which can result in large anoxia areas and have serious impacts on benthic animals. An opportunity exists to instead recover these wastes for a variety of uses. To utilize this waste, the Montlake Process produces a high protein-low ash meal, oil, bone meal, and gelatin from processing wastes.

Data were developed to fill gaps, including missing equipment specifications and distances to landings and to the processing plant (for the representation of feedstock transport). In support of objective 1, Assess Alaskan Salmon Processing Waste Alternatives, these accomplishments are the basis for models needed for LCAs of the Montlake Process and the conventional, ocean dumping-based system. The final models will allow the interpretation of the results pursuant to discharge regulations in Alaska and the evaluation of the Montlake Process as a "Best Available Technology" for salmon fisheries.

Life Cycle Assessment of Process Options for Fish Process Waste Management

University of Washington Design for Environment Lab



Assessing the Atlantic Meridional Overturning Circulation (AMOC) in Climate Models

PI
Albert J. Hermann, UW — JISAO

Other UW Personnel
Wei Cheng, Dongxiao Zhang, JISAO

Task III

NOAA Contact
Daniel Barrie, Climate Program Office

NOAA Goal
Climate Adaptation & Mitigation

Description
The Atlantic Meridional Overturning Circulation (AMOC) is one of the major players in the global climate system. Variability of AMOC has been linked to fluctuations in a wide range of oceanic and atmospheric processes. There is, however, a large spread of AMOC mean states and decadal-to-multidecadal variability simulated in previous IPCC AR4 climate models. The AMOC in models is often estimated from a zonally integrated transport stream function which is not directly measurable. Inferring long-term AMOC changes in observation therefore requires usage of proxy data - measurable parameters in the climate system that are closely related to AMOC and its variability. This research uses several observational parameters, both new and conventional, to check against AMOC in the climate models prepared for the IPCC AR5. Results from this study are anticipated to provide better benchmarks for future AMOC assessment and its global climate impact.

Objectives
1. ***Investigate the degree of agreement between simulated and 'observed'/inferred AMOC***
2. ***Explore the sensitivity of the modeled AMOC to model parameters.***
3. ***Investigate the relationship between AMOC and meridional heat transport in the ocean and atmosphere. The latter is a manifestation of AMOC on earth system energy balance.***

Accomplishments
Meridional mass transport streamfunctions from IPCC AR5 (CMIP5) models were examined by Wei Cheng. Most models do not show a significant trend of AMOC in their historical simulations (1850-2005). The spread of AMOC amplitudes across available models has narrowed compared to previous generation CMIP3 runs, even though the spread is still larger than internal variability of any one particular model. With few exceptions, the simulated mean AMOCs in available models in the 20th century are within the observational range of 11-22 Sv. Under low emission scenarios, all models show a decrease of AMOC in the first half of the 21st century, but the majority of the models also indicate a rebound of AMOC starting in mid-century around 2060. A few models have extended runs to year 2300 where the radiative forcing stabilizes after year 2100; all these runs show a slow recovery of AMOC after 2150.

The results were presented at the WCRP Open Science Conference in 2011 and the CMIP5 workshop in 2012. Cheng will submit a paper on this work, to be considered by IPCC AR5 chapter lead authors.

Lightning Studies

PI
Robert Holzworth, UW — Earth and Space Sciences

Other UW Personnel
Cliff Mass, Greg Hakim, Lynn McMurdie, Department of Atmospheric Sciences

Task III

NOAA Contact
Steven Goodman, NOAA NASA Goddard, Scientific officer for NOAA/GOES-R satellite and the GLM (Geostationary Lightning Mapper) to be launched in 2014 or 2015)

NOAA Goal
Climate Adaptation & Mitigation

Description
This is the middle of the first year of a three year grant with two primary tasks: 1. to participate in the prelaunch validation for what the GLM on NOAA/GOES-R will be able to detect, and 2. to use data assimilative techniques to add lightning location data into the WRF model.

Accomplishments
1. We have begun sharing the WWLLN lightning data with scientists at NOAA as part of the NOAA GOES-R prelaunch validation effort. The realtime lightning data are distributed in collaboration with our realtime distributor WDT (Weather Decisions Technology).
2. We have conducted lightning climatology study in part to validate the WWLLN data, and as a solid research topic in and of itself. You can see the results of this work at *http://wwlln.net/climate*
3. As a preliminary step toward helping the planning for the prelaunch validation of the GLM (geostationary Lightning Mapper) I attended a 2 day workshop last September at Huntsville, AL called by NOAA.
4. Several new computers have been purchased, installed and the WRF model software has been loaded for testing.
5. So far we are working with 3 faculty members and a new graduate student in Atmospheric Sciences to begin to arrange the assimilation of the WWLLN lightning data into the model. This is the main new science we are starting to do, and it is expected to take 2 to 3 years to have definitive results. Prof. Cliff Mass is co-investigator for this part of the work.

Evaluation of Reanalysis Products in the Arctic

PI
Ron Lindsay, UW — Polar Science Center, Applied Physics Laboratory

Task III

NOAA Contact
Dan Barrie, Climate Program Office

NOAA Goal
Climate Adaptation and Mitigation

Description
How well can we estimate the state of the atmosphere and the rate it is changing in the polar regions in retrospective analyses? In the data sparse Arctic, atmospheric analyses are poorly constrained by observations and are strongly influenced by model parameterizations. There are currently seven different sets of global reanalysis products that are current or near current in temporal coverage: NCEP-1, NCEP-2, CFSR, 20CR, MERRA, ERA-Interim, and JRA-25 (definitions follow).

Retrospective analyses have been a critical tool in studying weather and climate variability for the last 15 years. Reanalyses blend the continuity and breadth of output data from a numerical model with the constraint of vast quantities of surface, radiosonde, and satellite observational data. The result is a long-term continuous and spatially complete data record. Reanalysis products are used in many different applications including evaluation of atmospheric circulation patterns and processes, change detection, the forcing of ice–ocean models, regional atmospheric models, land models, or air chemistry models, and for establishing the initial conditions for forecast models. Better understanding the strengths and weaknesses of these products will improve our ability to evaluate the long-term trends in the rapidly changing Arctic environment and may also improve our ability to make seasonal projections of sea ice and weather conditions in the Arctic.

In this focused study we will compare the monthly mean estimates of the surface and tropospheric air temperature, the surface pressure and winds, the total precipitation, and the surface and top-of-the-atmosphere radiative fluxes in a three-tiered set of analyses. The first-order comparisons will be made to independent point observations from a selected set of land stations and drifting ice stations. The second-order comparisons will be made of the statistical properties (mean, standard deviation, and extremes) of the fields from each of the reanalyses. Finally, the third-order comparisons will be made of the 30-year trends in the fields of each of the reanalyses. While this is an ambitious project to accomplish in just one year, we plan to use the economies of scale to perform the identical analysis procedures on all six of the reanalysis products.

The ultimate goal is to better understand the strengths and weaknesses of these products in a data-sparse region where the reanalysis models may differ the most. Better understanding of these products may improve the ability for NOAA to make seasonal projections of sea ice and weather conditions in the Arctic.
This study has just commenced and the plan is to present preliminary results this spring at the 4th WCRP International Reanalysis Conference in Washington D.C., planned for May 7-11, 2012.

A New Unified Sea Ice Thickness Climate Data Record

PI
Ron Lindsay, UW — Polar Science Center, Applied Physics Laboratory

Other UW Personnel
Mark Wensnahan, Applied Physics Laboratory

Task III

NOAA Contacts
Chris Miller and Bill Murray, Climate Program Office, Climate Observations and Monitoring Program

NOAA Goal
Climate Adaptation and Mitigation

Description
In our third year of this project we have added more data to the new unified sea ice thickness climate data record (the Sea Ice CDR), publicized the data set, and participated in three publications using the data. All of the data are in a common format and have been averaged to approximately one month of time or 50 km of track. The Sea Ice CDR currently contains data from upward looking sonars (ULS) on moorings and on submarines, from airborne electromagnetic measurements, coastal fat ice stations, and ICESat laser altimeter measurements. The mooring data come from 27 different locations and now represent 900 station-months. The submarine data come from 34 different cruises and represent 109000 km of track. The Airborne EM data come from 15 different campaigns and represent 13000 km of track.

Objectives
1. ***intercompare different ice thickness measurements***
2. ***evaluate the changing state of the ice pack***
3. ***validate sea ice models***

Accomplishments
The observations from ICESat are a major new addition to the data set. We have incorporated the ice thickness estimates made by the team at the NASA Goddard Space Flight Center and archived at the National Snow and Ice Data Center. The point observations from this data set are for 25-km segments of satellite track. In the unified data set they are clustered in 50-km regions and a cluster includes all observations for each 1-month ICESat campaign. There are 6 campaigns with a total of 16,834 clusters, representing19,716,995 point values and 3,345,242 km of track. A second ICESat ice thickness estimate is from JPL. This dataset is already clustered for each campaign, so we have just provided a link to the JPL data set.

Moored ULS measurements from Davis Strait, provided by a team at the Applied Physics Laboratory, are a second significant addition. The data are from four locations across the strait from 2006 to 2008. There are 559,948 point samples collected in 70 monthly averages in this collection.

Two additions were added from Environment Canada: one for moored ULS measurements in Lancaster Sound (2003-2007); and the second from the large collection of ice thickness measurements made on fast ice at a set of 27 different coastal locations in northern Canada (1947-2011).

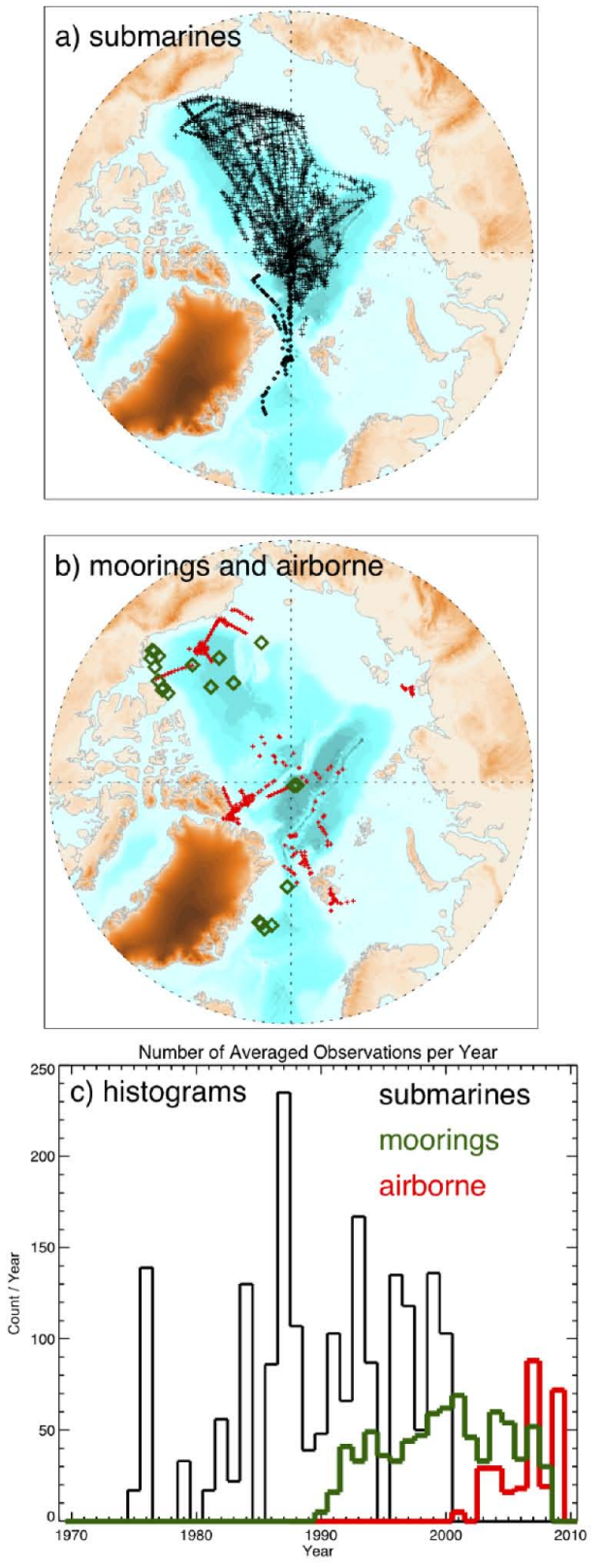
The entire data set currently contains over 20,000 averaged observations representing over 350 million point measurements. The maps in the figure below show the locations of all of the non-satellite observations currently in the database. The new data set debuted at the Portland AGU Ocean Sciences Meeting in February of 2010 and was highlighted in a poster at the Fall 2011 AGU Meeting. The website is *http://psc.apl.washington.edu/sea_ice_cdr*

In order to create this new data set we have: 1) acquired data from several different data providers; 2) decoded all of the observations that often were in different formats even from the same data provider; 3) performed quality control and removed duplicate data; 4) in some cases wrote point data files for the data base; 5) averaged the data over one month time intervals for the moorings and clustered the data in 50 km regions for the submarines, airborne, and satellite measurements (multiple passes in the same region were combined); 6) determined the mean statistics of the ice draft for the ULS measurements, snow+ice thickness for the airborne EM measurements, and freeboard and ice thickness estimates for ICESat; 7) determined the distributions of draft, freeboard, or thickness; 8) wrote all of the data in standard formats; 9) constructed a metadata record in a spreadsheet format with a worksheet for each data source and a column for each moor-

ing, cruise, or campaign; and finally 10) constructed a website with introductory descriptive material, all of the averaged data, some of the point data, and the metadata. Each data source has its own descriptive page. The data set uses information provided by a number of different institutions: Woods Hole Oceanographic Institution, Institute of Ocean Sciences, University of Alberta, Alfred Wegener Institute for Polar and Marine Research, Arctic Submarine Laboratory, Goddard Space Flight Center, University of Washington Polar Science Center, and the National Snow and Ice Data Center. Three significant publications have been accomplished or submitted under this project. One announced the data set in Eos (Lindsay, 2010). A second used the data set to evaluate the errors of ice thickness and ice volume estimates in a coupled ice-ocean model and determined the error in the trend in the model ice volume (Schweiger et al, 2011). Total sea ice volume anomaly trends have been highlighted on a PSC web page that has received considerable attention (*psc.apl.washington.edu/wordpress/research/projects/arctic-sea-ice-volume-anomaly/*).

The Sea Ice CDR plays a prominent roll in establishing the uncertainty of the model ice thickness estimates, the volume estimates, and the trend estimates. The paper also determined that retrospective model ice volume trends over the last 30 years were significantly larger, considering model trend errors, than any trends found in IPCC climate models run with constant greenhouse forcing. The third paper compares the ice thickness estimates from seven coupled ice-ocean models participating in the Arctic Ocean Model Intercomparison Project (AOMIP) to the observations collected in the Sea Ice CDR (Johnson, 2011).

This year we anticipate adding the first installment of the IceBridge laser altimeter measurements of ice thickness to the data set (the PI is on the IceBridge Science Team). Our future plans are to perform detailed intercomparisons of the thickness estimates from different data platforms to determine the magnitude of any relative biases that may be in the data sets. We will also submit the data and metadata to the National Snow and Ice Data Center for archiving. We have already been in contact with a representative of NSIDC to establish the best means to do this.



Locations of all submarine observations (top), moored and airborne observations (middle) in the Sea Ice CDR. The bottom panel shows the temporal distribution of the observations from 1970 to 2010. The ICESat observations (2005-2007) and those from Davis Strait (2006-2008) are not included.

Mountain Hydrometeorology for Weather and Climate Forecasting Applications

PI
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Other UW Personnel
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NOAA Personnel
Marty Ralph, Mimi Hughes, Paul Neiman, Allen White, OAR/ESRL-Physical Sciences Division

Task III

NOAA Contact
Marty Ralph, NOAA OAR/ESRL-Physical Sciences Division

NOAA Goal
Climate Adaptation & Mitigation

Description
We have been addressing the following questions, which were developed through discussions with NOAA staff both at ESRL in Colorado and at the River Forecasting Center in California: 1) What measurements are most critical for accurate modeling of snow accumulation and melt in complex terrain? When such measurements are unavailable, what is the best alternative way to provide model inputs (e.g., satellite, mesoscale model, nearest station(s) plus a lapse rate, or some combination thereof)? 2) How do these different driving datasets impact

Objectives
1. ***Characterizing snow to address uncertainty in forecasting, flood control, and water management***
2. ***Evaluating advanced observations of rain and snow, temperature, and soil moisture to provide best possible "forcings" for river prediction, in conjunction with NOAA's Hydrometeorology Testbed in the North Fork (NF) American River Basin of California***

Accomplishments
We retrieved and deployed a network of temperature, relative humidity and stream pressure sensors distributed across the NF American River Basin. We compared ways of estimating annual precipitation and peak snow water equivalent spatially in time to assess the best way to map spatial patterns of snow accumulation across the landscape (Raleigh and Lundquist 2012). This addressed the project objective of characterizing snow. We evaluated low-cost humidity sensors and their utility as key hydrologic forcing for river prediction (Feld and Lundquist, submitted). We assembled and quality-checked data from a network of 63 temperature sensors over three years and assessed the best way to patch missing data from temperature networks of different sizes and with different lengths of missing data (Henn et al., submitted). These two addressed the project objective of evaluating advanced observations. Finally, in work led by Nic Wayand, we assessed the impact of different observational and mesoscale-model-generated input datasets on snow and hydrologic simulations in the Distributed Hydrology Soil Vegetation Model (DHSVM) set up over the NF American River Basin.

Graduate student Brian Henn pointing to the location of buried temperature sensors. Note the metal detector in the foreground that we use to find the temperature sensors. These are part of a distributed ground network for validating MODIS products of fractional snow covered area (because temperature sensors flat line at 0 deg C when snow covered).

Graduate student Mark Raleigh was awarded the James E. Church Award for best student paper and presentation at the 2011 Western Snow Conference. Mark Raleigh was also recently awarded a CH2MHill Engineers without Borders USA Scholarship.

Graduate student Nic Wayand doing winter snow surveys in the headwaters of the American River Basin.

Ensemble-Based Regional Data Assimilation

PIs
Cliff Mass, Greg Hakim, UW — Department of Atmospheric Sciences

Task III

NOAA Primary Contact
Steve Lord, National Weather Service

NOAA Goal
Climate Adaptation and Mitigation

Accomplishments
This project has supported one graduate student during this period: Luke Madaus. Luke Madaus is now working on assimilating high-density pressure observations using the Ensemble Kalman Filter approach.

Development of an Experimental National Hydrologic Prediction System

PI
Dennis P. Lettenmaier, UW—Department of Civil & Environmental Engineering

Task III

NOAA Contact
Jin Huang, OGP/Climate Prediction Program for the Americas

NOAA Goal
Climate Adaptation & Mitigation

Description
This project is joint between Princeton University and the University of Washington. The proposal was common to both institutions, and involves merging work done at both institutions on continental scale hydrologic forecasting and nowcasting into a unified National Hydrologic Prediction System (NHPS). This is a progress report on those tasks for which the University of Washington is the lead.

Objectives/Accomplishments
Task 1: Integrate UW west-wide forecast system, SWM, and Princeton DMaPS into a National Hydrologic Prediction System

We proposed to merge aspects of the University of Washington's Westwide Seasonal Hydrologic Forecast System and national Surface Water Monitor with a similar system developed by Princeton University for the eastern U.S. Our intent was to merge the three systems into a unified experimental national nowcast and prediction system. The core system is to run at UW, however elements of the processing (including multimodel merging) will be performed at Princeton, and output made available to the UW system.

Princeton University and the University of Washington share responsibility for this task. To date, we have developed the nowcast system at 1/8 degree resolution for the continental United States based on the VIC model. We have tested the parameters for each of the major basins and the VIC model runs with daily updates over CONUS. We have selected about 300 forecast points across the country that will be used for streamflow nowcast and forecast. The real time nowcast on April 30, 2011 for soil moisture and SWE conditions for the PNW is shown in Figure 1. We are in the process of expanding the system to include the other models that are now included in the Surface Water Monitor. Following completion of (ongoing) system testing, we will implement the nowcast online in real time.

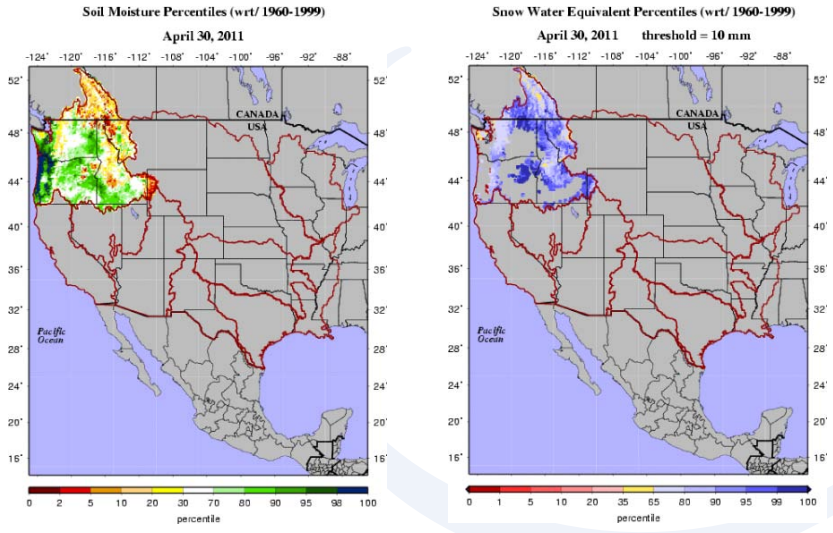


Figure 1. Soil moisture and Snow water equivalent nowcast on April 30, 2011 for the Pacific North West (PNW)

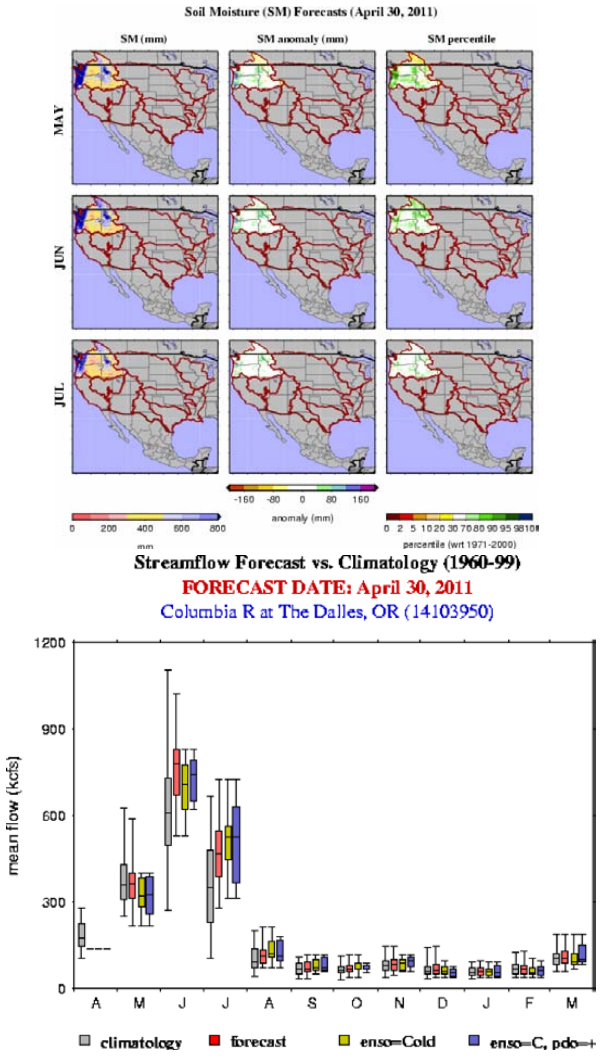


Figure 2. Soil moisture and streamflow forecasts made on April 30, 2011 for the PNW. For streamflow, Columbia River at The Dalles, OR is shown as an example.

We are in the process of implementing the ESP based forecast method into the NHPS. The CPC and CFS based forecast systems will be integreated after ESP has been implemented. We have tested the ESP based forecast for soil moisture, runoff, and streamflow at selected gage stations for the PNW basin (Figure 2).

***Task 2: Incorporate multiple land schemes into the forecast system* (UW) :**
We proposed to use the VIC, Noah, Sac-SMA, and CLM models for both nowcasts and forecasts in NHPS.

We have completed the setup for the VIC model at 1/8 degree for U.S. We are in the process of implementing the SWM suite of models in NHPS, augmented with the Unified Land Model (ULM; Livneh et al., 2011)

Task 3: Evaluation of transfer of Sac-SMA calibration parameters:
We proposed to conduct experiments to evaluate parameter transferability for the new ULM model, and to extend the experiments reported in Shi et al (2008) which document performance of seasonal forecasts made with calibrated and uncalibrated (but bias corrected) models.

We have calibrated ULM for six river basins across the U.S (Figure 3). Figure 4 shows the ULM performance in simulating monthly streamflow for the selected basins. We have determined that more sensitivity experiments will be required to understand parameter interactions, and in turn to improve model performance.

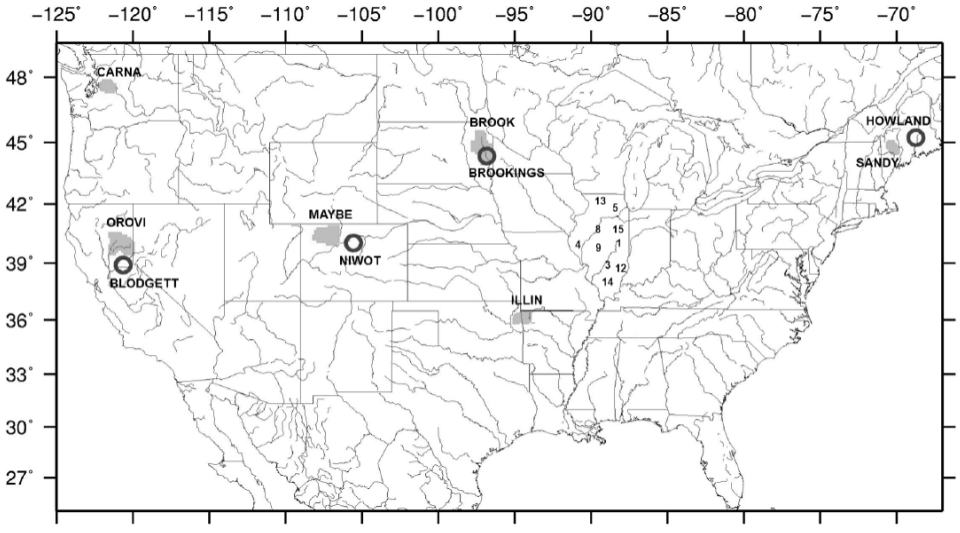


Figure 3. Location of study basins (shaded), flux tower sites (circles), and ICN soil moisture stations (numbered) [from Livneh et al., 2011].

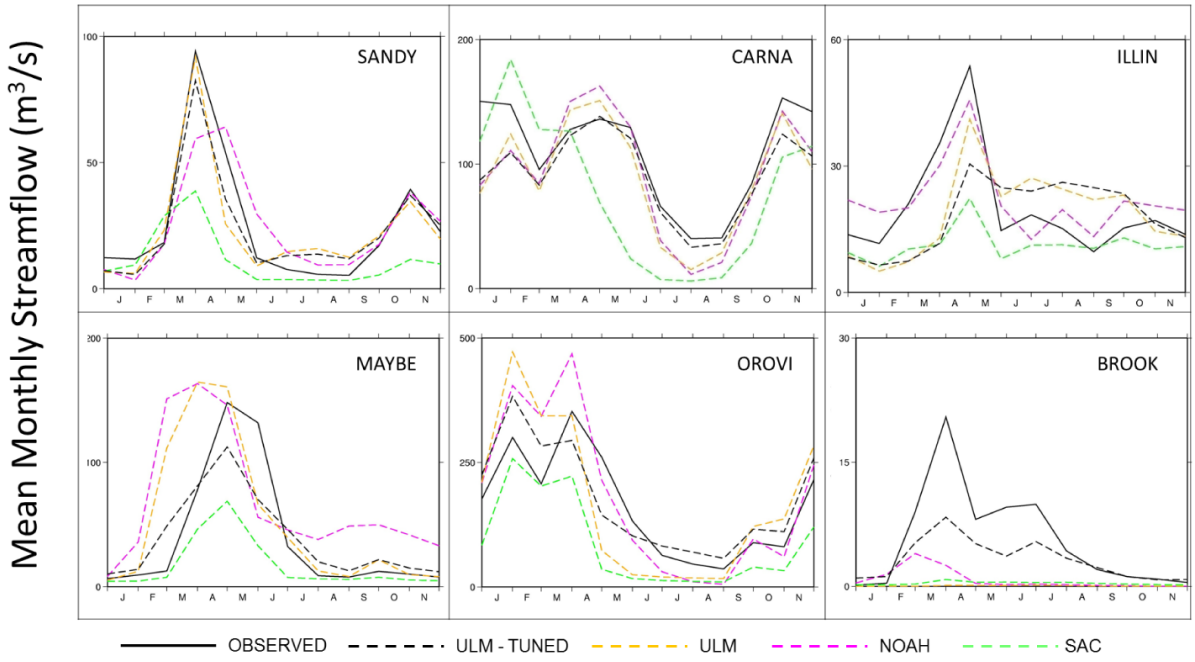


Figure 4. Mean monthly streamflows (1960 – 1969) for ULM using a *priori* parameters (ULMA), ULM with parameters tuned towards maximized model efficiency (ULMM), Noah, Sac, and observations (from Livneh et al., 2011).Figure 2. Soil moisture and streamflow forecasts made on April 30, 2011 for the PNW. For streamflow, Columbia River at The Dalles, OR is shown as an example.

***Task 4: Development of an ensemble seasonal reservoir forecast capability (UW)*:**
We proposed to develop a unified national reservoir storage outlook product.

We have collected and analyzed reservoir data for their locations and other characteristics (storage capacity, supply and demand parameters, and water balance). We have implemented and tested the simple reservoir operation scheme for two basins in the Pacific Northwest. The VIC model was run for both basins and the output from the VIC model (runoff and baseflow) was provided as an inflow to the reservoir operation scheme. We intend to test the reservoir scheme for other basins in the eastern part of the U.S.

Task 5: Hydrologic forecast error estimation and forecast verification
Princeton University has primary responsibility for this task.

Task 6: Data assimilation:
Princeton University has primary responsibility for this task.

Task 7: Develop GFS-based near-term hydrologic forecast capability
Princeton University has primary responsibility for this task.

International Arctic Buoy Programme (IABP) — Monitoring the Eurasian Basin of the Arctic Ocean

PI
UW — Ignatius Rigor, Polar Science Center, Applied Physics Laboratory (APL)

Other UW Personnel
Mark Ortmeyer, Polar Science Center, APL

Task III

NOAA Contact
John Calder, Arctic Research Office

NOAA Goal
Climate Adaptation & Mitigation

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 Polar Science Center, Applied Physics Lab at the University of Washington (PSC/APL/UW), and the National Ice Center (NIC) co-manage the US Interagency Arctic Buoy Program (USIABP), which coordinates the US contributions to the IABP. The USIABP purchases and deploys buoys using a pool of funds provided by NOAA, and contributions from other US agencies (Coast Guard, National Aeronautics and Space Administration, National Science Foundation, Naval Oceanographic Office, and the Office of Naval Research. Funds from this particular USIABP grant are focused on monitoring the Eurasian Basin of the Arctic Ocean. This progress report highlights USIABP activities and accomplishments during the last year.

Objective
Maintain a well-spaced observing network, to monitor air, sea, and ice conditions across the Arctic Ocean.

Accomplishments

1. USIABP Buoy Purchases and Deployments in 2011

- One Polar Arctic Weather Station (PAWS) deployed by PSC at the North Pole Environmental Observatory (NPEO) in April 2011.
- Two Airborne eXpendable Ice Beacons (AXIB) deployed during the USCG Arctic Domain Awareness Flights in August, 2011.
- Two eXpendable Ice Beacons (XIB) deployed from the US ice breaker Healy in September, 2011.
- Fifteen Surface Velocity Program (SVP) Barometer Upgrade buoys, were deployed during the summer of 2011.

2. IABP Coordination

In addition to the buoy purchases and deployment logistics described above, this grant also partially funds the coordination of the entire IABP. All the Arctic buoys are purchased and deployed using a combination of equipment and logistics coordinated with the researchers' collaborators in the IABP.

The latest maps showing the locations of buoys purchased and deployed by the USIABP can be seen at:

- *http://iabp.apl.washington.edu/owners.html*
- *http://iabp.apl.washington.edu/logistics.html*

3. Outreach

Rigor has a multi-faceted outreach program which engages the popular press, shares the science with the public, and mentors students.

3.1 Press Interviews and Articles (reverse chronological order):

3.1.1 Adrian Bishop: *River water hundreds of miles off course*, Earth Times, January, 6, 2012.

3.1.2 Andy Revkin: *The Arctic Ice Watch*, Dot Earth Blog, New York Times, Sep. 12, 2011.

3.1.3 National Public Radio: Race to the Arctic Series: *The Arctic's Diminishing Sea Ice*, Aug. 15, 2011.

3.1.4 Andy Revkin: *A Bad Bet on Arctic Sea Ice*, Dot Earth Blog, New York Times, Aug. 11 2011.

3.1.5 Andy Revkin: *An Ice Expert Muses on Greenhouse Heat*, Dot Earth Blog, New York Times, Aug. 10, 2011.Kieran Mulvaney: A New Fisheries Frontier *in the Arctic*, Discovery News, May 25, 2011.

3.2 Pacific Science Center

We have an ongoing relationship with Seattle's main science museum, the Pacific Science Center (PacSciCen), where we have hosted an annual 4-day Polar Science Weekend (PSW), since 2006. The most recent event in March 2011, drew 6918 visitors, including 832 school children on field trips. In past years, arctic buoys were displayed as part of a "grab-bag" exhibit on arctic technology. We have "hands on" science demonstrations. For example, in order to demonstrate the forces driving sea ice motion, we built an ice tank in which visitors can control the speed and direction of the winds and ocean currents. This demonstration helped explain our animations of buoy drift and how changes in wind may affect the distribution and age of sea ice on the Arctic Ocean. The booth also includes a computer simulation of buoy motion in various climate states, and we have a "game" in which a player can seed the Arctic Ocean with buoys and guess where they will go, after first learning about the mean circulation and its variability.

To ensure that our work truly connects with our target audience, we work with the PacSciCen staff, who have extensive experience in helping scientists brainstorm exhibit ideas and make them into reality.

The success of this activity has spurred PacSciCen to develop the "Portal to the Public" initiative, in which partnerships with other scientific institutions have been built. As part of this effort, we have been developing a Portal to Current Research exhibit space (*http://www.pacificsciencecenter.org/portal-to-current-research*). This is a new space at the museum with a revolving, season-long focus on an area of current science interest (currently, it features an exhibit on ocean vents). The exhibit space comprises a 10-panel flexible display system for graphics, artifacts and text, 2) digital and interactive media (including a multi-touch table) and 3) a program space for live interactions between scientists and public audiences. Rigor has been working with PacSciCen staff to adapt our PSW booth for a longer-term display in this space. In addition, Rigor has committed to visiting the exhibit at least once monthly to present material and answer questions from the public.

The Polar Science Weekend gives us a chance to interact one-on-one with the scientifically curious public, familiarizing them with the current state of the Arctic and Antarctic, and ongoing polar research. A recent press release announcing this year's PSW can be viewed at *http://www.washington.edu/news/articles/kids-can-explore-icy-worlds-with-scientists-at-polar-science-weekend-with-video*.

3.3 Invited Outreach Presentations:

3.3.1 Seabeck Family Camp is held at a historic site that was developed for logging in the mid-1800's, and has been a conference center for almost 100 years. In the early 1950's, the YMCA Christian Youth Movement started hosting family camps that emphasized music, theater and adult education. In July 2011, Rigor was the adult education speaker and provided 5 days of presentations on global and Arctic weather, climate, and climate change.

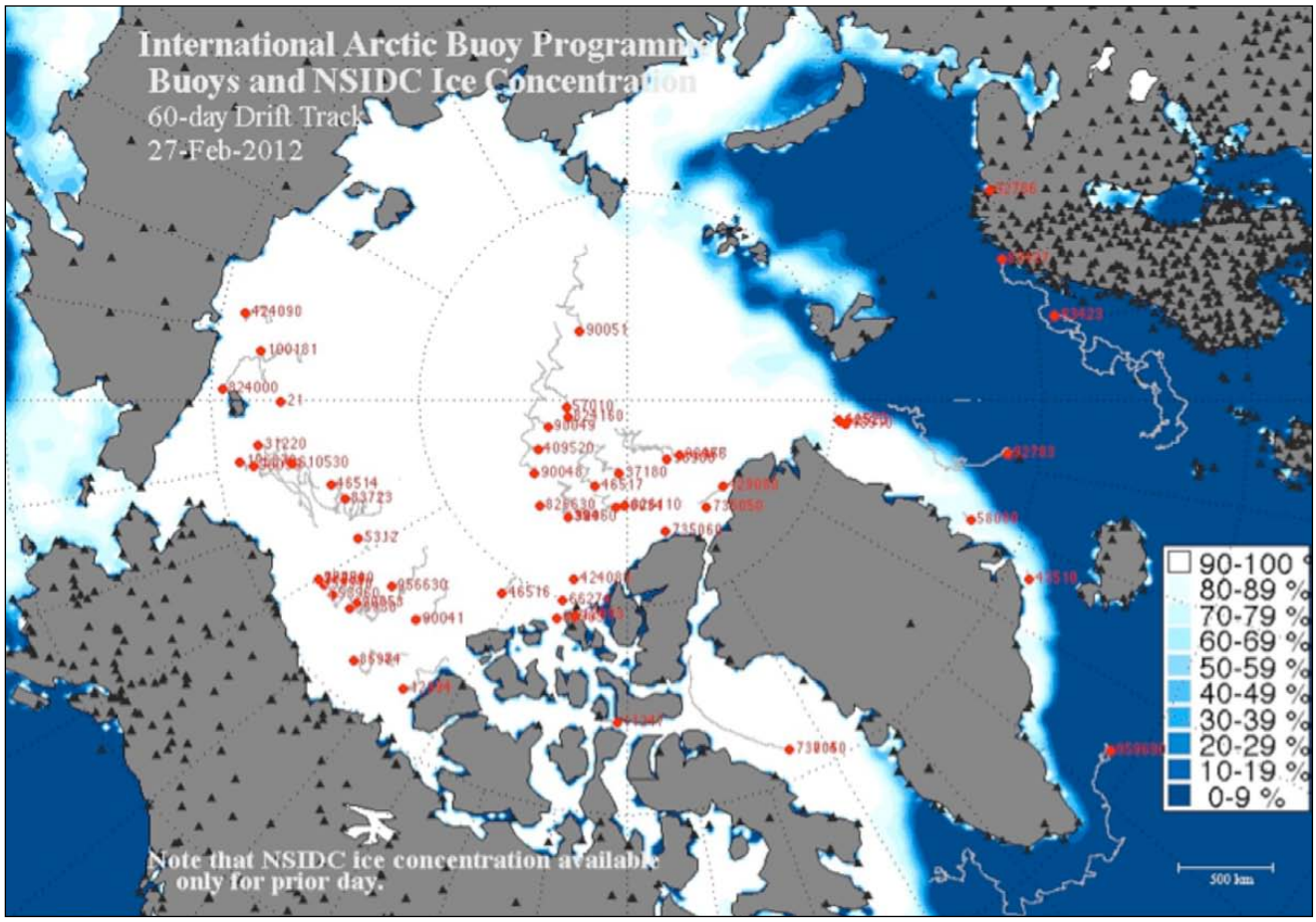


Figure 1. Map of buoys reporting from the Arctic Ocean on February 27, 2012. There are currently 63 buoys reporting in the IABP observing network.

3.3.2 Science Café: In February 2011, Rigor gave an invited lecture to about 80 people at a "Science Café" at the Wilde Rover Pub in Kirkland, WA. This is a monthly event sponsored by the PacSci to bring scientists to the community.

3.4 Rigor also advises two graduate students in Physical Oceanography, Melinda Webster and Cynthia Travers.

Although not directly funded by this grant, Webster deployed some GPS buoys from the ice breaker Healy during the spring of 2011, from which data will be used for this project.

Preparing for Climate Change: A Workshop on Assessing and Planning for Climate Change Impacts on West Coast Fisheries

PI
Amy Snover, UW — JISAO/Climate Impacts Group

Other UW Personnel
Lara Whitely Binder, JISAO

NOAA Personnel
Penny Dalton, Washington Sea Grant; Jon Stein, Northwest Fisheries Science Center; Mindi Sheer, Northwest Fisheries Science Center; Pat Corcoran, Oregon Sea Grant; Carrie Pomeroy, California Sea Grant; Jonathan Phinney, Southwest Fisheries Science Center; Yvonne deReynier, NWR Sustainable Fisheries Division

NOAA Contact
Penny Dalton, Washington Sea Grant

NOAA Goal
Climate Adaptation & Mitigation, Resilient Coastal Communities & Economies

Description
Climate Impacts Group hosted a workshop in May 2011 to assess the vulnerability of three West Coast fisheries to climate change in partnership with Washington Sea Grant programs and other partner agencies. The fisheries evaluated were Pacific whiting, sablefish, Canary rockfish, and Dungeness crab.

This workshop drew upon the expert knowledge of managers, scientists, industry, NGOs, and tribes associated with these fisheries in order to apply and test frameworks for rapid assessment of climate change vulnerabilities developed by Johnson and Welch (2010) and Chin et al. (2010). The vulnerability assessment frameworks have the advantage of being specific to fisheries and intended for use in data-limited situations. Through discussion and application of the frameworks, workshop participants helped identify the factors that influence the vulnerability of these fisheries to climate change and the relative significance of those factors to each other. The results of this effort will be summarized in a workshop report (currently in progress) that can be used as a starting point for developing targeted climate change adaptation strategies for each fishery.

Pre-workshop surveys of a subset of workshop participants on their existing knowledge and perspectives on climate vulnerability were done in conjunction with Oregon Sea Grant's ongoing NOAA SARP project and analyzed in a summary report. White papers synthesizing current scientific understanding of how climate variability and change affect the three fisheries were developed as part of this project, distributed to workshop participants, and are currently under revision for submission for journal publication. Additional funding from The Moore Foundation supported development of the white papers and post-workshop analysis.

Objectives
Workshop goals and objectives included:

1. ***Increasing understanding of the vulnerability of fisheries to climate change and implications for marine users and managers.***
2. ***Articulating the need for and begin development of useful decision support tools that enable more informed resource management approaches and enhance community resiliency to climate change.***
3. ***Identifying research and information gaps.***
4. ***Providing opportunity for discussion among, and for collaboration between, participants coming from a range of backgrounds in the fisheries, including research, management, and commercial fishing.***

Accomplishments

Through the pre-workshop surveys, the white papers summarizing climate change impacts on three west coast fisheries, and workshop presentations and discussions on climate change impacts and vulnerabilities, the understanding of the vulnerability of the target fisheries to climate change and implications thereof were increased among marine users and managers. (obj 1)

Via discussion at the workshop and the ongoing analysis for the workshop paper, the need for useful decision support tools, and the degree to which the tested methods of rapid vulnerability assessment meets those needs, were explored. (obj 2)

Research and information gaps were identified and will be described in the final white papers (obj 3)

The workshop brought a diverse group of stakeholders together to discuss vulnerability of the target fisheries (Figure 1). Pre-workshop interviews were used to help plan and structure a workshop designed to benefit workshop participants in identifying and discussing opportunities for collaboration. (obj 4)

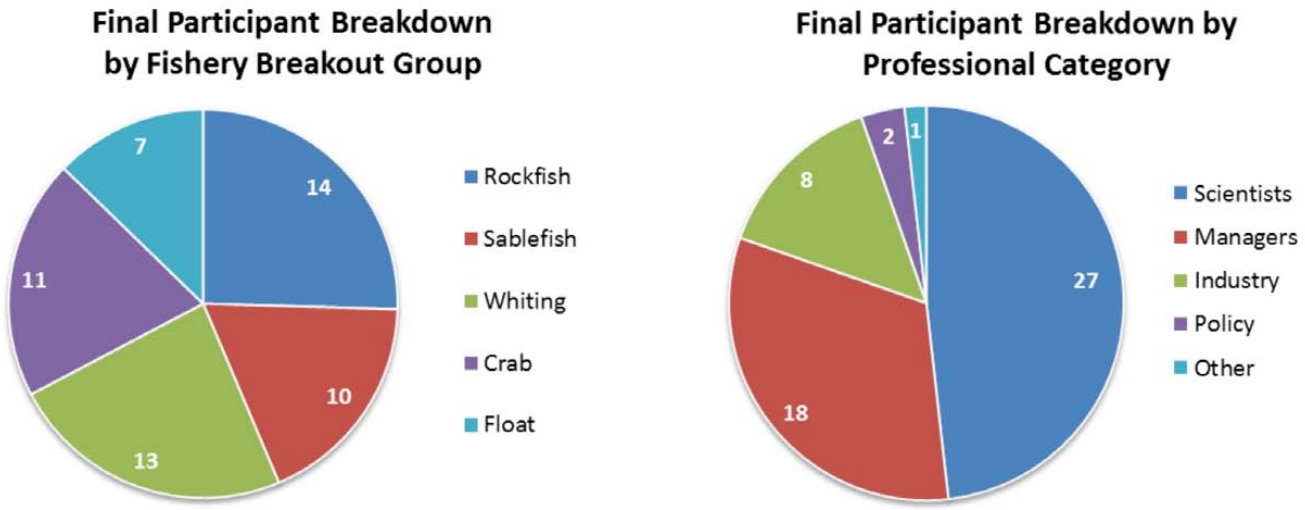


Figure 1. Final participant breakdown by fishery breakout group (left) and profession (right). In the figure on the left, "float" refers to individuals who were allowed to self-select their breakout group based on the nature of their expertise.

Methods of Assessing Fisheries Vulnerability to Climate Change (International)

PI
Amy Snover, UW — JISAO/Climate Impacts Group

Other UW Personnel
Lara Whitely Binder, JISAO; Nathan Mantua, School of Aquatic & Fishery Sciences

Task III

NOAA Contact
Roger Griffis, NOAA Fisheries Service

NOAA Goal
Climate Adaptation & Mitigation

Description
The project is not yet fully underway. Work to-date consists of background reading/preparation/strategizing/identification of potential collaborators and participants.

Objectives
1. Review published materials (peer-reviewed literature on fisheries vulnerability assessment, management agency reports) related to methods of assessing fisheries vulnerability to climate change
2. Work with NOAA Fisheries staff to hold an expert workshop to identify and review methods of assessing fisheries' vulnerability to climate-related ocean changes, including increasing water temperature, ocean acidification, changing ocean currents, hypoxic zones and sea-level rise
3. Enable knowledge transfer and shared learning among experts in fisheries science and management, focusing initially on efforts in the United States, Australia and the Philippines, while open for expansion to include other leaders in assessment of fisheries vulnerability to climate change.

Accomplishments
Project not fully underway.

California NIDIS Pilot

PI
Anne C. Steinemann, UW — Civil and Environmental Engineering, Public Affairs

Task III

NOAA Primary Contact
Robin Webb, NOAA/OAR/ESRL PSD

NOAA Goal
Climate Adaptation and Mitigation

Description
The California National Integrated Drought Information System (NIDIS) Pilot will be planned and launched over the next two years. In this project, PI Steinemann will provide advice and support to NIDIS in the design, implementation, and evaluation of both the process and the pilot study, all while maintaining close collaboration with NIDIS personnel. In addition, the PI will actively coordinate and communicate with stakeholders, and keep the process moving forward, while managing numerous and diverse interests. Results of this work will contribute not only to California, but also to the larger NIDIS effort, ensuring innovations through the pilot study that can be transferable to the nation.

Objectives
To assist in the:
- ***Design of NIDIS pilot***
- ***Implementation of pilot***
- ***Evaluation of pilot***

Accomplishments
This is year two of a three-year project. These accomplishments relate to project objective 1 and project objective 2 for years one and two. Project objective 3 will be conducted during the final year of the project.

The first NIDIS Pilot meeting was held in September 2010 in La Jolla, California. Twenty-four participants representing federal, state, and local agencies attended, with input from fifteen additional contributors. The meeting began with three presentations: a NIDIS overview and update, a Pilot Drought Early Warning System in the Colorado River, and a Pilot Drought Early Warning System in the Southeast. This was followed by a structured round table discussion of existing drought information activities in California, and another on drought information needs in California.

Criteria for a Pilot Drought Early Warning System in California (Year 1 – Requirements and design of the California DEWS; Year 2 – Implementing and sustaining the California DEWS) were presented, followed by a discussion on opportunities for enhanced coordination of federal and state activities, and a brainstorming session on partnerships and stakeholder identification for designing and implementing the early warning system. Topics included

- Monitoring and forecasting
- Risk and impact assessment
- Preparedness, planning and communication
- Large scale water system partners
- Urban/local water supply partners
- Ecosystems and recreational resource partners

The second NIDIS Pilot meeting was held in Sacramento, California, on February 17, 2011. Thirty-seven participants representing federal, state, and local agencies attended. Results from the first (September 2010) meeting were presented, including a comprehensive list of existing drought information activities and drought information needs in California, selection criteria for possible Pilot Drought Early Warning Information System Projects, and potential areas to focus a NIDIS Pilot Drought Early Warning Information System in California Projects.

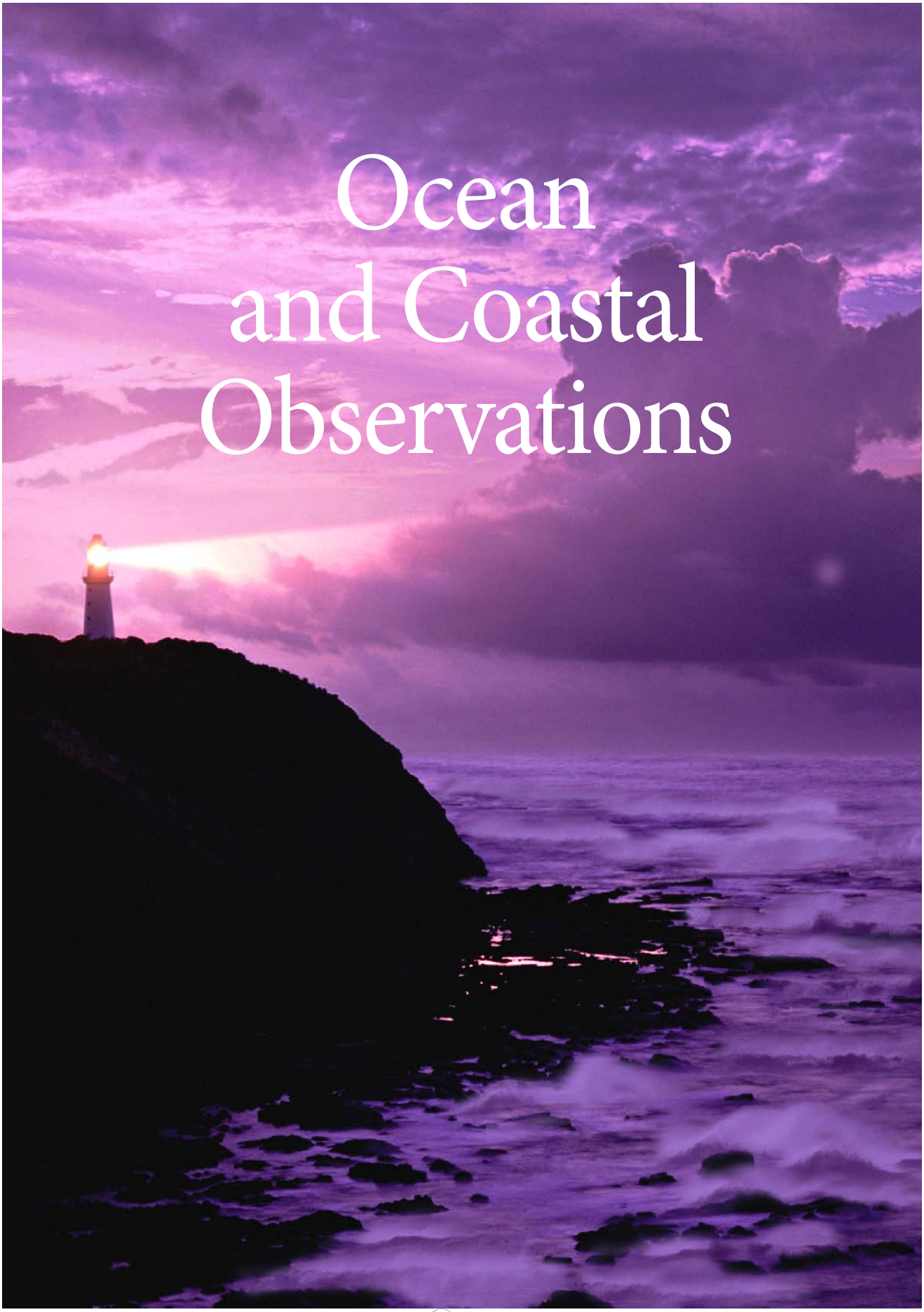
Participants discussed critical drought information needs and requirements. PI Steinemann helped guide decisions on determining priorities, and the group identified key additional partners needed for the NIDIS effort in California. The PI, presenters, and participants outlined the goal and mission of NIDIS, summarized existing NIDIS pilot activities, explored requirements and design for a drought early warning information system pilot within California, assessed criteria for selecting a NIDIS pilot within California, and identified additional key partners and stakeholders.

Participants highlighted a number of drought and water supply characteristics of California, ultimately providing an underlying context for identifying information needs across the state, including Scientific and Technical Needs, Institutional and Coordination Needs, Framing, Scoping, Developing and Implementing of NIDIS Pilot Activities. The group developed a list of potential geographic areas for a NIDIS pilot drought early warning system in California and explored potential metrics for tracking progress and measuring the success of California pilot activities. The meeting closed with plans to launch scoping workshops in the four regions aimed to gauge local stakeholder interest, support, and level of involvement in the development and implementation process.

PI Steinemann is providing coordination among the four NIDIS Pilot Activities in California (Southern California, Central Valley, Russian River, Klamath) by participating in meetings, working with the leaders and stakeholders in each Activity, and ensuring coordination, cohesion, and cross-learning among the Activities.

For details and more information, please visit the NIDIS website at: *http://www.drought.gov/portal/server.pt/community/california/California_Joint_Preplanning_Meeting*

Ocean and Coastal Observations



Pacific Marine Environmental Laboratory (PMEL) Ocean Climate Stations

PI
Nicholas Bond, UW — JISAO

Other UW Personnel
Keith Ronnholm, Jennifer Keene, JISAO

NOAA Personnel
Meghan F. Cronin, Christian Meinig, Chris Sabine, PMEL

Task II

NOAA Contact
Diane Stanitski, Climate Program Office

NOAA Goal
Climate Adaptation & Mitigation, Healthy Oceans

Description
High-quality, in situ reference time series are needed to assess uncertainties in the global analyses of air-sea exchanges of heat, momentum, and freshwater, ocean carbon uptake, surface currents and other important climate parameters. To this end, the Pacific Marine Environmental Laboratory (PMEL) Ocean Climate Station (OCS) program maintains two Ocean Sustained Interdisciplinary Time series Environmental Observatory (OceanSITES) reference stations: The Kuroshio Extension Observatory (KEO) at 32.3°N, 144.5°E and Station Papa at 50°N, 145°W (see Fig. 1).

The North Pacific OCS reference stations are in distinct oceanic regimes. The KEO mooring is located in the Kuroshio Extension recirculation gyre, which has some of the largest air-sea heat, moisture and carbon dioxide fluxes found in the entire basin. The Station Papa mooring is located in the Gulf of Alaska at the site where a weather ship was stationed from 1949-1981 and where the impacts of ocean acidification, resulting from increasing levels of atmospheric carbon dioxide, are expected to be felt first. Both the PAPA and KEO moorings were successfully refreshed in 2011.

The OCS stations were initiated during large collaborative process studies and have strong international partners. KEO was first deployed in June 2004 as part of the National Science Foundation (NSF) funded Kuroshio Extension System Study (KESS). At the conclusion of KESS, a partnership with the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) was formed and the mooring deployment and recovery operations have usually been performed on JAMSTEC cruises. Station Papa was initially funded through an NSF grant to Dr. Emerson (University of Washington) to study the North Pacific Carbon Cycle. At the conclusion of the NSF process study, NOAA Office of Climate Observations took over support of this site. Ship time for the Station Papa mooring has been provided by the Canadian Fisheries and Oceans Canada, Pacific Region, Line-P program.

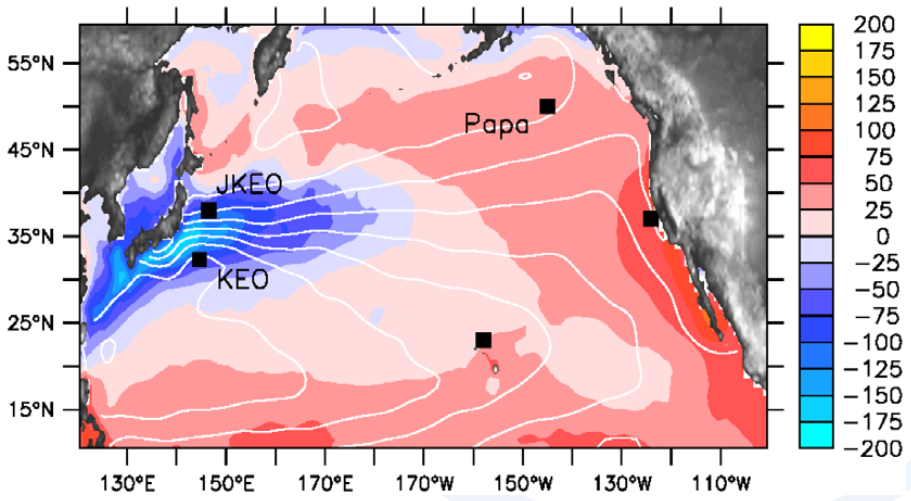


Figure 1. The network of OceanSITES reference stations in the North Pacific are shown relative to the mean net air-sea heat flux in Watts per meter squared and mean sea level height contours.

All OCS moorings carry a suite of sensors to monitor air-sea heat, moisture, momentum as well as the upper ocean temperature, salinity, and currents. The surface buoy also contains systems for measuring the carbon fluxes (CO_2) into or out of the ocean, and the associated effects on ocean acidification (pH measurements of surface water). Surface and subsurface data are telemetered to shore in near-realtime. OCS data are made available through the project website: *www.pmel.noaa.gov/OCS/* in a variety of formats, including ASCII and netCDF. In FY11, there were 192 download requests from the OCS data display and delivery page alone. The OCS data are also served through the PMEL OceanSITES Data Assembly Center (DAC) and the OCS group is working with National Data Buoy Center (NDBC) to make the data available also through the OceanSITES Global DAC (GDAC) in the standard OceanSITES format. A subset of the surface meteorological data are also made publicly available in near real-time through the Global Telecommunications System (GTS), used by operational data centers. The data serve a broad community of researchers and operational centers in the US and internationally.

Objectives

PMEL OCS stations contribute to the global network of OceanSITES reference stations. These stations provide high quality data that can be used:

1. ***to assess biases and uncertainties in forecasting model and observational product analyses;***
2. ***to detect rapid changes and episodic events, as well as long-term changes, in the climate system; and***
3. ***to identify mechanisms and relationships within the climate system***.

The OCS program's goals are to:

1. Obtain calibrated surface meteorological and subsurface temperature, salinity, and currents at the OCS stations
2. Provide access to OCS data and metadata through linked web pages in a standard format to encourage broad use of data
3. Contribute to the scientific understanding of the global climate system, through analysis of the reference data and analyses of numerical model or satellite products that have been validated against reference data.

For more detail on the OCS project, see: *http://www.pmel.noaa.gov/OCS*

Accomplishments

JISAO and NOAA scientists participated in 2 cruises during 2011 in support of the Papa and KEO stations. In June 2011, JISAO employee Keith Ronnholm, along with NOAA mooring specialist John Shanley and UW graduate student Seth Bushinsky, deployed a refresh of the Papa mooring at 50°N 145°W while onboard the Canadian Coast Guard Ship R/V *John P. Tully*. The prior mooring and all instruments were recovered, and will be refurbished and reused for a June 2012 deployment. Currently, all systems are functioning properly and real-time data are being telemetered from the buoy by the ATLAS, CO_2 and FLEX systems.

In November 2011, JISAO employee Jennifer Keene, along with NOAA mooring specialist J. Michael Strick and UW graduate student Seth Bushinsky, successfully recovered the KEO mooring and deployed a replacement mooring. Work was performed from the Military Sealift Command's salvage ship USNS *Safeguard*. The prior KEO mooring and all subsurface sensors were recovered, and the newly deployed system remains fully functional.

During the late summer and early fall 2011, the OCS group was assigned a new laboratory work space in Building 8 on the NOAA campus. Previously, the OCS working area was a shared corner of another group's lab. The new space is six times larger, and allows sensor and cruise preparation work to be done much more efficiently.

OCS web site pages were viewed a total of 11,800 times in the April 2011-Feb 2012 portion of the reporting period, and over 88 GB of text and data was downloaded by visitors. In addition, the OCS Data Display and Delivery page had 201 download requests, yielding 489 .ascii files and 173 .cdf files. Data was requested by users in government agencies (NOAA, NASA, DFO Canada, JAMSTEC, UK Met Office), universities (UW, UW/APL, JHU/APL, Scripts, MBARI, Univ of Cape Town, Univ of Tokyo, Imperial College London) and many more anonymous users. Usage descriptions included model, sensor and satellite data validation, assessment studies, mooring design, prediction, forecast verification, research (air-sea interactions, mixing processes, nutrient transport, mixed layer saturation), and student projects. The development of an integrated and improved website for the OCS project was begun during the period.

An ongoing project, begun in the FY12 reporting period, is the development of data processing procedures for the release of additional data in standardized formats from the moorings. Cronin participated in the OceanSITES meeting in San Diego in Dec 2011 to help determine the data formats and procedures for delivery of data in netCDF format and JISAO employee J. Keene has been coordinating this activity with NDBC.

The JISAO team has published four peer-reviewed articles; two peer-reviewed articles are in press, while two others are under review. Several more articles are currently in preparation, and two non-peer review articles were published or are In Press in professional newsletters. Cronin was lead author on a book chapter on "Ocean Reference Stations" that was published through InTech. As this is an open publisher, the book is freely available on the web to the general public, without need for professional society membership.

JISAO employee Nick Bond and NOAA PI Cronin participated in KIP/HotSpot meeting in Hawaii (Sept 2011) to discuss past results and future projects in the Kuroshio region east of Japan.

Cronin presented results of the "Ongoing time series at Station P" at the WCRP meeting in Denver in Oct 2011. The presentation showed all the collaborative projects that have resulted from the OCS mooring deployment at Station P, including enhancements of the OCS mooring with various biogeochemical sensors to monitor the carbon cycle and ocean acidification (PIs: S. Emerson, C. Sabine), butterfly surveys around the OCS mooring by a UW underwater glider (PI: C. Eriksen) that will be used to analyze the carbon export from the upper ocean (Pelland PhD dissertation in prep.), deployment of a nearby ADCP mooring (PIs: Alford, Cronin, Klymak) to analyze deep penetration of near-inertial waves at Station P (Alford et al. 2011), and deployment of a nearby surface waverider mooring (PIs: E. D'Asaro, J. Thomson, R. Harcourt) to analyze the impact of waves on the ocean mixed layer.

Bond and Cronin presented three talks at the Ocean Sciences meeting in Salt Lake City in Feb 2012. Topics included the use of KEO data to determine which type of storms are most effective at exciting oceanic near-inertial waves, the influence of these near-inertial waves on ocean mixing and the formation and erosion of the seasonal thermocline at KEO, and a vision of ocean observations in 2030. Cronin was a session convener for the "Air-sea interaction in western boundary currents and marginal seas" session and organized a Kuroshio Extension group dinner with more than 90 US and Japanese scientists (including Cronin and Bond).

JISAO team members participated in the Line-P workshop held in Sydney, B.C. in March 2012. The purpose of this workshop was to help coordinate work on the upcoming Line-P cruises (JISAO will participate in the June 2012 cruise), and to foster collaboration with Line-P and Station P data. Several publications using the Station P mooring data are underway and one publication led by UW scientist Emerson, quantifying the flux of $CaCO_3$ and organic carbon from the surface ocean using in situ measurements of O_2, N_2, pCO_2 and pH, was published in 2011.

The Argo Project: Global Observations for Understanding and Prediction of Climate Variability

PI
Stephen C. Riser, UW — Oceanography

Other UW Personnel
Dana Swift, Annie Wong, Anil Rupan, Dale Ripley, Alison Rogers, Tyler Hennon, Oceanography

Task III

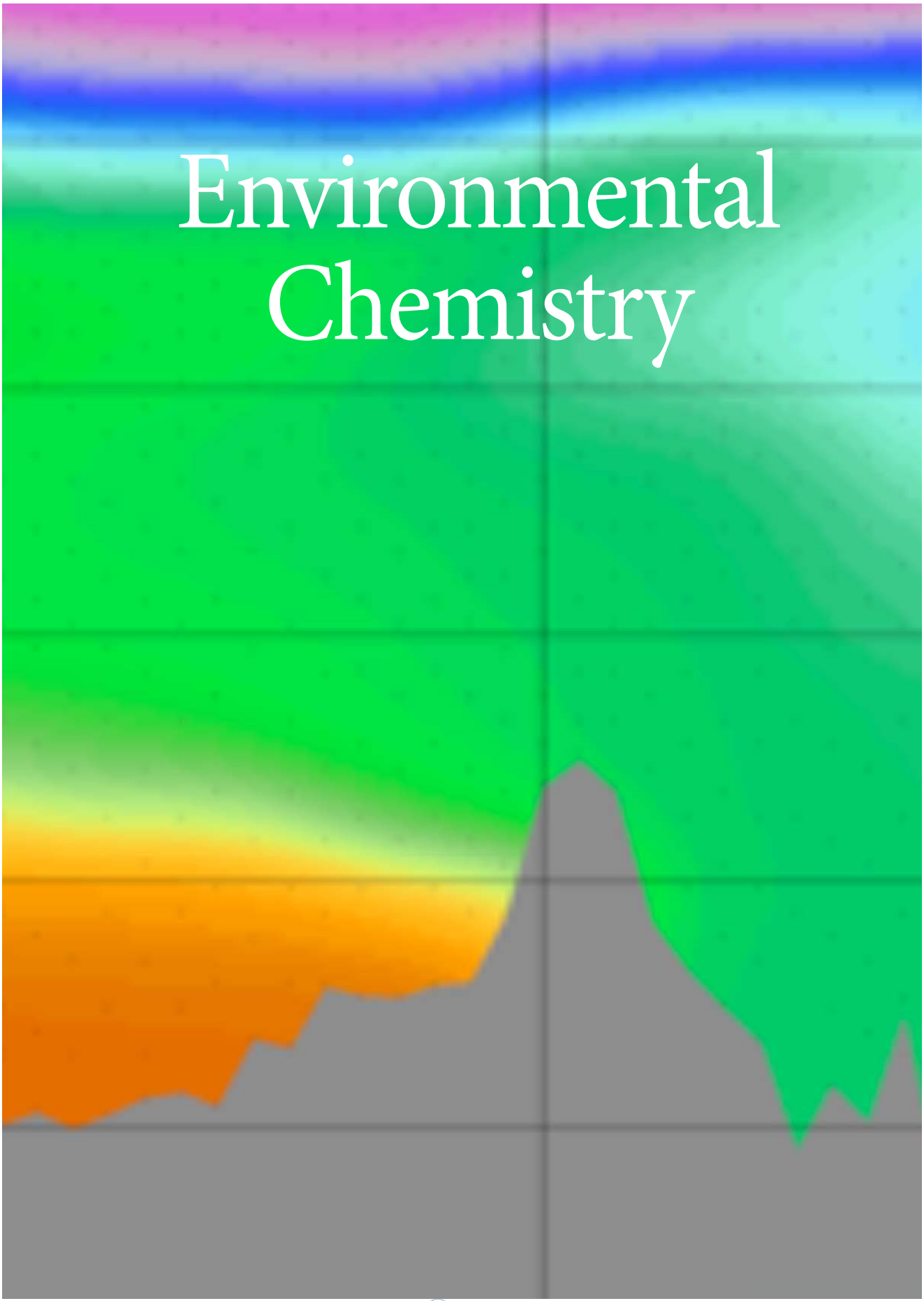
NOAA Contact
Steve Piotrowicz, OAR-CPO

NOAA Goal
Climate Adaptation & Mitigation, Healthy Oceans

Description
Argo is an international project that has deployed over 3,000 profiling floats in the world ocean since the year 2000. Each of these floats collects temperature and salinity profiles at about 10 day intervals, between the ocean surface and a depth of 2,000 m, and transmits the data to shore stations in real-time while on the sea surface. Over thirty countries are now participating in Argo, with the US providing about half the total number of floats. The University of Washington (UW) is one of four US sites that provide Argo floats. In addition to constructing and deploying floats, the UW group carries out delayed-mode adjustment of the salinity data collected by the UW floats, and the project PI, Dr. Stephen Riser serves as a member of the US and International Argo Steering Teams.

Objective
To continue participation in the Argo program. This international program is designed to deploy 3,000 profiling floats in the world ocean (approximately 300 km resolution over the globe) that will collect profiles of temperature and salinity over the upper 1,000 m of the world ocean at approximately 10 day intervals. This is the first subsurface global ocean observing system. The US is committed to providing about half of these floats. For the past several years, the US has been providing over 300 floats per year, split among four institutions (SIO, WHOI, PMEL, and UW). In the past year funds were received to build and deploy 110 floats. The UW floats were deployed in the Indian Ocean, the Antarctic, the Atlantic, and the Pacific. Most continue to operate as designed for at least four 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, long-term (decade to century) scale of variability of salinity in the North Pacific, and the circulation and heat and freshwater balances near Antarctica.

Accomplishments
During the past year, the team deployed 161 profiling floats as part of Argo, the largest number of any float group in the world. Floats were deployed in the Atlantic, Pacific, and Indian Oceans, as well as around Antarctica. Some of the UW floats in the Antarctic have now been operating for 5 winter seasons. Some of the floats deployed in the past year (about 15) were deployed in the Southern Ocean, for the third year in a row. These floats used new software that allowed them to operate for extended periods under seasonal Antarctic ice. All of the Antarctic floats used the Iridium communication system, and many carried dissolved oxygen sensors.


Environmental
Chemistry

Standardization of Methods to Quantify Marine Microdebris: Laboratory Intercomparison and the Development of Polymer Composition, Size, and Shape as Indicators of Sources of Marine Microplastics

PI
Joel Baker, UW Tacoma — Center for Urban Waters

Other UW Personnel
Julie Masura, UW Tacoma Center for Urban Waters, Giora Proskurowski, School of Oceanography

NOAA Personnel
Courtney Arthur, Marine Debris Program

NOAA Contact
Courtney Arthur, Marine Debris Program

NOAA Goal
Resilient Coastal Communities & Economies

Description
This work continues a research program on the occurrence, sources, and potential impacts of marine microplastic debris begun with NOAA funding in 2008. During the reporting period, we participated in a number of workshops (e.g., PICES in Khabarovsk, GESAMP in Paris) and continued collaborations with scientists at other institutions interested in participating in the laboratory intercomparison exercise. This exercise is planned for Summer 2012. Also during the reporting period we established a FTIR-based microplastic characterization method in our laboratory, using Puget Sound samples to initially evaluate operational details of the method.

Objectives
1. ***To conduct a laboratory intercomparison of methods used to quantify microplastics in marine samples***
2. ***To develop methods to characterize the size, shape, and polymeric composition of individual microplastic particles***

Accomplishments
We have developed a standardized protocol for assessing the size, shape, and polymeric composition of marine microplastic particles, using a new FTIR instrument installed at the University of Washington Tacoma Environmental Science laboratory. During Summer/Fall 2011, two test samples were evaluated to demonstrate the utility and practicality of the method. This method will be used in Summer 2012 to characterize archived samples from the Sea Education Association (SEA) collection.

Developmental work was conducted during the reporting period to create a 'standard reference material' type sample for use in the upcoming interlaboratory comparison.

Atmospheric Chemistry - Aerosol Program

PI
David Covert, UW — Department of Atmospheric Sciences

Other UW Personnel
Drew Hamilton, James Johnson, JISAO

NOAA Personnel
Tim Bates, Patricia Quinn, Derek Coffman, Kristen Schulz, Pacific Marine Environmental Laboratory (PMEL)

Task II

NOAA Contact
A.R. Ravishankara, Climate Program Office

NOAA Goals
Climate Adaptation & Mitigation

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.

Objectives
1. ***To assess the regional climate and air quality impacts of atmospheric aerosol particles through measurements of their physical, chemical, radiative, and cloud nucleating properties.***
2. ***To improve our capability to observe, understand, predict, and protect the quality of the atmosphere through national and international partnerships.***

Accomplishments
1. The oceans are a major source of aerosol number and mass to the atmosphere. In the marine boundary layer (MBL) over remote oceans, most of the aerosol mass is comprised of coarse-mode sea-salt particles. These particles dominate aerosol light scattering but contribute little to the aerosol number concentration. The source and composition of the particles that comprise most of the aerosol number concentration varies, adding uncertainty to cloud condensation nuclei (CCN) concentrations and aerosol/cloud/climate models. Atmospheric aerosols over the ocean include primary particles directly emitted from the ocean and associated reaction products, particles produced in the atmosphere via nucleation and growth pathways, and particles mixed into the MBL from the free troposphere. It is difficult to distinguish between these three sources based on measurements of ambient aerosol. Characterization of particles freshly emitted from the ocean surface requires a sampling method that is able to isolate those particles and prevent them from interacting with ambient gases and particles. Here we report measurements of particles directly emitted from the ocean using a newly developed in-situ particle generator (Sea Sweep). The Sea Sweep was deployed alongside *RV Atlantis* off the coast of California during May of 2010. Bubbles were generated 0.75 m below the ocean surface with stainless steel frits and swept into a hood/vacuum hose to feed a suite of aerosol instrumentation on board the ship. The number size distribution of the directly emitted, nascent particles had a dominant mode at 55-60 nm (dry diameter) and secondary modes at 30-40 nm and 200-300 nm. The aerosol was not volatile at 230°C. This temperature rules out ammonium sulfate and nitrate as significant components of the nascent aerosol but does not distinguish between particulate organic matter and sea salt. The nascent aerosol was not enriched in Ca^{++}, K^{+}, or Mg^{++} above that found in surface seawater. The organic component of the nascent aerosol (6% of the dry submicrometer mass) volatilized at a temperature between 230 and 600°C. The submicrometer organic aerosol characterized by mass spectrometry was dominated by non-oxygenated hydrocarbons. The nascent aerosol at 50, 100, and 145 nm dry diameter behaved hygroscopically like an internal mixture of sea salt with a small organic component. The nascent organic aerosol mass fraction did not increase in regions of higher surface seawater chlorophyll but did show a positive correlation with seawater dimethylsulfide (DMS). A manuscript describing these results was submitted to the Journal of Geophysical Research in Feb. 2012.

2. Model estimates indicate that black carbon (BC) transport to the Arctic and deposition to the surface contributes to the warming of the Arctic through darkening of the surface, enhanced absorption of solar radiation, and melting of snow and ice. The PMEL/JISAO atmospheric chemistry group conducted the Soot Transport and Deposition Study (STADS) in Svalbard, Norway in April 2011 as part of the Coordinated Investigation of Climate-Cryosphere Interactions campaign (CICCI). The primary goal of the campaign was to provide a measurement-based assessment of black carbon-snow albedo forcing. The NOAA/PMEL MANTA Unmanned aerial systems (UAS) were used to measure particle number concentration and light absorption aloft. A total of 18 flights were flown during the campaign totaling 38 flight hours. The data show frequent aerosol layers aloft with high particle number concentration (1000 cm^{-3}) and enhanced aerosol light absorption (1 Mm^{-1}). Complementary ground-based measurements were made of aerosol light absorption, light extinction, and chemical composition. In addition, snow samples were collected and analyzed for light absorbing aerosol content and chemical composition. These data, combined with FLEXPART aerosol dispersion modeling, were used to assess sources of BC to the Arctic, processes controlling its deposition to the surface, and radiative impacts.

3. The PMEL/JISAO atmospheric chemistry group conducted aerosol measurements during October-December, 2011 aboard the R/V Revelle as part of the DYNAMO field campaign. Our objective was to improve the understanding of the effects of aerosol particles on clouds and radiation transfer over the equatorial Indian Ocean. Aerosols in this region have both natural (ocean-derived) and anthropogenic (continental) sources as the Inter-Tropical Convergence Zone (ITCZ) can extend well south of the equator during the dry winter monsoon season allowing for transport of air masses from the Indian subcontinent to the DYNAMO region. The Indo-Asian haze that spreads over the region north of the ITCZ has a major impact on the regional radiative forcing. During INDOEX the low-level heating induced by the aerosol haze led to enhanced moist convection and strengthened the rainfall along the ITCZ. Aerosol data are thus essential to understanding the radiation budget and evolution of the cloud population (DYNAMO hypothesis II) in this region.

4. In January/February 2012 the PMEL/JISAO atmospheric chemistry group conducted aerosol measurements in Vernal, Utah as part of the Uintah Basin Winter Ozone Study. The purpose of this study was to advance an understanding of the chemical processes that control winter ozone formation and its sensitivity to VOC and NOx. This includes radical species that initiate the formation of ozone and heterogeneous processes, including snow and aerosol photochemistry that might produce radical precursors. The data will be used to develop mitigation strategies to reduce the high ozone concentrations in the Basin.

5. Modeling work is continuing with UW Department of Atmospheric Sciences faculty and doctoral students as well as with NOAA CIRES scientists using data collected by NOAA PMEL and UW scientists on the NOAA R/V *R. H. Brown* as input to and validation of modeling studies.

The International Global Atmospheric Chemistry (IGAC) Core Project Office

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Other UW Personnel
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Tasks II and III

NOAA Contact
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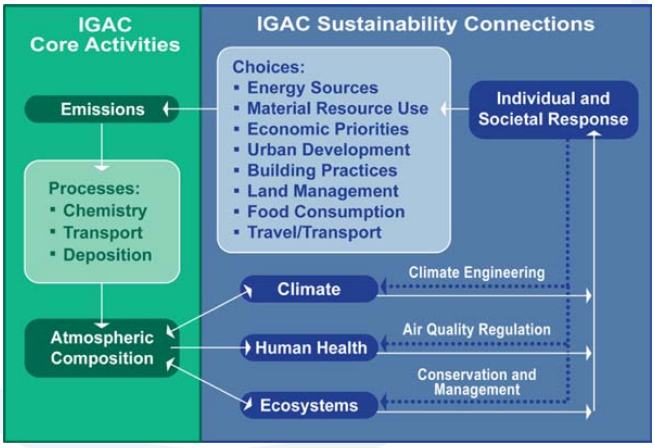
NOAA Goal
Climate Adaptation & Mitigation

Description
The International Global Atmospheric Chemistry (IGAC) project is jointly sponsored by the International Geosphere-Biosphere Programme (IGBP) and the international Commission on Atmospheric Chemistry and Global Pollution (iCACGP) of the International Association of Meteorology and Atmospheric Sciences (IAMA). IGAC's mission is to promote and facilitate international atmospheric chemistry research that addresses societal needs in order to achieve global sustainability. IGAC activities are conducted through the Core Project Office under the guidance of an international volunteer Scientific Steering Committee (SSC) and IGAC's parent organizations IGBP and iCACGP. The IGAC Core Project Office is hosted by JISAO and funded by NASA, NOAA, and NSF. IGAC carries out its activities via four main pathways:

1. ***Leading and endorsing proposed activities:*** The SSC identifies areas within atmospheric chemistry research that need to be addressed and promotes and facilitates international atmospheric chemistry research in the identified areas. Each sponsored activity is outlined by a specific set of goals that provide a structure for the activity to flourish.
2. ***Sponsorship of national/regional working groups:*** IGAC sponsors national/regional working groups that aim to facilitate the coordination of research both within the nation/region and between the nation/region and the international atmospheric chemistry community.
3. ***Co-sponsorship of workshops:*** IGAC co-sponsors focused workshops on specialty topics that typically produce a tangible outcome, such as a journal publication(s) or research plan(s).
4. ***Communications/Networking:*** This covers a myriad of activities, including biennial conferences, a recently reformatted newsletter (mailed or sent electronically to ~4000+ researchers around the world), a completely redesigned webpage that enhances community interaction, and various networking activities conducted throughout the year.

Objectives
As IGAC enters its third phase, in response to the Future Earth Initiative, its mission is to coordinate and foster atmospheric chemistry research towards a sustainable world. This is achieved by integrating, synthesizing, guiding, and adding value to research undertaken by individual scientists through initiating new activities, acting as a hub of communication for the international atmospheric chemistry research community, and through building scientific capacity. More specifically, IGAC's core activities, which focus on emissions, atmospheric processes, and atmospheric composition, will integrate more closely with sustainability issues. These issues include climate, human health, ecosystems, and the way in which individual and societal responses reflect the core research-led activities of IGAC. IGAC believes by viewing the environment as a resource and the basis of energy and economic activities, human wellbeing can be sustained. This strategy has been outlined in the figure below.



Accomplishments

2011 Conferences and Workshops

- **ACCMIP 1st Workshop**
  13-15 April 2011
  Toulouse, France
    - This was the first workshop for this activity, which provided summaries of the status of different model simulations. The first set of model runs were completed this past year, and the results of the data were presented at this workshop. A follow-up workshop will be held in February 2012 in Pasadena, CA, USA conjoined with a HTAP meeting.

- **AICI 3rd Workshop**
  6-7 June 2011
  New York, NY USA
    - 3rd Workshop on AICI discussed new research from AICI studies, including Ocean-Air-Sea Ice-Snow (OASIS) project, Halogens in the Troposphere (HitT) and the International Polar Year (IPY)
    - Workshop dialogue established emphasis towards understanding AICI in a changing environment and also advancing snow chemistry modelling to eventually interface with Earth System models
    - Currently in preparation are review articles to be published and featured in a joint special issue between Atmospheric Chemistry and Physics, and Earth System Science Data called "New Perspectives on Air-Ice Chemical Interactions (AICI)"

- **Air Pollution & Climate: Tackling the Air Pollution and Climate Change Challenge**
  9-10 June 2011
  Arona, Italy
    - The purpose was to discuss the development of a science-policy dialogue that addresses the Air Pollution and Climate Change Challenge.
    - 22 attendees, representing 13 countries, from all backgrounds of science-policy experience.
    - Created an arena for policy and scientific communities to come together and combine efforts towards addressing issues from an integrated perspective.

- **First International Workshop on the Long-Range Transport & Impacts of African Dust on the Americas**
  7 October 2011
  San Juan, Puerto Rico,
    - Specialists presented on topics relating to long-range transport and impacts of African dust on the Americas
    - Workshop designed to promote discussions and improve knowledge about the research of African dust, its transport and chemical reactions, as well as its impact on climate, health, and ecosystems.

- **AC&H: Current Knowledge and Future Directions**
  12-14 October 2011
  Boston, MA, USA,
    - Brought together leaders in the atmospheric chemistry, epidemiology, and toxicology communities.
    - Identified the key scientific question at the interface of atmospheric chemistry and air pollution health effects
    - Identified key areas in which integrated research is needed.
    - Discussed the benefits for scientific research and environmental and health policy that would accrue from dealing with air pollution and atmospheric chemistry in a more integrated way.

- **Air Pollution & Climate: A Science-Policy Dialogue in Asia**
  7-10 November 2011
  Taipei, Taiwan
    - Follow-up workshop to the first Air Pollution & Climate Initiative workshop in Arona, Italy with a focus on Asia
    - Participants also took part in a one-day symposium with Taiwanese scientist and policy makers
    - The outcome of the workshop will be an IGBP Statement on the Air Pollution and Climate Change Opportunity to be released at the Planet Under Pressure Conference in March 2012.

Communication and Outreach

- IGAC has a completely redesigned newsletter, which is mailed to over 4000 researchers around the globe. Electronic versions of our newsletter and updates regarding IGAC activities and conferences are sent out to ~2500 via our new mail service with MailChimp. IGAC's completely redesigned website (*www.igacproject.org*) was created to provide ease of communication and accessibility to the IGAC community.
- To compliment the new website, IGAC has invested significant effort into creating meaningful logos for long-lasting activities and working groups.
- IGAC sponsored a meeting for the IGAC/WMO Assessment of Atmospheric Chemistry in Megacities Initiative. The initiative is in the final stages of writing an assessment on atmospheric chemistry in megacities. The assessment will be published summer 2012.
- IGAC is now sponsoring the first IGAC National Working Group in China. This working group will encourage participation of Chinese atmospheric scientists to fully engage their leadership in international atmospheric chemistry research programs.

Nutrients

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NOAA Goal
Healthy Oceans

Description
The Repeat Hydrography CO_2/tracer Program is a systematic and global re-occupation of select hydrographic sections to quantify changes in storage and transport of heat, fresh water, carbon dioxide (CO_2), chlorofluorocarbon tracers and related parameters. It builds upon earlier programs (e.g., World Ocean Circulation Experiment (WOCE)/Joint Global Ocean Flux Survey (JGOFS) during the 1990s) that have provided full depth data sets against which to measure future changes, and have shown where atmospheric constituents are entering the oceans. The Repeat Hydrography CO_2/tracer Program will reveal much about internal pathways and changing patterns that will impact the carbon sinks on decadal time scales.

Goals
The primary goal is to assess changes in the ocean's biogeochemical cycle in response to natural and/or man-induced activity. For example, global warming-induced changes in the ocean's transport of heat and freshwater could affect the circulation by decreasing or shutting down the thermohaline overturning. Because the Argo array has a depth range of 2000 m, repeat hydrographic measurements are the only global measurement program capable of observing these long-term trends deep in the ocean.

Objectives
1. ***To make high-quality measurements of inorganic nutrient (nitrate, nitrite, phosphate and silicate) concentrations in seawater on CLIVAR repeat hydrographic cruises.***
2. ***Perform data quality control.***
3. ***Make this data available to the climate and carbon research community.***

The data are used for:

- Measuring spatiotemporal trends in biogeochemical properties
- Model calibration and validation
- Carbon inventory and transport estimates
- Deep and shallow water mass and ventilation studies

Accomplishments
The team was responsible for nutrient analysis on the Repeat Hydrographic Line A10 in the Atlantic Ocean. P. Proctor participated on the cruise, and conducted high precision shipboard analysis of phosphate, nitrate, nitrite and silicic acid on 2736 samples collected from the CTD rosette at discrete depths (see sections below). Quality control of the data set is being completed, and final data will be available and archived at the CCHDO website: *http://ushydro.ucsd.edu/cruise_data_links.htm*. These nutrient data will be compared with nutrient measurements made on earlier expeditions along the same section: a *Meteor* cruise in 1992/1993, and a *Mirai* cruise in 2003. These data allow us to detect decadal scale changes in physical and biogeochemical processes in the region, are a necessary component of many techniques quantifying decadal uptake of anthropogenic carbon dioxide into the ocean, and provide important data constraints on the rates of biological cycling in the South Atlantic Ocean.

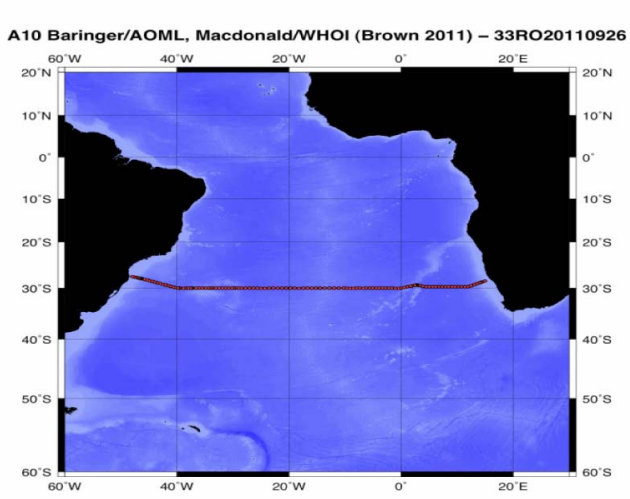

Figure 1. Cruise track of the CLIVAR repeat hydrographic cruise A13.5 with station numbers in blue.

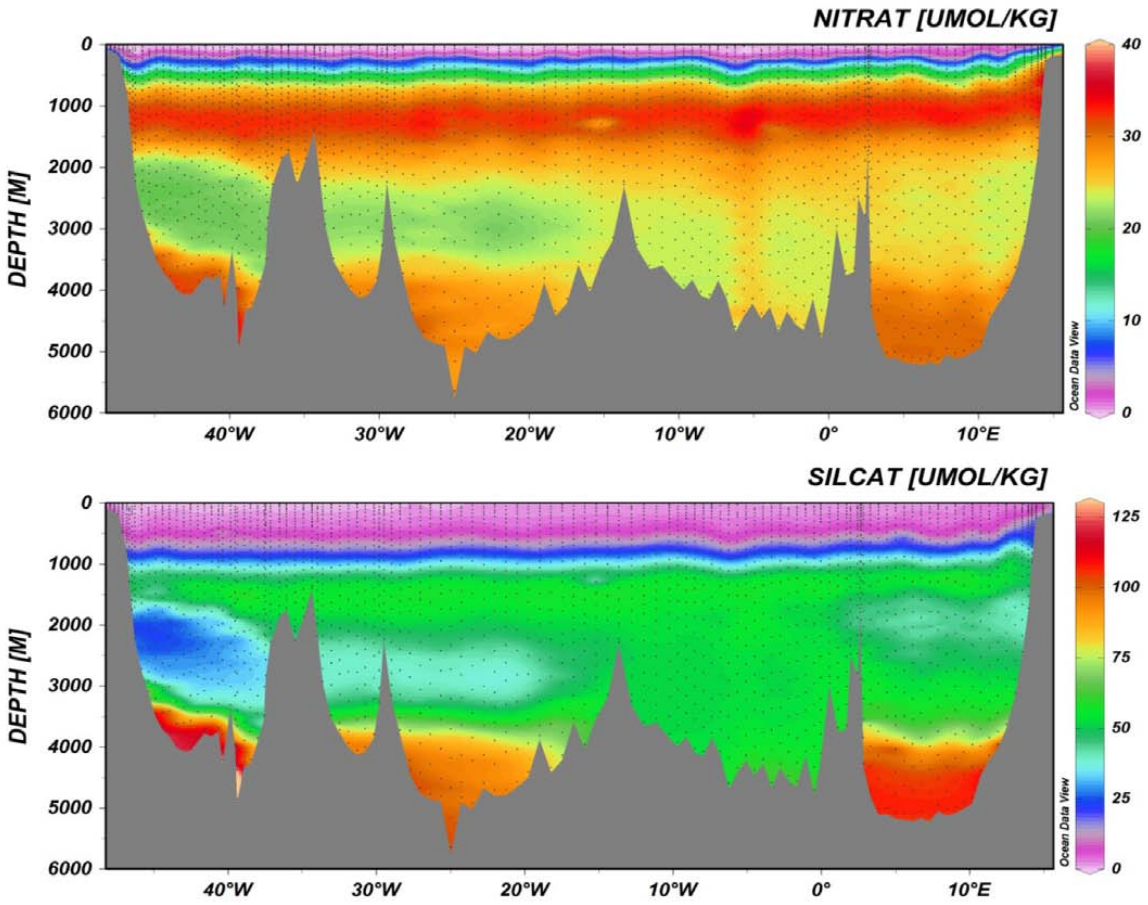

Figure 2. Sections of nitrate (top) and silicic acid (bottom) along the A10 cruise track.

Tropical Atmosphere-Ocean Interaction

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NOAA Goals
Climate Adaptation and Mitigation

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. Scientists in JISAO and at PMEL maintain the TAO array in collaboration with NOAA's National Data Buoy Center. In combination with the TRITON array maintained by Japanese scientists in the western Pacific, the TAO array is comprised of 70 moorings at 11 different longitudes, spanning the equator from 8°S to 8°N. Data from the array are used for ENSO forecasting and a variety of oceanographic and climate research studies. The array also 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 biogeochemical measurements. Ships servicing the TAO array provide a platform for the regular launch of Argo floats and drifting buoys.

Complementing the TAO array in the tropical Pacific is the Prediction and Research Moored Array in the Tropical Atlantic (PIRATA), maintained by PMEL and JISAO scientists in collaboration with NOAA's Atlantic Oceanographic and Meteorological Laboratory and 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. In addition, PMEL and JISAO scientists, along with members of the international community, are engaged in developing an Indian Ocean moored buoy observing system for monsoon research and forecasting. This system is called the Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA). TAO Project Office at PMEL manages PIRATA and RAMA and is responsible for providing much of the scientific instrumentation in TAO. Together TAO/TRITON, PIRATA and RAMA comprise the Global Tropical Moored Buoy Array. Research related to several aspects of ocean-atmosphere interaction and the role of the ocean in climate is conducted within this programmatic framework.

Goals
1. Ensure high quality and timely access to moored time series data for climate research.
2. Contribute to our understanding of the ENSO cycle, the monsoons, and tropical Atlantic climate variability.
3. Advance the understanding of decadal variability and trends in the tropics.
4. Establish RAMA in the Indian Ocean for climate studies.

Objectives

1. ***Maintain and enhance the TAO web pages.***
2. ***Increase the number of ATLAS moorings in RAMA and maintain an array of ADCP moorings as part of a process study within the context of RAMA.***
3. ***Improve understanding of the ENSO cycle in the Pacific.***
4. ***Advance understanding of the dynamics of ocean circulation in the Indian Ocean.***
5. ***Improve understanding of the coupling between the Atlantic Meridional Mode and Atlantic Niños.***
6. ***Define decadal time scale variations of the North Brazil Current and their relation to the Atlantic Merdional Overturning Circulation***
7. ***Investigate role of African dust in tropical Atlantic climate variability***

Accomplishments

1. Research carried out at JISAO and elsewhere using data from the TAO/TRITON, PIRATA and RAMA 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 1, 2011, and February, 22, 2012, TAO web pages received more than 9 million hits and delivered more than 200,000 mooring data files to the international community. We also developed a new set of web pages specifically for RAMA, highlighting the international partnerships involved and progress towards implementation of this new observing system.

2. Since last year's report we deployed 2 new ATLAS Flux moorings in the Indian Ocean: at 12°S, 93°E from the Indonesian research vessel *Baruna Jaya3* in March 2011 and at 16°S, 81°E from the Indian research vessel *Sagar Nidhi* in June 2011. These moorings represent progress in a developing RAMA, which is now 65% complete. As the ATLAS system ages, several key components have gone out of production and replacements have been difficult to locate. At the same time, new and improved sensors have become commercially available. PMEL has developed a new instrument system, dubbed Tropical Flex, or T-Flex, for use with ATLAS mooring hardware. Two prototype systems were deployed in 2011, one in PIRATA and one in RAMA.

3. We addressed the question of whether the increased occurrence of Central Pacific (CP) vs Eastern Pacific (EP) El Niños is consistent with greenhouse gas forced changes in the background state of the tropical Pacific as inferred from global climate change models. Our analysis used high quality satellite and in situ ocean data combined with wind data from atmospheric reanalyses for the past 31 years (1980-2010). We found that changes in background conditions are opposite to those expected from greenhouse gas forcing in climate models and opposite to what is expected if changes in the background state are mediating more frequent occurrences of CP El Niños. A plausible interpretation of these results is that the character of El Niño over the past 31 years has varied naturally and that these variations projected onto changes in the background state because of the asymmetric spatial structures of CP and EP El Niños. Results were published in McPhaden et al (2011).

4. Variability in the equatorial Indian Ocean on intraseasonal time scales (defined as periods of 30-110 days) was investigated using satellite and in situ observations and a simple analytical linear long wave equatorial β-plane model. Despite the extreme simplicity of the model, which includes just the two gravest baroclinic mode Kelvin waves and first meridional mode Rossby waves, simulated surface zonal velocity and sea surface height compared very well with observations. Both observations and model are characterized by a red shift in the velocity spectrum relative to the wind forcing spectrum, which is attributable to a combination of factors including: 1) the resonant excitation of Kelvin waves by eastward propagating winds; 2) constructive interference between wind-forced waves and waves reflected from the eastern boundary; and 3) the favored excitation of low frequency waves whose zonal wavelengths are long compared to the zonal fetch of the wind. We decomposed variability in two broad period bands, namely 30-70 days and 70-110 days for detailed analysis. At periods of 30-70 days, velocity tends to be stationary in the zonal direction along the equator due to the competing contributions of Kelvin and Rossby waves. In contrast, at 70-110 day periods, zonal velocity propagates westward despite eastward propagation of zonal wind stress because of the predominant influence of reflected and wind

forced Rossby waves. Kelvin waves reflected from the western boundary are negligibly small, indicating that basin mode resonances are not prominent as has been previously suggested. Results were published in Nagura and McPhaden (2012).

5. In the first half of 2009, anomalous cooling of sea surface temperatures (SSTs) in the equatorial North Atlantic triggered a strong Atlantic meridional mode event. During its peak in April–May, SSTs in the equatorial North Atlantic were 1°C colder than normal and SSTs in the equatorial South Atlantic (0°-5°S) were 0.5°C warmer than normal. Associated with the SST gradient were anomalous northerly winds, an anomalous southward shift of the intertropical convergence zone, and severe flooding in Northeast Brazil. We used in situ and satellite observations to examine the mechanisms responsible for the anomalous cooling in the equatorial North Atlantic during boreal winter and spring of 2009. It was found that the cooling was initiated by stronger than normal trade winds during January and February 2009 associated with an anomalous strengthening of the subtropical North Atlantic high pressure system. Between 6° and 12°N, unusually strong trade winds cooled the ocean through wind-induced evaporation and deepened the mixed layer anomalously by 5–20 m. Closer to the equator, surface equatorial winds responded to the anomalous interhemispheric SST gradient, becoming northwesterly between the equator and 6°N. The anomalous winds drove upwelling of 0.5–1 m day^{-1} during March–April, a period when there is normally weak downwelling. The associated vertical turbulent heat flux at the base of the mixed layer led to unusually cool SSTs in the central basin, further strengthening the anomalous interhemispheric SST gradient. These results emphasize the importance of mixed layer dynamics in the evolution of the meridional mode event of 2009 and the potential for positive coupled feedbacks between wind-induced upwelling and SST in the equatorial North Atlantic. Results were published in Foltz, McPhaden, and Lumpkin (2012).

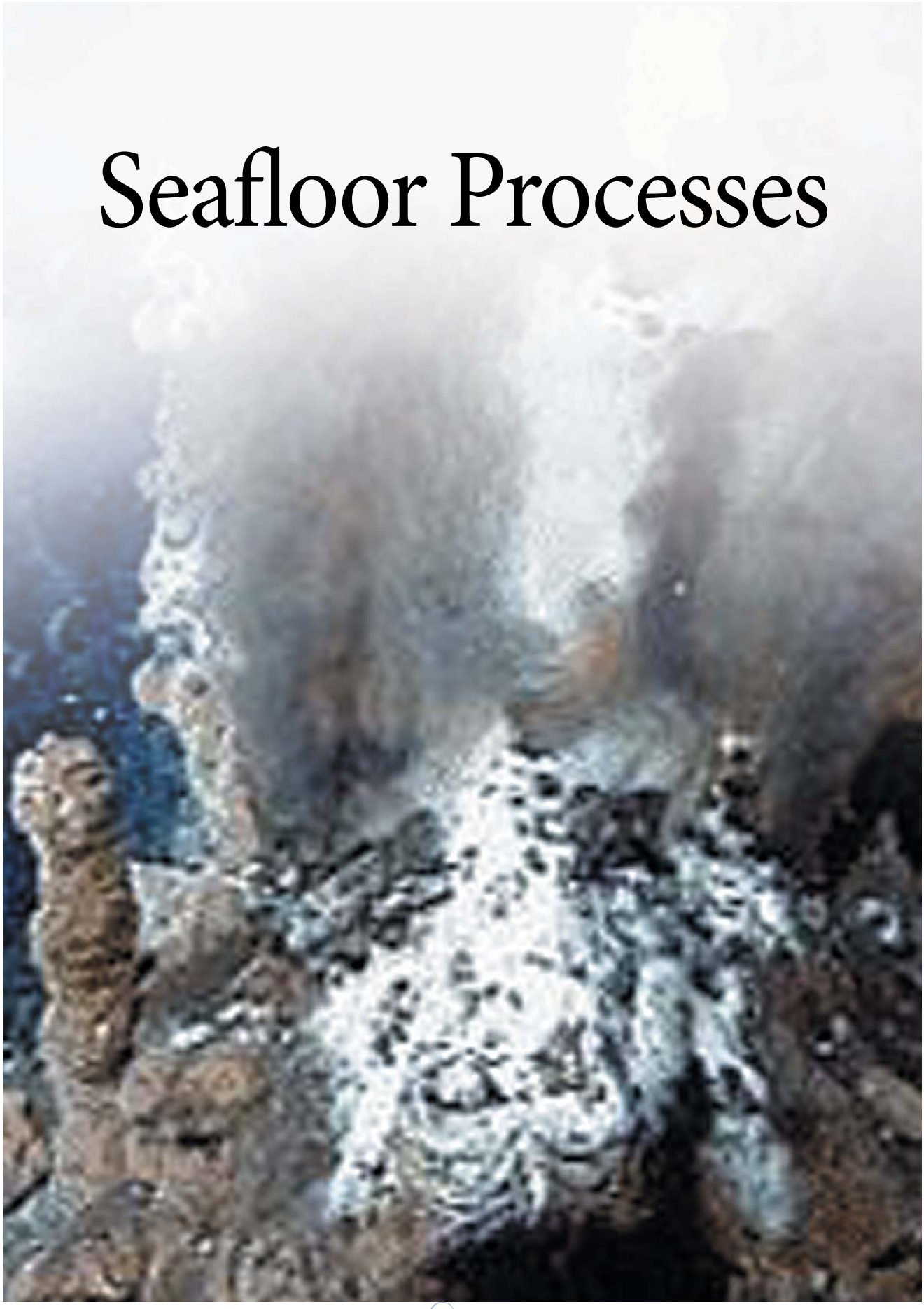
6. We performed an in-depth data analysis to understand the occurrence of a high sea surface temperature (SST) front in the central Bay of Bengal before Cyclone Nargis (2008). Nargis changed its course after encountering the front and tracked along the front until it made landfall. One unique feature of this SST front was its coupling with high sea surface height (SSH), which is unusual for a basin where SST normally decorrelates with SSH. The study proposed that the interaction between Rossby waves and surface fresh water convergence was a key mechanism for this unusual coupling. This work was published in the Journal of Phyiscal Oceanography (Yu and McPhaden, 2012).

7. Subtropical western boundary currents are warm, fast-flowing currents that form on the western side of ocean basins. They carry warm tropical water to the mid-latitudes and vent large amounts of heat and moisture to the atmosphere along their paths, affecting atmospheric jet streams and mid-latitude storms, as well as ocean carbon uptake. The possibility that these highly energetic currents might change under greenhouse-gas forcing has raised significant concerns, but detecting such changes is challenging owing to limited observations. We used reconstructed sea surface temperature datasets and century-long ocean and atmosphere reanalysis products to find that the post-1900 surface ocean warming rate over the path of these currents is two to three times faster than the global mean surface ocean warming rate. The accelerated warming is associated with a synchronous poleward shift and/or intensification of global subtropical western boundary currents in conjunction with a systematic change in winds over both hemispheres. This work was published in Nature Climate Change (Wu et al, 2010) and generated considerable interest in the press. It was also featured in a "News and Views" article in the issue in which it appeared.

8. The usefulness of NBC to track low frequency variability of AMOC (Zhang et al. 2011) is further examined in newly available IPCC AR5 models. All models suggest excellent correlation (above 0.8) between the NBC and AMOC in the tropical Atlantic and that the NBC can be used to detect future AMOC trends. Further, we found that the decadal salinity anomaly in the western subtropical Atlantic influences the northeastern subpolar North Atlantic. This decadal salinity variation was attributed to the interaction of AMOC and northern Atlantic Subtropical Cell. Results were presented in the World Climate Research Program Open Science Conference in Denver, October 2011 and AGU/Ocean Science Meeting in Salt Lake City, February 2012.

9. The dominant source of coupled ocean–atmosphere variability in the tropical Atlantic is the so-called Atlantic Meridional Mode. This mode of variability is characterized by an interhemispheric gradient in sea surface temperatures and by oscillations in the strength of surface winds that cross the Equator, thereby reinforcing sea surface temperature anomalies. The Atlantic Meridional Mode is thermodynamically damped and must receive external forcing to persist as observed. However, it is not known which external forcing factors have excited the Atlantic Meridional Mode in the historical record. We conducted simulations with an ocean general circulation model that is forced by a record of surface radiation from anomalous dust concentrations in the atmosphere, reconstructed from a coral proxy and satellite retrievals. We show that the Atlantic Meridional Mode is excited by variability in African dust outbreaks on interannual to decadal timescales. Our analysis indicates that sea surface temperature anomalies resulting from the aerosol direct effect persist in time through the positive ocean–atmosphere feedback that defines the Atlantic Meridional Mode. We conclude that on interannual to decadal timescales, the state of the tropical Atlantic ocean is directly tied to dust emissions over West Africa, which in turn are linked to land-use change. This result was published in Evan et al. (Nature GeoScience, 2011).

Seafloor Processes



Physical Mechanism of Droplet Formation for Immiscible Fluids Injected into Water Through a High Reynolds Number Jet: Modeling Droplet Breakup to Determine the Fate of *Deepwater Horizon* Oil

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NOAA Goal
Healthy Oceans

Description
The goal of this project is to provide NOAA ERD with better understanding of the physics that determine oil droplet and gas bubble size distributions in underwater blowout conditions. Models derived from carefully controlled laboratory experiments will provide quantitative capabilities to the effort of determining the fate of oil from underwater oil spills.

Objectives
1. ***To provide experimental evidence of gas bubble and oil droplet break up in high Reynolds number turbulent flows.***
2. ***To analyze the data to understand the mechanisms that lead to breakup and determine the daughter size distribution, for different values of the physical properties of the discrete phase (bubbles and droplets) and of the turbulent flow characteristics (turbulent dissipation rate, length scales, mean shear rate, …).***
3. ***To create quantitative models to include these mechanisms in large computational codes that simulate the global physics, but contain only a highly parameterized picture of the microphysics that control the break up processes.***

Accomplishments
The project started on July 1, 2011. We have designed and constructed a large water tank to house the experiments. A nozzle body and several nozzles with different diameters have been designed and built also. We have started to characterize the flow field in the jet issuing from the nozzle. This is the environment in which the bubbles or droplets will be injected. The turbulent fluctuations from the jet, together with the shear in the mean flow, will provide the stresses necessary to deform the bubbles/droplets and induce break up. An image of a Particle Image Velocimetry experiment can be seen in Figure 1.

We have built and tested the experimental facility and started collecting data. We will be proceeding with the analysis as the datasets are completed.

We have not yet published this in peer review journals or presented it at conferences. We expect to present the first results at the APS conference in November.

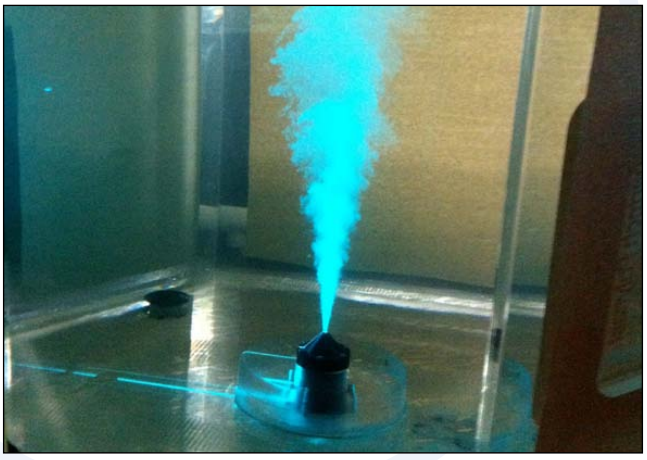

Figure 1: Photograph of high Reynolds turbulent jet submerged in a water tank. The laser light (blue) creates a plane and is scattered by the particles with which the flow has been seeded.

Vents Hydrothermal Research Group

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Task II

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NOAA Goals
Resilient Coastal Communities & Economies, Healthy Oceans

Description
The Vents program addresses ecosystem goals for the Office of Oceanic and Atmospheric Research as a part of the NOAA cross-cutting Ecosystem Research Program (ERP). The ERP is responsible for the systematic exploration of the ocean environment where new resources are discovered or developed and new regions are explored.

Continued exploration and discovery in new areas will expand the boundaries of the scientific community's understanding of the Earth system. JISAO scientists Joseph Resing and David Butterfield are actively engaged in research that discovers and characterizes novel hydrothermal ecosystems and their impact on the ocean environment. Submarine volcanoes and their hydrothermal vents affect marine ecosystems from the deep sea to the surface ocean. They present uniquely valuable natural laboratories to study the potential impact of ocean acidification and carbon dioxide sequestration in the deep ocean. Iron from hydrothermal vents may play a significant role as a limiting nutrient for primary productivity. In addition, the harsh ecosystems are homes to novel microbes, enzymes, and macro fauna which are a valuable resource to be explored, understood, and preserved. Natural products with anti-pathogen activity have recently been extracted from biological material collected during Vents cruises. Finally, these submarine volcanoes are responsible for the creation of economically significant ore deposits that international mining companies seek to exploit. The research conducted by JISAO Vents researchers Butterfield and Resing is critical to NOAA's mission for healthy oceans, ocean stewardship, and technological development and is not duplicated anywhere else in NOAA.

The Vents Program discovery of two submarine volcanoes with persistent ongoing eruptions has afforded a spectacular first look at deep ocean volcanic processes, including the first high-definition video of a deep eruption and the first direct sampling of fluids and rocks from an eruptive vent. The researchers published papers in 2011 describing the eruption at West Mata volcano, the first eruption of the lava-type boninite ever observed, and the chemical processes associated with magmatic gases escaping from erupting lava at NW Rota. Erupting and hydrothermally active volcanoes emit large quantities of acid and carbon dioxide, creating conditions of local acidification and adding metals and nutrients to the overlying ocean. When hydrothermal metals and nutrients enter the shallow ocean, as they do along the western Pacific volcanic arcs, they have a potential impact on productivity in nutrient-starved tropical waters. The study of biological communities in acidified environments also provides a window to the physiological effects of high CO_2 and low pH on marine life.

Axial Seamount, a mid-ocean ridge volcano in the NE Pacific, is the site of PMEL's long-term NeMO observatory and the NSF-funded OOI cabled observatory now under construction. During the past year, Vents researchers conducted submersible dives at Axial and discovered that it experienced a large eruption in April, 2011. Researchers quickly responded to this information and communicated with other scientists while still at sea to organize additional responses by other ships. Time-series data collected from 1998 to 2011 now encompass an entire eruptive cycle in a seafloor hydrothermal system, and make it possible to observe and potentially model how habitats change and organisms adapt to the repetitive volcanic cycle. The researchers are using state-of-the-art technology and detailed studies of volcanic and hydrothermal processes at Axial Seamount and Endeavour, site of the NEPTUNE-Canada

cabled observatory, to gain a deeper understanding of the complex links between volcanic activity, hydrothermal chemistry, and microbial ecology.

Objectives

1. ***To explore the deep ocean to locate and characterize neovolcanic areas, their associated hydrothermal ecosystems, and their impact on the oceans.***
2. ***To understand the interplay between the chemical environment of deep ocean habitats, biodiversity and the structure and function of deep ocean ecosystems.***

Accomplishments

Accomplishments in Exploration.

- ***Western Pacific***. JISAO and NOAA scientists have participated in a multi-year project funded by NOAA Ocean Exploration and the National Science Foundation to study submarine volcanic arcs in the western Pacific. The scientists have conducted more than eight major oceanographic expeditions to study submarine arc volcanoes in this region. Highlights from many of these expeditions can be seen on Ocean Exploration web sites:
  http://oceanexplorer.noaa.gov/explorations/explorations.html
  http://laueruptions.blogspot.com/

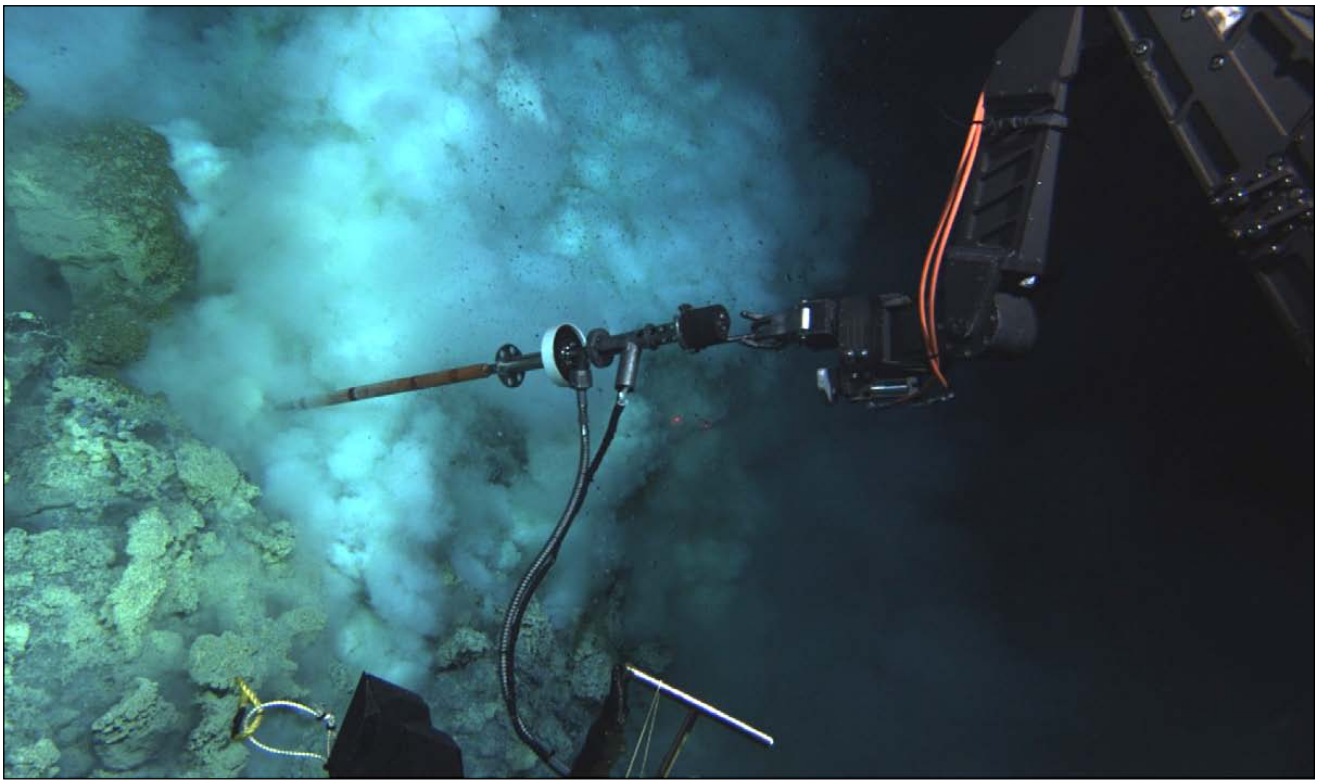
- ***Mariana Arc.*** The Mariana Arc is among the most volcanically active island arcs in the western Pacific and the only one within waters of U.S. jurisdiction. In 2008, part of the Mariana Arc was made into a Marine National Monument, based partly on the team's discoveries in expeditions from 2003 through 2008. The researchers' results show that the hydrothermal chemistry of the submarine volcanoes on the Mariana arc is very different than that observed along the mid-ocean ridge spreading centers. These distinct and unique chemistries host equally novel macrofauna and microbial communities. Butterfield et al., 2011 published the first measurements of significant quantities of sulfur dioxide in hydrothermal fluids. They show that erupting arc volcanoes release magmatic sulfur dioxide, which in turn produces sulfuric acid and rapidly dissolves volcanic rock, resulting in a significant impact on the global hydrothermal fluxes of sulfur and aluminum. Huber et al. analyzed communities of Epsilon-Proteobacteria from seamounts in the Mariana arc and used a statistical analysis of community structure to conclude that there may be barriers to dispersal and migration of vent bacteria between seamounts. The issue of what controls the biogeography of benthic macrofauna and microbial communities on seamounts in the Mariana arc is a central aspect of a planned proposal to the NSF Frontiers in Earth System Dynamics. This directly addresses biological diversity and marine resources in a Marine National Monument. Resing attended a workshop to develop plans for future exploration and research in the National Monument.

- ***Lau Basin.*** The Lau basin has been examined by NOAA and JISAO scientists on five different cruises between 2004 and 2010. Resing was the chief scientist and led the effort on two of these cruises. Like the Marianas, the Lau basin contains many novel hydrothermal systems and geological settings. Of particular interest is the "Mata" series of volcanoes whose morphology is similar to that of the erupting W. Mata Volcano. Six of the seven Matas are hydrothermally active making the density of hydrothermal activity among the highest anywhere in the world.

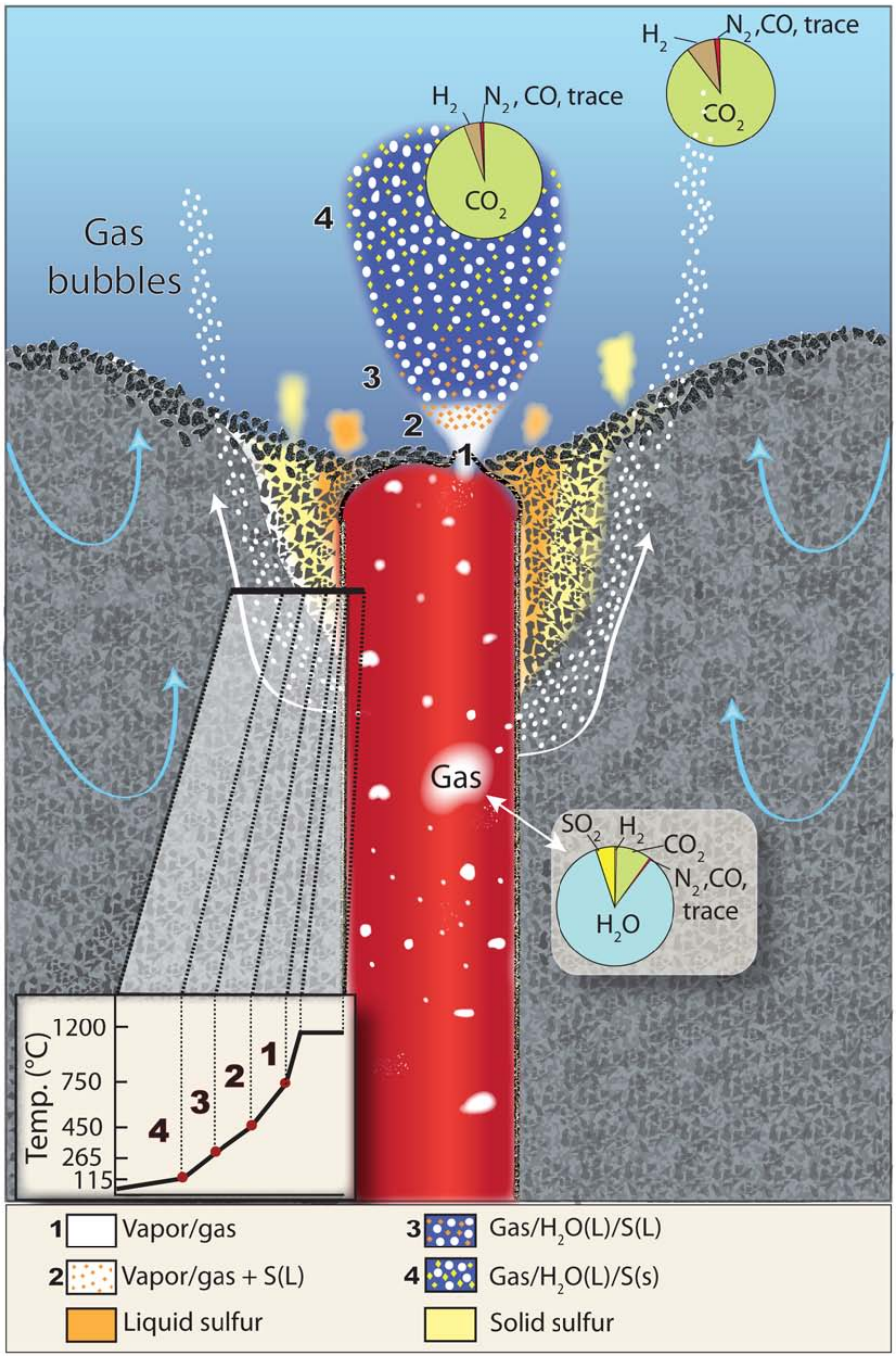
  In 2011 a paper (Resing et al.) was published on the active eruption at West Mata volcano and a second paper (Baker et al.) was published on the eruptive activity at the NE Lau Spreading center. After a year of active planning, the next ocean exploration cruise to this region is scheduled for September 2012.

Summary

In order to properly understand the volcanic-hydrothermal cycle and its effect on the ocean, it is critical to collect the volcanic and hydrothermal products of eruptions as soon after the eruption as possible. The closer the groups' studies come to the time of the eruption, the better their understanding of the evolution of hydrothermal venting and biological succession. Their work in the Mariana Arc (e.g., NW Rota), suggests that there must be a transition in hydrothermal systems from those dominated by magmatic fluids rich in SO_2 and CO_2, to systems dominated by the interaction between hot rock and seawater. The ability of microbes and macro-fauna to colonize these new sites may depend on the evolutionary state of these systems. A system rich in sulfurous acid is likely to host a small number of adapted species. As the system becomes less magmatic, the biologic assemblage is likely to shift to one closer to that observed at longer-lived systems in the same oceanographic region. As submarine mining of sulfide mineral deposits in the western Pacific is poised to begin, the environmental impacts of this economic activity are unknown. It is possible that the impact of eruptive activity and chemical output of active submarine volcanoes may provide some advance indication of the potential impacts of mining submarine deposits.



NW Rota volcanic vent, March 25, 2010. An instrument designed to sample hydrothermal and volcanic fluids from a remotely operated vehicle is inserted into an active volcanic vent, which erupted molten sulfur over the underlying volcanic rock within the 24 hours preceding this image. Clouds of particulate sulfur and gas bubbles are venting.



Schematic of chemical processes surrounding degassing lava conduit. Magma ascends slowly and gas pockets more rapidly in Strombolian-style eruption. Magmatic gases with primary composition (H_2O-CO_2-SO_2-H_2-S_2-trace gas; pie chart inset) escape vertically when gas pockets reach the top of the conduit and laterally when conduit walls are breached. H_2S is not a significant portion of the primary magmatic gas. The magma-to-seawater temperature gradient (numbered zones linked to transect) imposes a structure common to sulfur-rich degassing systems. 1. Water-rich gas escapes the magma near the brittle-ductile transition temperature (~750 °C). 2. Magmatic S_2(g) condenses to form sulfur liquid in water vapor medium near 450 °C. 3. Water vapor condenses to liquid at the two-phase boundary (~265° at NW Rota) producing a hot solution of sulfurous acid; the disproportionation reactions begin, and a CO_2-rich gas phase separates; strong acid dissolves rock. 4. Sulfur liquid freezes to solid near 115°. After SO_2 dissolves in water, the remaining sulfur-depleted gases (~90% CO_2/5% H_2 with minor methane and trace gases) ascend (white arrows) through the porous rock surrounding the conduit and exit the seafloor as free gas bubbles. Solubility fractionation (scrubbing) makes the free gas phase relatively depleted in more soluble gases. Liquid (orange) and solid (yellow) S_e accumulate around and over the top of the conduit, and may be re-melted or vaporized and driven out the top of the conduit when magma ascends. Explosive bursts eject molten S_e into seawater, forming S_e spherules. Because of the insolubility and density of molten and solid S_e and the filtering capacity of porous volcanic deposits, only fine particulate S_e will escape with circulating water. Seawater (blue arrows) circulates freely through highly porous and permeable rock, maintaining high water/rock ratio and rapid cooling around the volcanic vent.

Accomplishments in ecosystem studies:
Ocean Observatories. The scientists are in the 14th year of continuous monitoring at Axial Seamount with the NeMO observatory, aiming to study a full volcanic cycle from one eruption to the next. Dave Butterfield led the chemistry and microbiology team on a 2011 research cruise on board R/V *T.G. Thompson* with Jason 2 ROV operating at Axial Seamount, Juan de Fuca ridge. The project was funded by NOAA for collaborative research into chemistry and microbial activity of the sub-seafloor habitat, and by NSF for Bill Chadwick's geodetic volcano monitoring. There was tremendous excitement when the researchers discovered that Axial Seamount produced a lava flow in April 2011 that was significantly larger in area than the previous eruption in 1998. A paper (Chadwick et al.) describing the forecasting of this eruption from volcanic inflation monitoring, as well as the eruption duration is in press at *Nature Geoscience*, and a second paper (Dziak et al.) on precursor seismicity, magma movement, and temperature on/near the lava is in review. The cruise included microbiologists from the laboratories of long-term colleagues Jim Holden (U. Mass. Amherst) and Julie Huber (Marine Biological Lab) and the more recent collaborator Kerry McPhail (Oregon State, Pharmacology). The researchers collected chemical and biological samples from the ephemeral "snowblower" vents which appear only after volcanic eruptions. Important collections of biological material from Axial Seamount from 2009-2011 have resulted in the exciting discovery of new bioactive chemical compounds with significant antibacterial properties. By providing expertise in hydrothermal systems and access for the OSU pharmacology group to critical sample material, Vents researchers are contributing to this frontier research area with importance to society and NOAA strategic goals. The plan is to continue to build this collaboration.

Construction of the Ocean Observatories Initiative Regional Scale Node (OOI-RSN, formerly NEPTUNE) has begun and will provide real-time cabled communication and power between Axial Seamount and land, with streaming data from multiple sensors and instruments providing an unprecedented view of dynamic processes on a submarine volcano. Butterfield has been operating an interactive water sampler on the Main Endeavour node of the NEPTUNE Canada network (*www.neptunecanada.org*) and is receiving funds from OOI-RSN to build two combination vent fluid chemistry/preserved DNA samplers. Data from these instruments will be publicly available through OOI. Additional Canadian funding is being sought to build chemistry/DNA samplers for NEPTUNE Canada. Butterfield organized and led a workshop, jointly funded by NSF and NOAA/PMEL, of 75 participants October 5-7, 2011 (with help from Bill Chadwick, William Wilcock and Julie Huber) to coordinate and optimize science community involvement in the OOI-RSN at Axial Seamount (*https://sites.google.com/site/axialrsn-scienceworkshop/*) . One outcome of the workshop was a revised plan for sensor placement as a result of observations about the 2011 Axial eruption.

Biogeochemistry. A recent publication (Bourbonnais et al. 2012) used the capabilities of Butterfield's specialized hydrothermal fluid sampler to measure rates of denitrification and ammonia oxidation by microbes living in the sub-seafloor habitat at Axial and Endeavour. Shipboard incubations were carried out on whole water samples collected in sealed Tedlar plastic bags. These are the first rate measurements of this kind made on hydrothermal fluids, and show that hydrothermal systems are quantitatively important in the biogeochemical cycle of nitrogen in the ocean. Other recent work (Ver Eecke et al, in prep) measures the rate of production of methane by archaeal microbes as a function of hydrogen availability in culture and in the real environment. These experiments are part of a larger effort to measure microbiological process rates and link them to chemical measurements to create biogeochemical models. A large proposal to help this effort is being considered by the Moore Foundation.

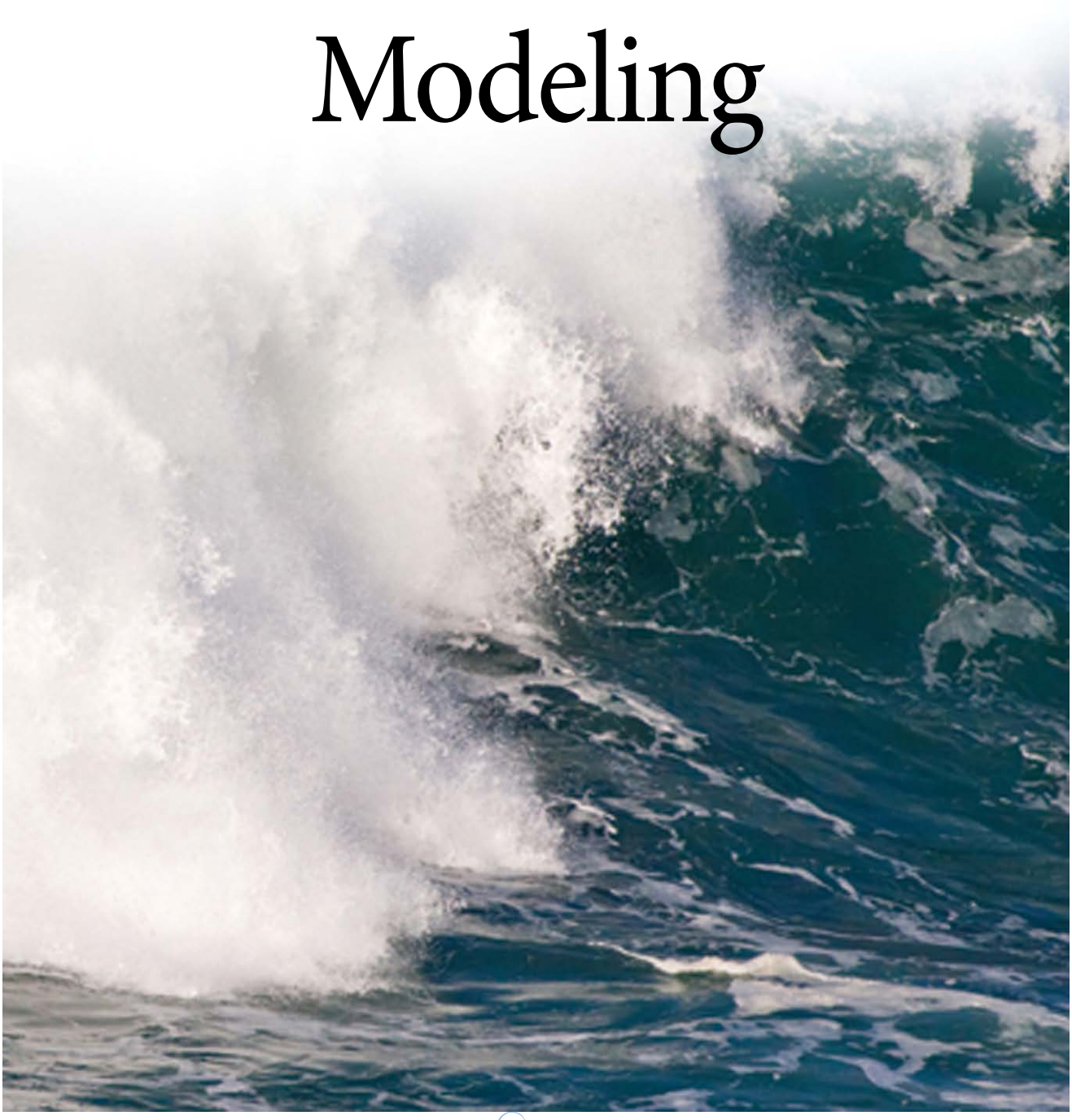
Global Distributions of Trace Elements. Resing conducts research on the processes that control the distributions of key trace elements and isotopes in the oceans and that establishes the sensitivity of these distributions to changing environmental conditions including hydrothermal activity. A manuscript by Slemons et al (in revision) discusses the possible sources of Fe, Mn, and Al to one of the largest currents in the world, the equatorial undercurrent, which transports more water across the ocean than the combined flow of the largest 50 rivers in the world. One of our operating hypotheses was that shallow hydrothermal activity might contribute to the trace metals in the under current. However results of the research suggest that coastal sources are the dominant source terms. More research will be required to understand this fully. A manuscript by Barrett et al is soon to be submitted to Marine Chemistry on the distribution of particulate matter in the Atlantic Ocean. The research, based on

a north to south transect of the North Atlantic Ocean, demonstrates that the major sources of particulate and dissolved metals to the Atlantic Ocean are Saharan dust and European pollutant aerosols. To better understand the role of particles in the ocean Resing attended the 3rd Geotraces Data-Model Synergy Workshop.

In an effort to understand the impact of hydrothermal activity on the global ocean Resing attended a workshop hosted by the U.S. Geotraces program. This workshop was undertaken to plan on an east-west transect of the South Pacific Ocean to explore the distribution of trace elements associated with the oxygen minimum zone and hydrothermal output from on the South East Pacific Rise. It has been postulated that hydrothermal Fe may be stabilized by a variety of processes such that it may be the major source of Fe to many parts of the deep ocean and may be ultimately upwelled into the surface ocean. Resing submitted a proposal to NSF to participate in the Geotraces' Pacific section cruise scheduled for Fall 2013.

Ocean Acidification. The long-term increase in atmospheric carbon dioxide and the consequent increased CO_2 content and lowered ocean pH raise serious concerns about the future habitability of the oceans for many species with critical ecological importance to our planet. There is a huge uncertainty in how ocean acidification will affect marine life. Can animals adapt to higher CO_2 and lower pH? Which species will survive and which will perish? Volcanic ecosystems provide natural laboratories to study these critical issues. Previous work supports the hypothesis that chemical energy and nutrients from hydrothermal plumes allow mussels to thrive in high-CO_2, low-pH waters that would normally dissolve their shells (Tunnicliffe et al., 2009). In work published in 2011, Shamberger et al. employ the same technology used to study time-variability in hydrothermal vents to calculate coral calcification rates in Kaneohe Bay, Hawaii. They found that net ecosystem calcification (NEC) rate is correlated to aragonite saturation and that NEC in Kaneohe bay is similar to other productive coral reefs, and this suggests that ocean acidification will not affect coral reefs uniformly. Much work remains to be done to understand and predict how the marine ecosystem will change due to ocean acidification. The researchers are seeking additional funding opportunities and collaborations to make progress in understanding the physiological adaptation mechanisms that allow hydrothermal fauna to thrive in low-pH, high- CO_2 environments, and to relate such adaptations to other marine environments.

Tsunamis Observations and Modeling



DART Data Inversion: Source Selection and Improved Alpha and Inundation Forecast Uncertainty Assessment

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Task III

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NOAA Goals
Weather-Ready Nation, Resilient Coastal Communities & Economies

Description
NOAA has deployed a series of DART buoys (primarily in the Pacific Ocean) that can directly record the passage of a tsunami over a pressure detector mounted on the bottom of the ocean. These buoys are strategically placed in the ocean off of coastlines where earthquake-generating tsunamis have occurred historically or are predicted to be likely to occur. Data collected in near-real time by DART buoys that are off-shore from an earthquake reflect the start of a tsunami and can be used to predict the impact of the tsunami along U.S. coastal communities away from the earthquake site. While very large tsunami-generating events will lead to an order to immediately evacuate, there is a need to assess the impact of moderate-sized events 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 to evaluate the possible impact of a tsunami. The most relevant statistical measure is a confidence interval (CI) that quantifies how large a tsunami event is likely to be when it reaches a coastal community. Such a CI necessarily depends upon the uncertainty in the estimated tsunami source amplitudes, which are intermediate measures of interest.

Objectives
The overall goal of this project is to estimate tsunami source amplitudes and to produce CIs for the true unknown amplitudes. The estimation of the amplitudes must not only be reliable, but also use methods that allow them to be computed as rapidly as possible. The estimated amplitudes are to be based upon fitting data collected in near real-time by the DART buoys to a database of pre-computed models for what these buoys would observe from a magnitude 7.5 reverse thrust earthquake located within a unit source.

Accomplishments
The scientists continued a study on methods for detiding data collected by DART buoys for use within NOAA's Short-term Forecast for Tsunamis (SIFT) tool. Removal of tides from DART buoy data is necessary because the inversion algorithm that is used to estimate tsunami source amplitudes assumes the absence of tidal components. In addition to methods based on harmonic analysis (including the so-called Foreman method), on Kalman filtering/smoothing and on empirical orthogonal functions, the study also looked at local polynomial methods for detiding with and without joint estimation of the tsunami source amplitudes. The local polynomial method with joint estimation, while computationally simpler than the other methods under consideration, has proven to be competitive with the other methods (and is often superior to them). A paper summarizing the conclusions of this study is under preparation.

The scientists also studied how well the so-called lasso method can automatically select unit sources to be used in estimating tsunami source amplitudes. The lasso method is a penalized least squares procedure that is popular in the statistical community, with the penalty acting here to automatically select unit sources. Currently operators at tsunami warning centers must hand-pick unit sources or rely upon a selection based purely on seismic information that does not take the data collected at the DART buoys into account at all. Automatic selection of unit sources is of interest because manual selection by operators can be time consuming and could cause delays in issuing timely warnings to the

public. Initial tests with the lasso pointed out the need for an adaptation that would enforce a degree of spatial coherence amongst the selected unit sources. The need for this adaptation led to development of a `sweeping lasso,' in which the lasso is applied to unit sources confined to particular rectangular grids, with the best grid being selected by an information criterion. The sweeping lasso works well with tsunami events that are localized such that only a few (one to four) unit sources are needed to describe the data. For large events such as the 11 March 2011 Honshu tsunami, approximate collinearity amongst the unit sources leads to undesired gaps in the spatial structure, which can be handled using a sweeping version of the elastic net (a generalization of the lasso that can handle collinearity). More investigation of this methodology is needed before a paper can be prepared.

Tsunami Research

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NOAA Goals
Weather-Ready Nation, Resilient Coastal Communities & Economies

Description
NOAA bears a national responsibility to address issues of public safety and economic costs associated with extreme weather and ocean hazards and, in particular, to "Increase Lead Time and Accuracy for Weather and Water Forecasts." Tsunami waves, having the potential for devastating effects, can in many cases be detected well in advance of coastal impact and clearly fall within that mandate. Following the horrific Indian Ocean tsunami of December 2004, the U.S. Congress passed the Tsunami Education and Warning Act which identifies four activities: tsunami forecast and warnings, mitigation, research, and international coordination which can further future preparedness.

Important contributions to each of these activities take place at the NOAA Center for Tsunami Research (NCTR) at the Pacific Marine Environmental Laboratory (PMEL) in Seattle through the collaborative efforts of NOAA and University of Washington/JISAO scientists through the Tsunami Research Program. Basic research into tsunami generation, and numerical modeling of propagation and inundation provide the basis for forecasting, and the SIFT tool, developed at NCTR, is employed at NOAA's Tsunami Warning Centers which have the operational responsibility for disseminating timely warnings. Input to the forecast system is provided by an array of bottom pressure recorders, in the Pacific, Atlantic and Indian Ocean, which detect and report in real time the passage of a tsunami wave. The instruments, called DART®s (developed at PMEL) are deployed and serviced by the National Data Buoy Center. Array studies, conducted at NCTR, assist in the choice of the optimal locations for the DART®buoys and assessment of the impact of instrument outages.

Other aspects of NOAA's tsunami-related activities include 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. Modeling efforts at NCTR facilitate risk assessment for exposed communities and existing or planned infrastructure. Public education, both within the U.S. and internationally, training and capacity building for scientific and emergency planning and response, and the development of partnerships, are vital to combating the tsunami threat. NCTR seeks to achieve these goals through presentations and workshops worldwide. In particular modeling and forecast tools are customized to facilitate this mission and establish warning services for global coastal communities.

Objectives
1. ***To develop and implement the main components of NOAA's operational tsunami forecast system "SIFT" (Short-term Inundation Forecast for Tsunamis) for use at the U.S. Tsunami Warning Centers in Hawaii (Pacific Tsunami Warning Center) and Alaska (West Coast/Alaska Tsunami Warning Center).***
2. ***To continue development, testing and implementation of the SIFT components, specifically, high-resolution forecast models for U.S. coastal communities.***
3. ***To conduct tsunami hazard assessment studies for several coastal locations in collaboration with State and Federal partners.***
4. ***To develop new tools for hazard assessment and forecast, including landslide-generated tsunami modeling.***

5. ***To help develop tsunami forecast and warning capabilities in the Pacific, Indian and Atlantic Oceans in collaboration with international partners using community modeling tools, including training, education and capacity building.***

Accomplishments

1. Development of SIFT Version 3.1.0 has been completed. This new version features a new user interface in which the inversion process has been streamlined for ease of use. Installation of Version 3.1.0 of SIFT at the Tsunami Warning Centers (TWCs) in Hawaii and Alaska is scheduled to take place in April 2012. This concludes the development stage of SIFT. Testing and evaluation of the software by the TWCs is scheduled to take place next. SIFT 3.1.0 is designed to act as a console with which the operator can prioritize and launch fast-executing numerical models for the communities most at risk to serve the needs of forecasters and emergency responders.
2. NCTR continues to provide analyses for tsunami hazard assessment projects for the State of Washington. Inundation modelling for Grays Harbor and Willapa Bay, WA from a Cascadia fault scenario for Washington State Emergency Management Division is scheduled to be delivered by the end of the current fiscal year. A study of the tsunami threat to the Commonwealth of the Northern Marianas Islands (CNMI) has been conducted in collaboration with NOAA's National Ocean Service. A report on the study is currently in review for publication. The second part of a two-year project with the Nuclear Regulatory Commission (NRC) will notify NRC officials of a tsunami event and will provide forecast esystem (TsunamiCast), in addition a *Nureg* document reflecting best modelling practices in evaluating tsunami hazard to nuclear power plants is being prepared.
3. During the period 2011-2012 NCTR has developed a state of the art version (Version 4) of the tsunami simulation code MOST featuring grid rotation, parallelization and multi-grid nesting. All these new features will allow faster tsunami forecast generation at the Tsunami Warning Centers (TWCs). MOST Version 4 is currently being integrated into the Forecast Software SIFT for use by the TWCs.
4. Tweb application development is progressing well with much of the multi-tier architecture in place. Development of the SIFT Translator tier, which translates SIFT data to a format compatible for web consumption, is at an advanced stage. The focus of development now is to emulate the SIFT functionality on the client. Client development is approximately 60% complete and closely followed in level of completion by the application tier. The application tier acts as an intermediary between the client and all server tiers. Tweb will allow for full tsunami event modeling capability from any internet connected web-browser.
5. NCTR is continuing the development of the high-resolution tsunami inundation models called Forecast Models (FMs) (formerly known as **S**tand-by **I**nundation **M**odels, SIMs) as part of the Tsunami Forecast System. The Implementation Plan calls for development of the Forecast Models for 75 coastal communities at risk in the U.S. by FY12. To date 65 FMs have been developed; 10 more are in progress to complete the series at the end of the current fiscal year.
6. A collaboration with the University of Malaga, Spain has been initiated in order to develop landslide modelling capabilities that could be applied to the study of landslide-generated tsunamis. Initial validation tests of the landslide simulation code are in progress including the simulation of the Lituya Bay, AK landslide event, which generated a tsunami with the highest run-up ever recorded.
7. A very large tsunami event (Japan (2011, Mw=9.0), occurred during the current reporting period. This was the largest tsunami ever recorded in the deep ocean. The appropriate location of NOAA's DART buoys (tsunami sensors) around the epicentre, and the high signal-to-noise ratio of the signal reported by these sensors resulted in the generation of an excellent forecast for Hawaii, and the US coastline. These unplanned events provide crucial opportunities to verify and validate the efficiency and accuracy of the SIFT forecasting software.
8. Four additional training workshops, using the Community Modeling Interface for Tsunami (ComMIT) were conducted during the current reporting period, in Tanzania, Mozambique and Guadaloupe under the auspices of UNESCO and in Australia under the organization of the Australian Bureau of Meteorology to further tsunami detection, forecasting, and warning capabilities in these countries, bringing the total number of ComMIT workshops taught overseas to thirteen.

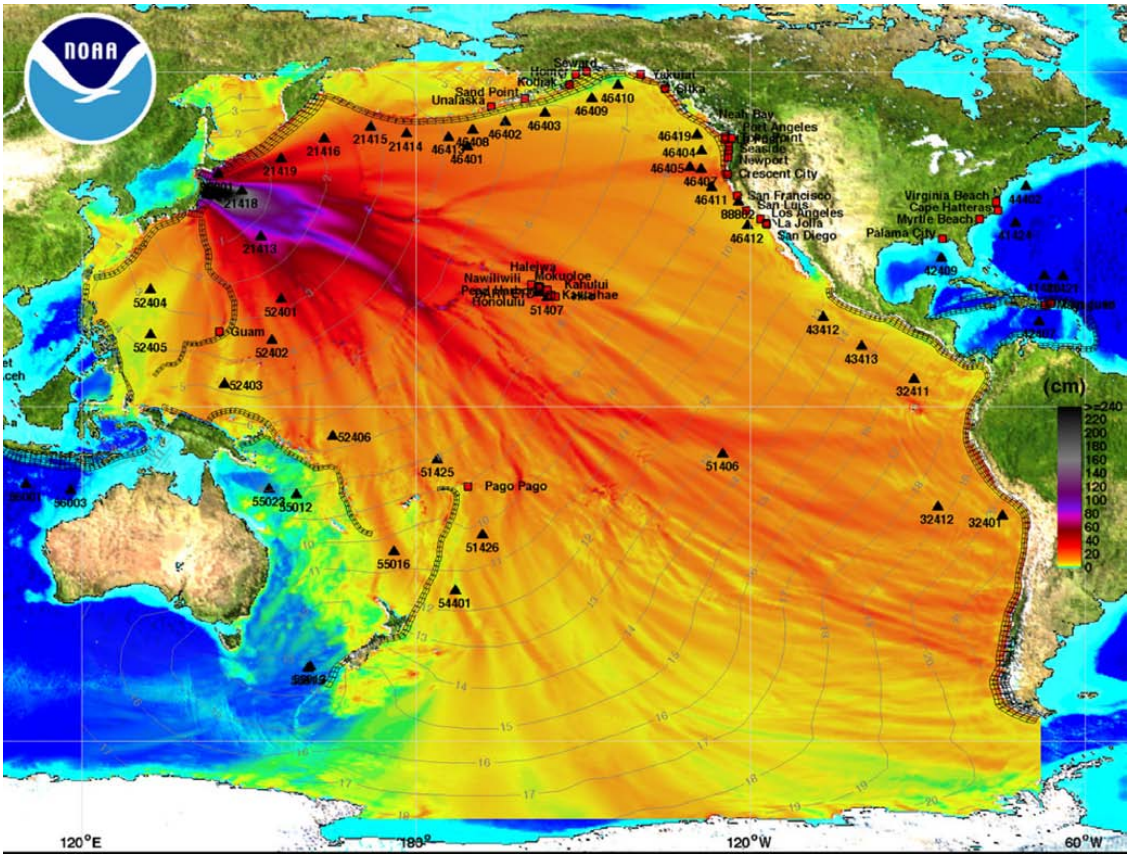


Figure1. Energy propagation pattern of the 11 March 2011 tsunami calculated with the MOST forecast model. Filled colors show maximum computed tsunami amplitude in cm during 24 hours of wave propagation. Gray contours show computed tsunami arrival time.

Figure 2. On 11 March 2011 Japan suffered the most devastating tsunami in recorded history with run-up heights of up to 40.5 metres in Miyako in Tohoku's Iwate Prefecture, and inundation reaching up tp 10 km inland in the Sendai area. The image is an example of the kind of devastation wreaked by the tsunami on many coastal towns by showing the before (left) and after (right) the tsunami pictures.

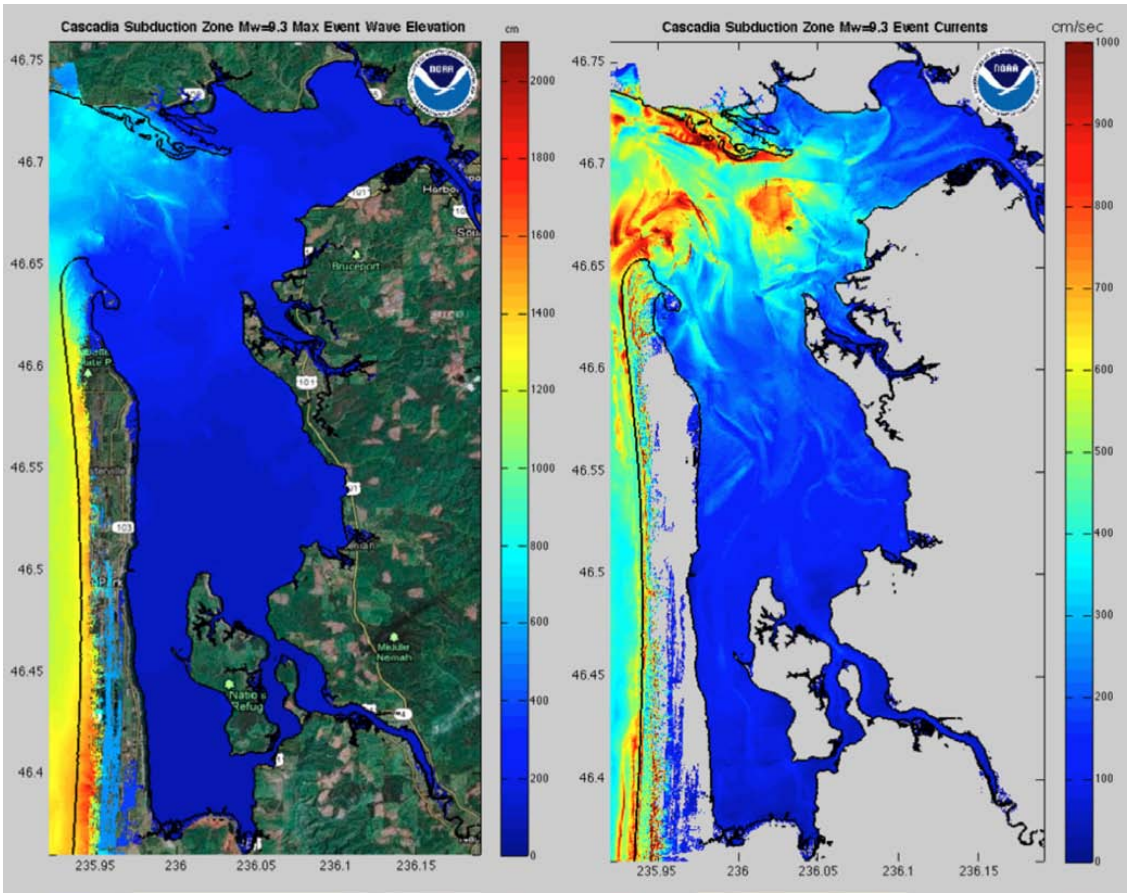
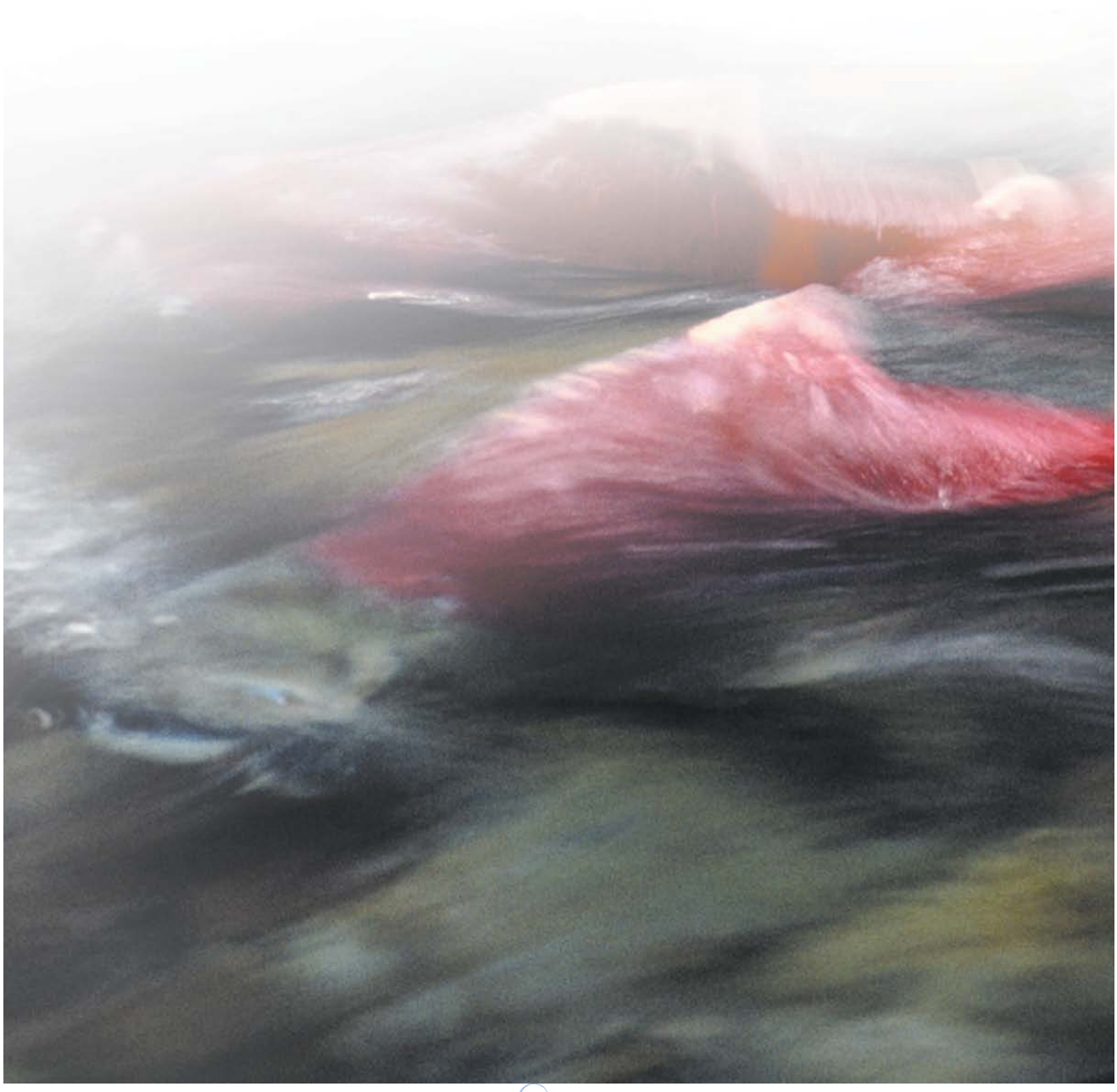


Figure 3. Distribution of the maximum elevation (left panel) and current speed (right panel) of a tsunami in Willapa Bay and Grays Harbor, WA from a Mw=9.3 seismic event along Cascadia Subduction Zone.

Marine Ecosystems



Partnership with the Northwest Fisheries Science Center and Alaska Fishery Science Center to Develop Increased Capacity in the School of Aquatic and Fishery Sciences to Enhance Teaching and Research

PI
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Task III

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NOAA Goal
Healthy Oceans

Description
The purpose of this project is to create a partnership with the Northwest Fisheries Science Center and the Alaska Fisheries Science Center to develop increased capacity in the UW School of Aquatic and Fishery Sciences to enhance teaching and research in stock assessment and resource management.

Objectives
Faculty Support: Hire and support two tenure-track faculty members at the University of Washington, School of Aquatic and Fishery Sciences.

Graduate Student Support: Identify, support and train graduate students in stock assessment and resource economics for fisheries management.

Accomplishments
The School of Aquatic and Fishery Sciences hired Dr. Trevor A. Branch as an assistant professor, tenure track as of September 16, 2010. He is running the Bevan Series to increase collaboration between SAFS and NOAA (e.g. speaker Rudy Kloser ran separate full-day workshops at both the NWFSC and AFSC). He lectures a course in R graphics and a course on basic fisheries population dynamics models.

Professor Branch is using money from this award to support Cole Monnahan, a graduate student who comes from the QERM program (Quantitative Ecology and Resource Management), and has completed 1.5 years of coursework in modeling and statistics at the graduate level. Cole Monnahan is working on a Bayesian population model of northeast Pacific blue whales with Dr. McClintock from the National Marine Mammal Laboratory, NOAA. He will also conduct a stock assessment-related summer project under the direction of Dr. Ian Stewart of the Northwest Fisheries Science Center.

The School hired Christopher M. Anderson as a tenured Associate Professor of Fisheries Economics. Professor Anderson began employment January 1, 2012. He will give a graduate-level course in fishery economics spring quarter, 2012. His research program presently includes two graduate students who transferred into SAFS with him from the University of Rhode Island, and he is actively recruiting a new student for this coming fall quarter.

Ecosystems and Fisheries-Oceanography Coordinated Investigations (EcoFOCI)

PI
Nicholas Bond, UW — JISAO

Other UW Personnel
Wei Cheng, Albert Hermann, Nancy Kachel, Scott McKeever, Calvin Mordy, Peter Proctor, Lisa Sheffield Guy, Margaret Sullivan, Muyin Wang, JISAO

NOAA Personnel
Phyllis Stabeno, Carol Ladd, Jim Overland, PMEL; Jeff Napp, AKFSC

Task II

NOAA Primary Contacts
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NOAA Goal
Resilient Coastal Communities and Economies; Healthy Oceans

Description
Ecosystems and Fisheries-Oceanography Coordinated Investigations (EcoFOCI) is a collaborative research effort among oceanographers, atmospheric scientists, chemists, and fisheries biologists from JISAO and NOAA's Pacific Marine Environmental Lab and Alaska Fisheries Science Center. The primary goal of EcoFOCI is to determine the influences of climate and environment on Alaskan marine ecosystems and apply research outcomes to resource conservation and fishery management. Investigations into the ecosystem impacts of fluctuations in temperature and salinity, sea-ice extent, atmospheric forcing, tides, freshwater influx, productivity and mixed-layer depth are on-going in the Gulf of Alaska, Aleutian Islands, Bering Sea, and Chukchi Sea. The timescales of interest range from short-term episodic and seasonal events to long-term annual and decadal trends. EcoFOCI incorporates field, laboratory and modeling approaches to determine how varying physical and biological factors influence these large marine ecosystems.

Objectives
1. ***Monitoring of the oceanographic ecosystem through analysis and processing of data from the North Pacific mooring array, satellite tracked drifters, and shipboard measurements***
   Biophysical moorings are maintained in the Bering Sea, providing critical information on the response of the environment to changes in climate. JISAO scientists contribute to maintaining these moorings, expanding the instruments on moorings to measure zooplankton abundance and oxygen, and introducing new technology to enable these moorings to report in real time.
2. ***Disseminating data through websites, presentations, publications and workshops***
   JISAO scientists contribute to the maintenance of web pages including those that presented ecosystem research operations aboard the USCG *Healy* (an NSF-funded cruise). JISAO scientists author and co-author numerous publications each year and present their findings at a variety of regional, national and international meetings.
3. ***Participating in cruises to examine the variability in physical and chemical oceanic processes that impact the North Pacific and Bering Sea ecosystems***
   JISAO scientists take a leading role in studies of North Pacific ecosystems. They participate on cruises as chief scientist and party chief. JISAO scientists are leaders in the measurements of nutrients, chlorophyll, and oxygen.
4. ***Projecting impacts of climate change***
   JISAO scientists are involved in an effort to apply simulations of future climate (IPCC AR4 models) to issues related to marine ecosystems. The output from these models is being used to force local dynamical models of the North Pacific Ocean and Bering Sea, and to make projections based on empirical methods.
5. ***Making data and analysis results available to Fishery Management Councils and other resource managers***

Accomplishments

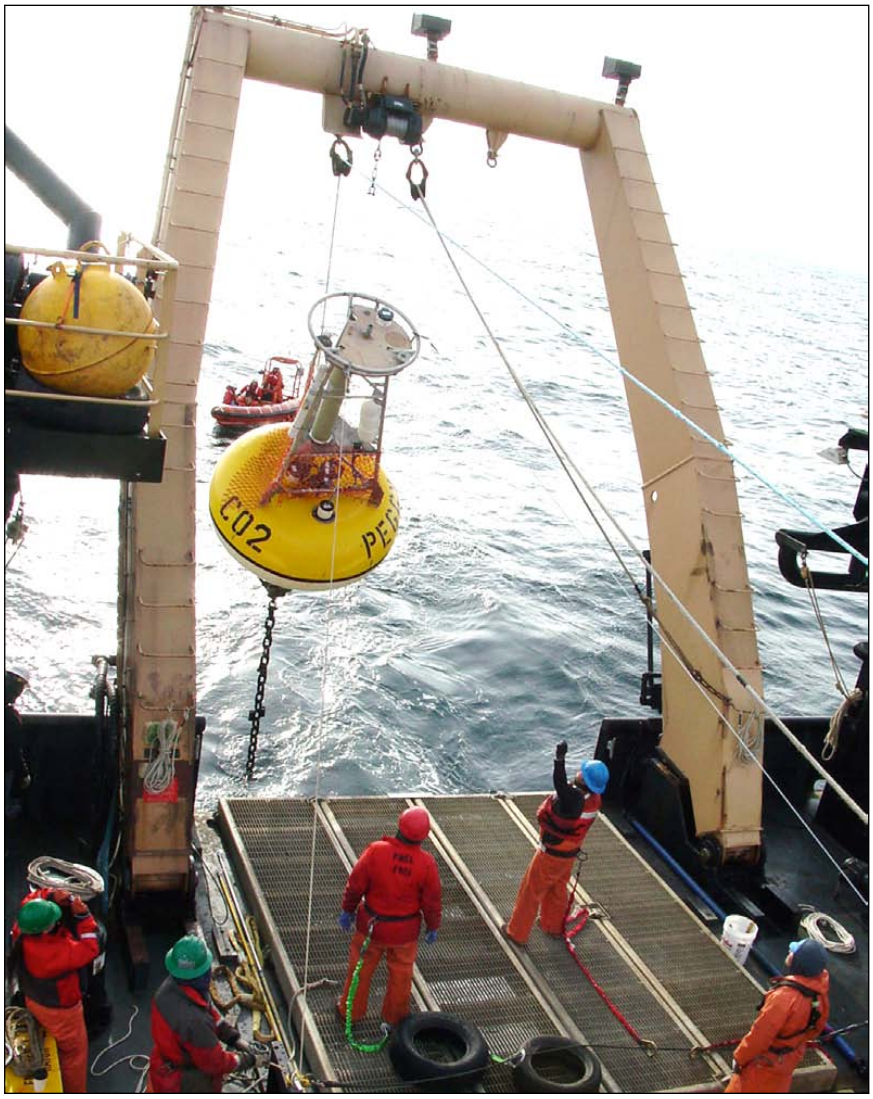
1. ***EcoFOCI's Arctic ocean observing system***
The second CHAOZ (CHukchi Acoustics, Oceanography, and Zooplankton) cruise took place on board the F/V Mystery Bay. This program incorporates biophysical moorings, hydrographic measurements and numerical climate models to examine the changing ecosystem of the Chukchi Sea where future offshore oil development activities may occur. The moorings were deployed in conjunction with passive listening devices for monitoring marine mammals. The cruise began in Dutch Harbor, AK on August 12, 2011 and ended in Dutch Harbor on September 11, 2011. In summary, a total of 24 passive acoustic and 9 oceanographic moorings were retrieved and deployed, over 70 hydrographic and 60 zooplankton stations were conducted, 24-hour passive acoustic monitoring (via sonobuoy deployments) occurred, and over 1,400 nm were surveyed for marine mammal and bird observations. The measurements of currents will provide information on mesoscale variability over the shelf and will be important ground-truth for oil spill models in the region. Direct observations of ice thickness will be used to provide understanding of how climate change relates to ecosystem shifts, and for potential impacts on oil development. The observations will be compared with the simulations from global climate models to determine how well these models characterize the physical environment of the region. The Bureau of Ocean Energy Management (BOEM) of the Department of the Interior is supporting this program. This study includes a modeling component examining the 5th IPCC climate models (M. Wang).

2. ***Bering Sea Project***
EcoFOCI completed the final field year of the large multi-year project (BSIERP-BEST; http://bsierp.nprb.org/) in 2010. The objective of this research was to enable scientists to predict the effects of global climate change on the Bering Sea. JISAO scientists played a critical role in the success of the field studies - 16 cruises in four field years (April 2007-September 2010). At least one JISAO scientist was on each cruise. These cruises supported process studies and long-term monitoring programs seeking to better understand the mechanisms important to the marine ecosystem of the Bering Sea shelf. Now that the field component of this research is completed, JISAO scientists are presenting and publishing the results of this study. Research findings were presented at the Alaska Marine Science Symposium during January 2012 and at the AGU Ocean Sciences meeting during March 2012. A special volume of Deep-Sea Research II with five publications including JISAO authors and co-authors will be published in March 2012. ROMS modeling is on-going (N. Bond, A. Hermann).

3. ***BEST Synthesis Project***
An NSF grant was awarded to JISAO PI Calvin Mordy to develop a synthesis of research that resulted from the BEST-BSIERP program. JISAO scientists Nancy Kachel, Albert Hermann, and Nick Bond are also contributors. The proposed BEST (Bering Ecosystem Study) Synthesis will examine the impact of sea ice on the distribution and abundance of zooplankton, and how they are partitioned among top predators. To this end, new and historical data will be used to test a series of hypotheses and answer questions relating to bottom-up and top-down control of large crustacean zooplankton and their impact on the flow of carbon and energy in the ecosystem. From the examination of these hypotheses, new mechanisms will be derived and old ones re-evaluated. Existing numerical models will be used to assess the relative importance of these mechanisms. Existing conceptual models will be tested, and new conceptual models of carbon and energy flow will be developed. This synthesis is a multi-disciplinary (climate to predators) collaboration among academic institutions, government (NOAA), and two countries. The first of two synthesis workshops was held from 7-9 February, 2012.

4. ***Gulf of Alaska Integrated Ecosystem Research Program launched***
The EcoFOCI program is part of a major multi-institution project in the Gulf of Alaska funded by the North Pacific Research Board (NPRB). EcoFOCI's role in the Gulf of Alaska Integrated Ecosystem Research Program (GOA IERP; *http://gulfofalaska.nprb.org/*) is to determine how physical transport mechanisms influence lower trophic levels, and subsequently the survival and recruitment of five species of groundfish (walleye pollock, Pacific cod, arrowtooth flounder, sablefish, and Pacific Ocean perch). JISAO scientists are playing a major role in this effort. The specific objectives are to deter-

mine: (1) the timing and magnitude of the different cross-shelf exchange mechanisms, using an extensive suite of oceanographic (i.e., moorings, drifters, cruises) and atmospheric measurements, (2) how these physical mechanisms influence the distribution, timing and magnitude of phytoplankton productivity, and (3) how both transport and primary productivity control the distribution, productivity, and fate of both zooplankton and ichthyoplankton. New observations will be supported by retrospective studies using previously collected data from these regions; in some cases extending the team's horizon back as much as 30 years. Moorings were deployed during 16-21 March 2011 (JISAO scientist Scott McKeever). A research cruise during 30 April – 21 May 2011 (including JISAO scientists Nancy Kachel [chief], Calvin Mordy, & Peter Proctor) described the physical and biological oceanographic conditions in the highly productive eastern Gulf of Alaska. This cruise took place aboard the R/V *Thomas G. Thompson* and deployed CTD, bongo, neuston, Multinet or MOCNESS, and satellite-tracked drifter equipment.



Recovering the Peggy mooring at M2 aboard the Oscar Dyson.

5. ***Synthesis of Arctic Research (SOAR)***
The Synthesis of Arctic Research is a BOEM-supported effort to bring together a multidisciplinary group of Arctic scientists and residents to explore and integrate information from completed and ongoing marine research in the Pacific Arctic. This five-year program began in May 2011 and is led by Phyllis Stabeno (NOAA/PMEL) and Sue Moore (NOAA/ST7). JISAO scientist Lisa Guy is Program Coordinator, and Margaret Sullivan and Calvin Mordy are also contributors. In the first year of the program, SOAR has selected an 11-member Science Steering Committee (SSC), held a SSC meeting to identify research goals and questions, selected a group of 43 Arctic interdisciplinary scientists as contributors, and planned a SOAR Workshop for all participants to be held in Anchorage in March 2012. At this Workshop, Analytical Teams will be tasked with research questions and proposals for synthesis support will be drafted. More details of the SOAR project can be found on the website at: http://www.arctic.noaa.gov/soar/

6. ***EcoFOCI continues work with Bering Sea Ecosystem Synthesis Team***
EcoFOCI (including JISAO scientists Nick Bond and Lisa Guy) participated in a "Bering Sea Ecosystem Synthesis" workshop to develop key indicators to track changes in the eastern Bering Sea ecosystem and enable an ecosystem-based approach to fisheries management in the region in 2010. This forecast was incorporated into the Ecosystems Considerations Chapter (ECC; *http://access.afsc.noaa.gov/reem/ecoweb/Index.cfm*) of the Stock Assessment and Fishery Evaluation reports and delivered to the North Pacific Fishery Management

Council by ECC authors Stephani Zador (JISAO and AFSC/REFM) and Sarah Gaichas (AFSC/REFM). The ECC has now transitioned from a collection of indices with a small amount of synthesis to a volume that emphasizes ecosystem synthesis and provides advice to both the SSC and the Plan Teams. EcoFOCI scientists continued to work with the main authors of the ECC to improve the product in 2011 based on the comments/critique of the SSC. In addition, EcoFOCI Program Leaders met with the lead authors of the individual assessment chapters (Plan Team reports) to discuss how and which climate indices to incorporate directly into the single stock assessments for 2012.

7. ***Arctic Sea Ice***
The research conducted by the EcoFOCI group includes an important Arctic climate component, as well as the ocean monitoring component mentioned above. Specifically, JISAO scientist Muyin Wang, in collaboration with Jim Overland of NOAA/PMEL and others, has led ongoing research on the past, present and future climate of the Arctic. This work represents an important foundation for the "Arctic Report Card" (http://www.arctic.noaa.gov/reportcard/). This year's edition emphasized three strong indications of climate change: (1) extremely low sea ice extent at the end of the melt season for the 4th year in a row, (2) all-time minimum sea ice coverage for the month of January in 2011, and (3) record warm temperatures and major ice losses in west Greenland during 2010. These changes are apparently having important biological consequences as evidenced by declines in caribou and increases in goose populations. It bears noting that the Arctic report card is becoming an increasingly valuable resource for scientists and other users of information for the region. Its effectiveness can be directly linked to the efforts of JISAO's Tracey Nakamura towards the development and maintenance of the web interface.

8. ***CLIVAR nutrient cruise***
JISAO scientist Peter Proctor sampled nutrients as part of the Climate Variability and Predictability (CLIVAR) A10 CLIVAR/CO2 Repeat Hydrography Cruise during September 28 - November 1, 2011 (Cape Town to Rio de Janiero) aboard the R/V *Ronald H. Brown*. *http://www.aoml.noaa.gov/ocd/gcc/A10/*

9. ***Coastal Forecast System***
A quasi-operational seasonal forecast system for the coastal waters of the Pacific Northwest is being developed. In collaboration with NOAA's Northwest Fisheries Science Center (NWFSC), JISAO scientists Nick Bond and Albert Hermann are involved in an effort to use the output from the Coupled Forecast System (CFS) global model, which is run operationally for seasonal weather prediction, as initial and boundary conditions for regional simulations using the Regional Ocean Modeling System (ROMS). The ROMS output will be post-processed to yield specific properties crucial to the ecosystem such as coastal upwelling, mixed layer depths, oxygen concentrations and plankton distributions.

K-12 Events

- Nancy Kachel (JISAO) and Dave Kachel (NOAA) presented EcoFOCI educational materials to middle schoolers at Jane Addams K-8 school during November 2011 as part of the school's 2nd Annual Science Day.
- Calvin Mordy, Lisa Sheffield Guy, and Scott McKeever (JISAO) presented at the Pacific Science Center's Polar Science Weekend 1-2 March 2012

Enhanced NOAA-UW Training and Collaboration Through the Bevan Series on Sustainable Fisheries

PI
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Other UW Personnel
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Task I

NOAA Contacts
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NOAA Goal
Healthy Oceans

Description
The purpose of this project is to support a teaching assistant (TA) for winter 2012 to run the Bevan Series: coordinate travel, logistics, plan meetings, set up and administer websites, and assist with two associated courses (one graduate and one undergraduate).

The 11th Bevan Series on Sustainable Fisheries is a prestigious public seminar series administered by the School of Aquatic and Fishery Sciences, University of Washington. Ten internationally renowned speakers are invited to speak on a wide range of topics such as fisheries management, acoustics, genetics, disseminating science to the media and the social impacts of fishing. In addition, an undergraduate class (30 students) and a graduate class
(15 students) read papers selected by the speakers, meet the speakers and discuss the seminars through an online website and in weekly, in-person discussion groups. Each speaker comes for two days allowing ample time for meetings with NOAA researchers and UW academics.

Other general expenses are covered in 2012 by multi-year donations received from the two Centers in previous years (anticipated to be requested again in 2012), and by the Donald E. Bevan Fund in Fisheries.

Objectives

Bring in outstanding researchers from outside Seattle at the forefront of marine and freshwater management, and fisheries.

- Increase collaboration between SAFS, other UW departments, NOAA centers, and industry.
- Promote scientific research to the public.

Accomplishments
Ten speakers have been invited (6 have delivered their presentations, 4 still to come). There has been broad audience support from UW and NOAA personnel. Organized events allow collaborative discussions in a more informal setting. These events included David Armstrong , SAFS director and André Punt, associate director, Russ Nelson (AFSC), John Stein (NWFSC), and Lisa Graumlich, the Dean of the College of the Environment. In addition, John Horne, SAFS professor, attended all-day workshops on acoustics at the NWFSC and AFSC. Guest speaker, Steven Campana, will visit the NWFSC during his stay. One speaker (Susan Jackson) was delayed due to the snow storm and will come in April.

NOAA Scholar Funding

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Task III

NOAA Contact
Kathleen Jewett, Northwest Fisheries Science Center

NOAA Goal
Healthy Oceans

Description
DO-IT (Disabilities, Opportunities, Internetworking, and Technology) serves to increase the participation of individuals with disabilities in challenging academic programs and careers, particularly those in science, technology, engineering and mathematics (STEM). The DO-IT Scholars Program works with high school students with disabilities, who have the potential to pursue college studies and careers and to develop leadership skills, yet face significant challenges because of their disabilities. During a 10-day, summer program at the University of Washington in Seattle, DO-IT scholars participate in academic lectures and STEM labs; live in residence halls; and practice skills that will help them become successful in college and careers. During the year that follows, each scholar completes a project, engages with staff in a presentation or meeting at his/her school, and participates in online and/or on-site activities.

Specific activities for April 1, 2011 – March 31, 2012 include:

April 2011
DO-IT Advisory Board selected one additional DO-IT scholar to be supported with NOAA funds. All scholars were notified and details for involvement shared. Scholars received program videotapes and materials.

May–June 2011
Computer was set up in scholars' homes, and they were "introduced" to mentors, peers, and near-peers online.

July 2011
Scholars engaged in 10-day residential Phase I Summer Study at the University of Washington. They gained Internet, college preparation, career planning, self determination, and leadership skills. Scholars chose year-long projects.

August 2011– March 2012
Scholars participated in DO-IT's online e-mentoring community; they received mentoring, near-peer, and peer support, weekly electronic lessons, and access to useful college preparation, academic, and career information online. Scholars participated in DO-IT conferences and other online and on-site activities. They completed year-long projects and helped DO-IT recruit DO-IT pals and scholars from their schools. DO-IT staff members participated with scholars in presentations and meetings at their schools.

Note that after this time period the scholar supported through this funding will continue to engage in DO-IT. He/she will attend a 1-week Summer Study session on the UW campus, during which he/she will present his/her year-long project. The following year they will engage in the e-mentoring community and learn about on-site activities and events in which they can participate. The third summer he/she will work as an intern in the Summer Study. After that, they can continue engaging in the e-mentoring community, gaining and offering resources and support.

Objectives

1. ***Increase Success of Students with Disabilities:*** The ultimate objective of the DO-IT Scholars Program is to increase the success of students with disabilities in challenging postsecondary academic programs and careers.
2. ***Financial Support:*** The objective of the funded project is to support one student with a disability interested in pursuing postsecondary education and a career in one of the areas of focus of NOAA through three years of the DO-IT Scholars Program.

Accomplishments

- Scholar identified, computer delivered, and training completed.
- Online and on-site interaction with peers, near-peers, mentors and staff.
- Participation in 10-day Phase I Summer Study.
- Funded scholar applied to three STEM related internships for the summer.
- Funded scholar applied to approximately 10 post-secondary institutions and awaits notification.

Evidence of Impact of DO-IT Scholars Participation: Pre/post surveys of DO-IT Scholar participants, participant evaluations of Summer Study activities and internships, progress of participants in longitudinal transition study, and other evaluation data (see *www.uw.edu/doit/Stem/tracking4.html*) suggest positive impact with respect to preparing participants for college and career success.

Investigations of Links between the Early Life History Dynamics of Fish Species and Climate/Ocean Conditions in the Gulf of Alaska

PI
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Other UW Personnel
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NOAA Personnel
Jeff Napp, Kathryn Mier, Alaska Fisheries Science Center

Task II

NOAA Contact
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NOAA Goal
Healthy Oceans; Climate Adaptation & Mitigation

Description
This research is being carried out in conjunction with the NOAA Alaska Fisheries Science Center's Recruitment Processes and EcoFOCI Groups. Early life history aspects of recruitment processes among Gulf of Alaska fish species are being investigated. Data are from ongoing (since 1972) collections of ichthyoplankton samples and associated oceanographic and climate measurements in this region. Ichthyoplankton surveys that sample the early ontogeny pelagic phase (eggs/larvae) of fish integrate information on a diverse range of species with variable adult habitats and ecologies. Synthesis of these ichthyoplankton and associated environmental data are being carried out in order to understand species pelagic exposure patterns and response outcome during early ontogeny. The research is contributing to a mechanistic understanding of environmental forcing on early life history aspects of recruitment dynamics among marine fish species.

Objectives
1. ***Project 1. Gulf of Alaska late spring ichthyoplankton time-series and associated environmental forcing variables.***
   Continue development of this time-series by calculating the late spring indices of species abundance from the designated study area for all available recent years. Investigate synchronicity among species interannual patterns in abundance. Match the new extension of the ichthyoplankton time-series with further development of the time-series of environmental forcing variables; basin-scale climate and ocean indices, and local-scale physical measurements.
2. ***Project 2. Conceptual Framework for evaluating early life history aspects of recruitment dynamics among Gulf of Alaska fish species.***
   Using multivariate statistics and analytical methods, explore multispecies patterns in the historical ichthyoplankton data, and species life history and ecological traits, to identify coherent patterns that may have predictive capacity in terms of exposure-response coupling during early ontogeny.
3. ***Project 3. Participate in the NPRB-sponsored Gulf of Alaska Integrated Ecosystem Research Program (GOAIERP).***
   Develop the synthesis of historical GOA ichthyoplankton data into a comprehensive review of the early life history of the GOAIERP focus species; walleye pollock, Pacific cod, arrowtooth flounder, sablefish and Pacific ocean perch. Help with field logistics and data dissemination for the 2011 field season and contribute to the analysis of ichthyoplankton data collected during 2010-2011.

Accomplishments

Project 1

Late spring larval fish abundance data continue to be accumulated annually and are now available through 2009. The species abundance indices have been calculated from the designated study area for all available recent years extending the time-series from 1981 through 2009. Synchronicity among species interannual patterns in abundance has been investigated as a contribution to Project 2. Time-series of physical variables comprising monthly mean values for January through May, 1981-2009, are being updated and developed in conjunction with scientists from the EcoFOCI research program at NOAA's Pacific Marine Environmental Laboratory. With extension of the data time-series, links between species abundance and the physical variables will be re-examined (as in Doyle et al., 2009) for consistency or variability.

Project 2

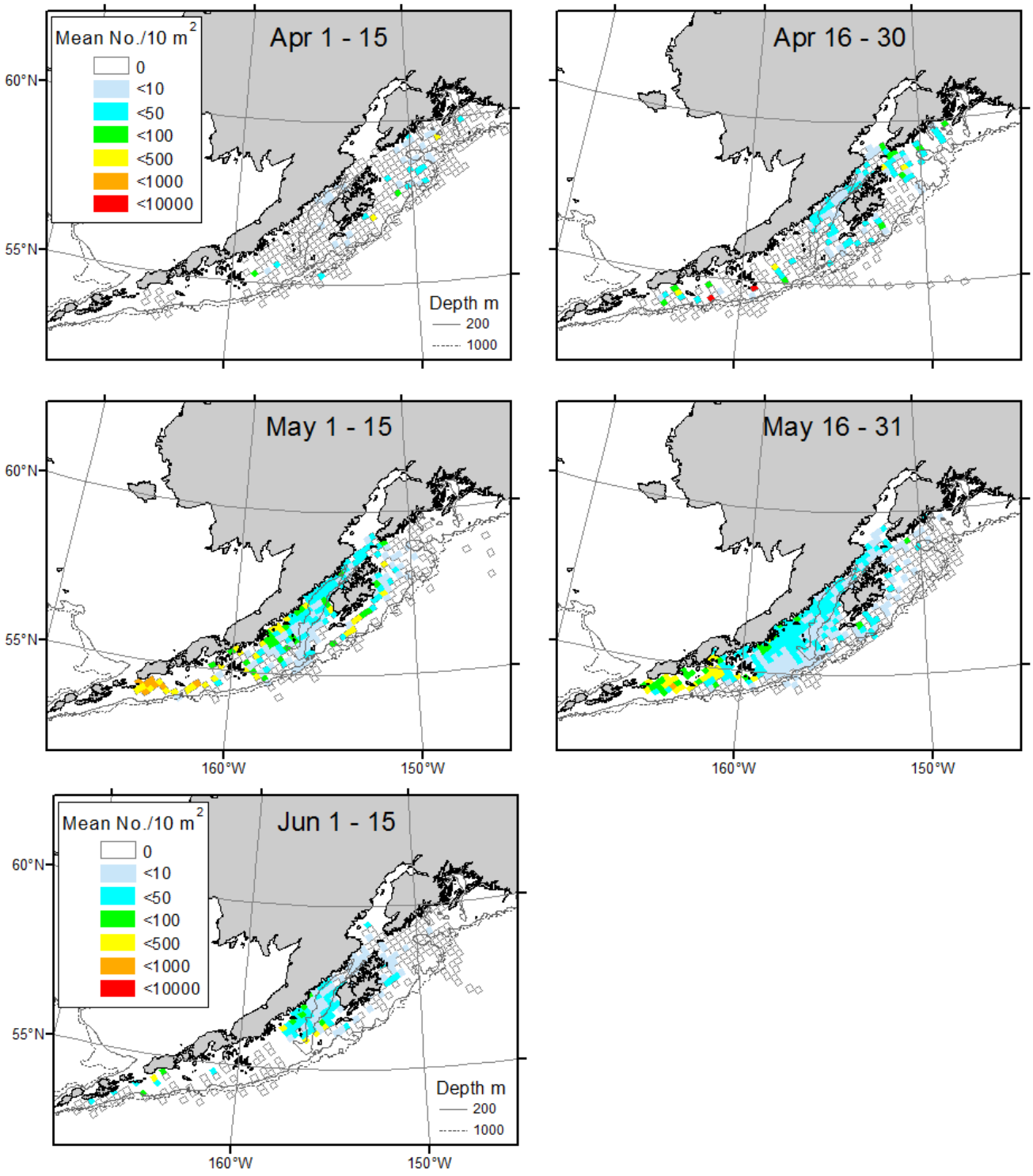
Identification of major early life history and ecological gradients among GOA fish species has been carried out by performing Principal Component Analysis ordination on a data matrix of species by early life history and ecological traits (numerically expressed). In addition, species have been assigned to groups based on their association with end-points of these gradients and associated ecological risk and resilience characteristics have been discerned. This pilot project has yielded an effective conceptual framework for evaluating the exposure and response of GOA species to the pelagic environment during early life (Doyle and Mier, in prep.). Continuation of Project 1 will contribute to future development of this work which will examine relationships between larval species abundance and groups of environmental variables from the extended time-series 1981-2009. The working hypothesis for this ongoing research is that we can utilize similarities in reproductive and early life history characteristics among species to identify: 1) ecologically-determined species groups that are pre-disposed to respond to environmental forcing during early life in similar ways, and 2) plausible environmental predictors of early life history aspects of recruitment variation. Presentations on this work have been given at the American Fisheries Society annual meeting in Seattle in September 2011, the ICES conference in Gdansk, Poland in September 2011, and at the Western Groundfish Conference in Seattle, February 2012. There is interest in the development of pan-regional applications of this multispecies early life history synthesis and exposure-response framework, and an initial pilot project has commenced for the Northern California Current region at the NOAA Northwest Fisheries Science Center in Newport, Oregon.

Project 3

Synthesis of historical GOA ichthyoplankton data continues as part of the Retrospective component of the NPRB-sponsored GOAIERP program. Spatial, seasonal, and interannual patterns of variation in abundance of the early ontogenetic stages of the five key species are being integrated into the development of individual pelagic exposure profiles for these species. Observed similarities and synchronies with other species, as well as evaluation of links between larval abundance patterns and the physical environment are also included in the exposure profiles. These comprehensive early life history reviews of the five key species are being developed into a single large manuscript for submission to the NOAA professional paper NMFS series (Doyle, in prep). Preliminary results have been presented at the 2012 Alaska Marine Sciences meeting, the 2012 Western Groundfish Conference, and will be reviewed at the GOAIERP March 2012 Principal Investigator's meeting.

Evaluation of the first GOAIERP field season (2010-2011) is being undertaken with respect to field logistics, and data integrity, dissemination and storage issues. A review of these issues will be facilitated at the March 2012 PI meeting, and will be incorporated into the planning for the 2013 field season.

Seasonal progression in distribution and abundance of Pacific cod larvae in the Gulf of Alaska during their period of occurrence in the plankton. In each panel, mean larval abundance during individual half month periods was calculated throughout a grid of 20 x 20 km squares covering historical sampling surveys (1972, 1977-2009) with mean abundance stratified by year.



Maps showing seasonal progression in distribution and abundance of Pacific cod larvae in the western Gulf of Alaska, based on historical ichthyoplankton sampling 1977-2009. Grid squares on the map are 20 x 20 Km and a stratified mean abundance of larvae within these squares was calculated by combining data over all years sampled for half month periods when larvae are present in the plankton.

Improving Ecosystem-Based Stock Assessment and Forecasting by Using A Hierarchical Approach to Link Fish Productivity to Environmental Drivers

PI
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Other UW Personnel
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NOAA Personnel
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Task III

NOAA Contact
Kenric Osgood, Office of Science & Technology

NOAA Goal
Healthy Oceans; Climate Adaptation and Mitigation

Description
A central feature of ecosystem-based fishery management is a broader consideration of environmental influences on stock productivity when assessing populations and setting harvest policies. Insights into environment-stock productivity relationships may be used in short term, tactical advice (e.g. annual catch limits) or in medium to long-term strategic advice that evaluates the long-term effectiveness of proposed harvest strategies in the face of climate change (A'mar et al. 2009). Thus, improved insight into how environmental factors affect stock productivity offers the promise of improved stock assessment and forecasting, especially when it allows for pre-emptive reductions in fishing effort on species likely to be worst affected. The emerging push for including ecosystem-based considerations in fisheries management decisions has therefore resulted in increased demands for information on how ecosystem dynamics affect fished stocks. This project seeks to conduct a synthetic analysis of environmental drivers of fisheries productivity to improve our capability of incorporating these drivers into stock assessments and forecasts.

Research regarding the direct inclusion of environmental information into stock assessments is still developing (Maunder and Watters 2003; Deriso et al. 2008; Schirripa 2009). Moreover, information on environmental links to stock productivity can be used to guide the specification of assessment models. For example, understanding environmentally forced changes in growth over time can be used to specify periods of good and poor growth in assessments. Hollowed et al. (2009) and A'mar et al (2009) demonstrate how long-term climate impacts on fish and fisheries can be predicted from a mechanistic understanding of how fish productivity responds to climate-sensitive environmental variables.

Given the large number of stocks that are presently managed by North Pacific and Pacific Fisheries Management Councils, the challenge of identifying key causative agents underlying production dynamics for each is daunting. This challenge is made even more difficult by the notorious problems that arise when attempting to identify causal relationships from serially autocorrelated time series data (Walters and Collie 1988; Myers 1998). Here we hypothesize that the process of including environmental information in stock assessments and forecasts can be improved by identifying groups of stocks that respond to environmental conditions in the same way. If this hypothesis is true, then the challenge is greatly simplified because instead of linking production to dynamic environmental features for each stock individually, one can predict the average response of groups of stocks that are expected to respond similarly. Therefore, our proposed work seeks to make a significant step forward for stock assessment and forecasting by using advances in numerical statistical methods that permit the estimation of hierarchical ensemble models.

There is considerable support for the notion that groups of stocks may respond to similar sets of environmental conditions. Previous studies revealed that patterns of recruitment variability in marine fishes showed similarities across species (Caddy and Gulland 1983) and these similarities produced recognizable patterns in population variability (Spencer and Collie 1997). In the North Pacific region, the well-known shift in the Pacific Decadal Oscillation transformed the ecosystems of Alaska and Northern California Current by enhancing the productivity of some species and diminishing the productivity of others (Anderson and Piatt 1999; Mantua et al. 1997; Hollowed et al. 2001). Mueter et al. (2007) demonstrated that in the Gulf of Alaska and eastern Bering Sea – Aleutian Islands, gadid and pleuronectid recruitment patterns were inversely related to each other, suggesting that stocks in these groups were responding to a common set of environmental forcing in opposing ways.

We will conduct a Bayesian hierarchical ensemble analysis to evaluate environmental drivers that govern the production dynamics of groundfish stocks in the Aleutian Islands, Gulf of Alaska and Northern California Current. These areas represent distinct ecosystems, and allow contrasts between groups of species that may be influenced by different environmental conditions. The statistical approach is ideally suited to identifying group-level effects of environmental features on populations: these models directly estimate the average effects of environmental drivers for entire groups of stocks (e.g. the average effect of SSH on recruitment for each group of stocks). These estimation models use information on all stocks simultaneously, resulting in enhanced statistical power and diminished probability of spurious correlations. By proposing a suite of candidate grouping / classification schemes and evaluating model fit for each alternative, we can identify which grouping scheme is best supported by the data. An additional strength of the Bayesian approach is that the resulting output (posterior probability distributions) can be used as an informative prior for data-poor stocks.

Objectives

1. ***Identifying ecologically relevant forcing functions and developing databases that contain time series for each.***
2. ***Collecting recruitment and growth data from target and non-target (likely growth only) fisheries data as time series and developing a database structure to house these data.***
3. ***Identifying candidate grouping structures for species (i.e., what attributes of species might predispose them to respond to environmental forcing in similar ways?)***
4. ***Running Bayesian hierarchical models under alternative grouping structures to estimate the effects of environmental variables on productivity and to test which group structure is best supported by the data.***

Accomplishments

We have compiled time series of recruitment rates for main assessed stocks in the Aleutian Islands, Gulf of Alaska and Northern California current. We have also devised and tested our analytic approach to determine the limitations of the analysis, specifically constraints on the way that hypothesized groups are selected. The main issue is that it is only possible to identify significant group structure when there are at least 5 stocks comprising each group – if group structure partitions the stocks at finer levels of aggregation, statistical power is lost. We are now working with local experts in oceanography and fish life history to develop candidate grouping structures and relevant environmental driving variables.

Reasons Why Objectives Not Met

Our progress has lagged slightly behind our expectations because the project award announcement was made too late for us to recruit a graduate student to the project. We have compensated for this lack of personnel by bringing other graduate students into the program. We intend to recruit a student for the fall 2012 admissions class.

Using HPCC Techniques to Power User Tools for Ecosystem Models: the Bering Sea example

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Task III

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NOAA Goal
Resilient Coastal Communities & Economies, Healthy Oceans

Description
This project explores methods for load balancing of visualization and model analysis operations, to expedite the distribution of model results to the scientific community at large. This work builds off efforts undertaken by the Alaska Ocean Observing System (AOOS) data management team to apply parallelism and load balancing to their model products. As a test dataset, the effort will use the biophysical ecosystem model of the Bering Sea being developed by NOAA/JISAO scientists participating in the Bering Sea Integrated Ecosystem Research Program (BSIERP). This model is based on the Regional Oceanographic Modeling System (ROMS) framework, and includes oceanography, plankton, and several major commercially-important fish species across the Bering Sea. This work enhances collaboration between modelers and field scientists, through efficient hosting and serving of biophysical model output.

Objectives
- ***Enhance networking, collaboration, visualization, and analysis capabilities of NOAA/JISAO and other scientists, through effective application of new or improved information technology.***
- ***Provide greater access to NOAA's holdings of real-time and historical data and information to customers in a more complete, more usable form, and in a timelier manner.***
- ***Improve technology for access to critical data, information and unique resources in a manner that increases mission effectiveness and furthers NOAA's service to the nation.***

Accomplishments
Both 40-year hindcast and 30-year forecasts of the Bering Sea (circulation and lower trophic level components) have been translated to regularly gridded (latitude-longitude-depth) files for hosting by AOOS. These files are also being used for local analysis and visualization at AFSC and PMEL.

An Evaluation of Management Strategies for Implementation of Annual Catch Limits for Alaska Groundfish

PI
André Punt, UW — School of Aquatic and Fishery Sciences

Other Personnel
Carey McGilliard, SAFS

NOAA Personnel
Anne Hollowed, Northwest Fisheries Science Center

Task III

NOAA Contact
Anne Hollowed, Alaska Fisheries Science Center

NOAA Goal
Healthy Oceans, Resilient Coastal Communities & Economies

Description
The NMFS National Standard 1 guidelines for implementing the Magnuson-Stevens Fishery Conservation and Management Act identified the need to formally incorporate uncertainty into future harvest projections. This project will review the impacts of implementing management strategies which aim to satisfy these guidelines for the Eastern Bering Sea Aleutian Islands (BSAI) and Gulf of Alaska (GOA) groundfish fisheries. A multispecies interaction model based on a linear programming approach developed at the Alaska Fisheries Science Center will be updated to reflect the constraints resulting from recent amendments to the North Pacific Fishery Management Council (NPFMC) groundfish fishery management plans for the GOA and BSAI. Methods will also be developed to estimate uncertainty buffers for species or species groups within these fisheries using the P* and decision theoretic approaches and these methods will be linked into the multispecies interaction model. Finally, alternative management strategies will be evaluated and presented to the relevant management bodies.

Objectives
1. ***Update the multispecies technical interaction model developed by NOAA to project future catch of groundfish under different harvest scenarios to include added constraints resulting from recent amendments to the NPFMC groundfish fishery management plans for the GOA and BSAI***
2. ***Develop methods to estimate uncertainty buffers for species or species groups within the BSAI and GOA fisheries using the P* and Decision Theoretic (DT) approaches***
3. ***Modify the multispecies technical interaction model to incorporate the P* and DT uncertainty buffers.***
4. ***Design alternative management strategies for evaluation by the NPFMC***

Accomplishments
This project started in fall 2011, but the student conducting the research is only allocated part-time to the project.

Three options for accounting for scientific uncertainty are being explored: (1) the status quo: the tier system that is being used currently by the NPFMC; (2) the P* approach, which is based on the choice of an "acceptable" probability of overfishing and the calculation of a probability density function describing the overfishing level; and (3) the Decision Theoretic approach where the magnitude of uncertainty buffers depends on the level of uncertainty about a fish stock.

The technical interaction model includes linear constraints that describe the behavioral and economic aspects of the fishery. Potential updates to these constraints, such as inclusion of a constraint on fishing due to protected species and the addition of more realism to economic constraints are being investigated. In addition, methods for accounting for recruitment dynamics in the model are being revised.

Evaluating the Performance of a Spatially-Structured Fish Population Assessment Model

PI
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Task III

NOAA Contact
Richard Methot, Northwest Fisheries Science Center (NWFSC)

NOAA Goal
Healthy Oceans

Description
The purpose of this project is to explore, test, and document features of Stock Synthesis (SS), a widely used, generalized stock assessment package. Various features of this package have not been widely used, in part because of lack of information on the implications of their use, or the quality of estimates derived from additional model complexity. This includes options for modeling spatial structure and movement among areas, division of stocks into "growth morphs" with different average growth rates, and additional complexity in correcting for bias in recruitment estimates.

Objectives
1. ***Develop methods to evaluate the performance of Stock Synthesis version 3 (SS) by means of simulation***
2. ***Explore and document the implications of using the growth morph approach to modeling the selection and removal of the faster-growing subset of fish populations***
3. ***Test the spatial extensions of SS***
4. ***Describe the problem of bias in recruitment estimates and provide advice on the methods needed to correct for it in fisheries stock assessment***s

Accomplishments
Dr. Ian Taylor who had been working on this project was offered a full-time position at the NWFSC during the last reporting period. No new personnel have been found to work on the project. The paper initiated during the project has now been published.

Improving Assessment Methods: Developing and Evaluating Alternative Estimators of Survey

PI
André Punt, UW — School of Aquatic and Fishery Sciences

Other UW Personnel
Mathieu Woillez, SAFS

NOAA Personnel
Jim Ianelli, Alaska Fisheries Science Center

Task III

NOAA Contact
Jim Ianelli, Alaska Fisheries Science Center

NOAA Goals
Healthy Oceans, Resilient Coastal Communities & Economies

Description
This project will improve geostatistical simulations of eastern Bering Sea walleye pollock by adding an age component, and refining the treatment of fish lengths in the simulation procedure. This will be done though a multivariate geostatistical model, which will incorporate relationships between length and proportions-at-age. Earlier work did not incorporate age information and used only a single summary statistic to represent the length frequency distribution. Use of a single statistic to describe a length distribution is only appropriate when distributions are narrow and unimodal. This project will use a more general and robust set of summary statistics, such as quantiles of length frequency data to develop a geostatistical model, which will infer potential relationships with proportions-at-age. The performance of the estimators developed will be tested within an assessment model application using simulated and real data with alternative likelihood specifications. In this investigation, assessment model results using survey-described estimates of age-composition together with covariates will be compared with the more common approach of using simple point estimates (i.e. proportions) and "effective sample sizes" that are assumed to follow a multinomial distribution (with implied covariance structure).

Objectives
1. ***Develop a multivariate model for geostatistical simulations of eastern Bering Sea walleye pollock which will incorporate relationships between length and proportions-at-age***
2. ***Test the performance of the geostatistical model and the associated summary statistics within a stock assessment model***

Accomplishments
Uncertainty due to sampling in space was evaluated using geostatistical conditional (co)simulations. Multiple realizations of acoustic backscatter were produced using transformed Gaussian simulations with a Gibbs sampler to handle zero values (Figures 1a to 1c). Multiple realizations of length frequencies were produced using transformed Gaussian co-simulations derived from the quantiles of the empirical distribution (Figures 1d to 1l). Practically, at each trawl location, sampling provides length frequency data. The quantile function of each length frequency datum was modeled using linear interpolation and the length quantiles estimated for some probabilities. Being far from Gaussian, a normal score transformation was applied to the length quantiles. The resulting Gaussian variables were jointly modelled using a linear model of coregionalization. Gaussian conditional co-simulation was performed. Multiple realizations of transformed length quantiles were produced and back-transformed to realizations of raw length quantiles using appropriate normal score models. At each grid node, simulated length histograms were reconstructed from simulated length quantiles. Finally, uncertainty due to errors in functional relationships (the target strength-to-length relationship and for the age-length key) was evaluated using bootstraps.

This simulation framework allowed uncertainty associated with the acoustic surveys conducted during 2006-2010 to be evaluated. Higher CVs were found on average for ages 1, 2, and 3 (22-48%); otherwise, CVs were mostly around 14% for abundance-at-age. CVs for total abundance were quite variable among years. The relative contributions of each of the major sources of uncertainty (acoustic backscatter, length frequency, target strength-to-length, and age-length key) to overall uncertainty was also assessed. On average, uncertainties

related to the acoustic backscatter and length data were largest for total abundance estimates, respectively 41% and 39%. For abundance-at-age, uncertainty regarding lengths (52%) contributed on average more than that associated with the acoustic data (34%), the target-to-length relationship (10%), and the age-length key (4%). In addition, this simulation framework allowed computation of variance-covariance matrices for abundance-at-age. These estimates were compared in terms of correlations with those derived from a multinomial distribution (the assumption made in the actual stock assessment model). The differences approached a maximum of ~1 in terms of correlation differences. Ultimately additional sources of uncertainty could be incorporated in this framework, providing more comprehensive variance estimates for abundance estimated using acoustic surveys.

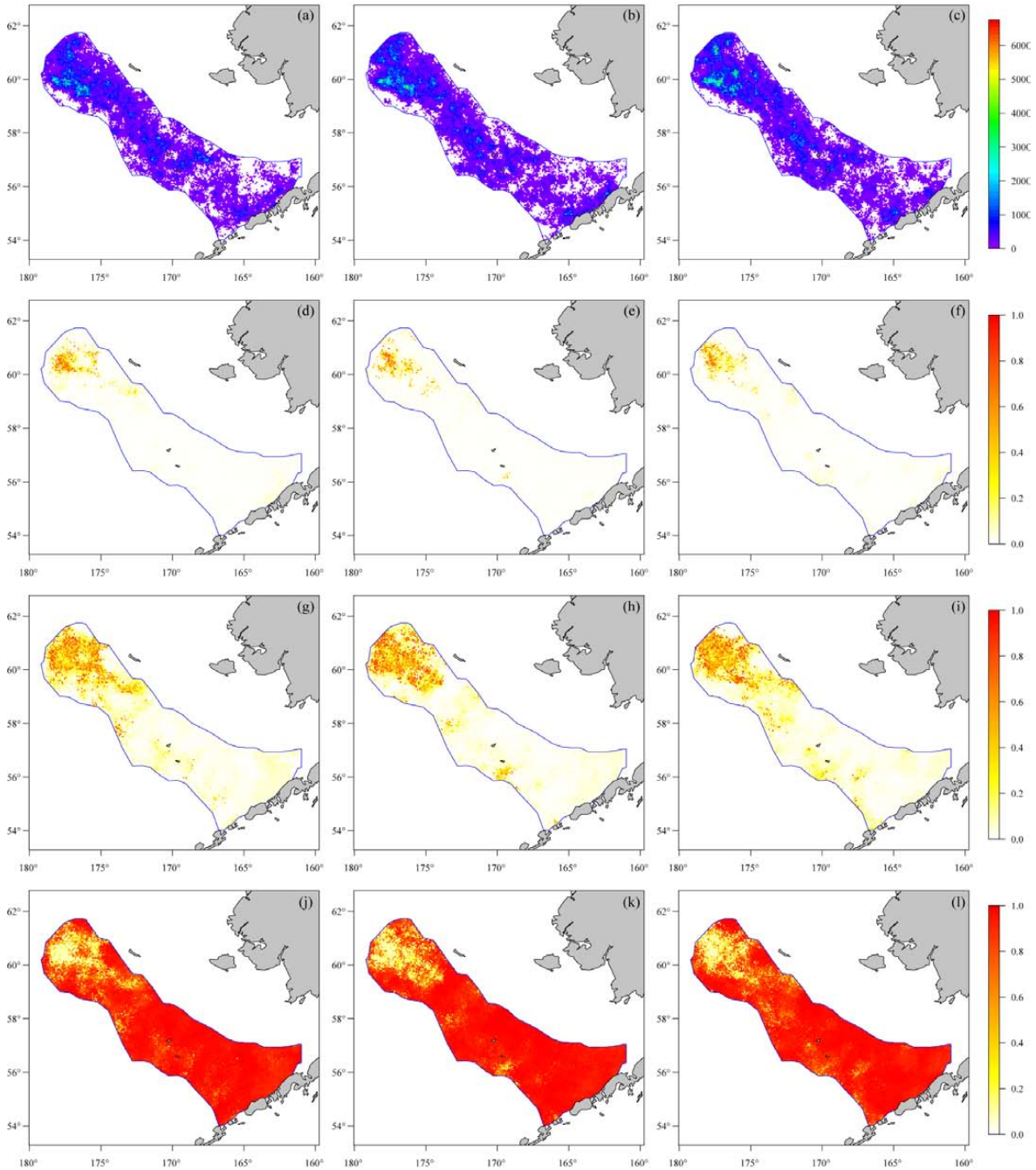


Figure 1: Three realizations of acoustic backscatter (m^2.nautical $mile^{-2}$) with a low (a), medium (b) and high means (c). Only simulated values above zero have been colored. Three realizations of length frequency histograms with a low (d, g, and j), medium (e, h, and k) and high mean length (f, i, and l) mapped as the proportion of walleye pollock < 20 cm (d, e, and f), > 20 cm and < 40 cm (g, h, and i), and > 40 cm (j, k, and l).

West Coast Groundfish Stock Assessment

PI
André Punt, UW — School of Aquatic and Fishery Sciences

Other UW Personnel
Kotaro Ono, Chantel Wetzel, Carey McGilliard, SAFS; Motoki Wu, Quantitative Ecology and Resource Management

Task III

NOAA Primary Contact
Kathleen Jewett, Northwest Fisheries Science Center (NWFSC)

NOAA Goals
Healthy Oceans, Resilient Coastal Communities & Economies

Description
The purpose of this project is to conduct research on the population dynamics and stock assessment of groundfish species occurring off the coasts of Washington, Oregon and California (west coast).

Objectives
1. ***Conduct research on the population dynamics of west coast groundfish. Develop quantitative methods for the analysis of population dynamics of groundfish species.***
2. ***Collaborate with NMFS scientists who are conducting quantitative stock assessments of west coast groundfish species to identify key research areas and on the application of methods and models.***
3. ***Present the results of the research at regional and national meetings, Stock Assessment Team (STAT) and Stock Assessment Review (STAR) meetings, as well as to relevant advisory entities for the Pacific Fishery Management Council (e.g. the Groundfish Management Team GMT, and the Scientific and Statistical Committee SSC) in addition to publishing these results in peer-reviewed scientific publications.***
4. ***Build expertise among scientists, particularly those working on west coast groundfish issues, in the application of state of the art methods for conducting management-related research for west coast groundfish.***
5. ***Provide support training, and mentoring for graduate students in the field of quantitative fisheries science.***

Accomplishments
Dr. André Punt continued to refine the software developed to estimate ageing error matrices for use in West Coast groundfish stock assessments. The paper on climate impacts on the performance of the rebuilding strategies used for West Coast groundfish species was completed and published. Dr. Punt, along with Dr. Mark Maunder (IATTC), proposed a special issue of the journal *Fisheries Research* on Stock Synthesis and its applications and are acting as Guest Editors. Drs. Punt and Maunder have written a paper on integrated analysis, which will be one of two central papers in the special issue. Several NWFS scientists will be submitting manuscripts to this special issue, and be acting as peer-reviewers.

Mr. Motoki Wu (UW MS student) has continued to evaluate the performance of methods of estimating meta-analysis-based priors for the steepness parameter of the stock-recruitment relationship. An extensive evaluation of factors impacting the performance of a non-linear mixed effects model given data without error has demonstrated that data contrast (quantified in terms of the mean steepness and the relative biomass of the stocks at the mid-point of the time series) are the primary determinants of performance. The number of stocks had a marked, but less pronounced, effect on estimation performance. Analyses in which the data used by an additional two meta-analysis methods are subject to uncertainty have been initiated and preliminary results are now being analyzed.

Mr. Kotaro Ono (UW Ph.D. student) is evaluating the efficiency of spatial management, ITQ systems, and gear modification as possible tools to reduce by-catch and increase species selectivity in a trawl fishery, using the West Coast trawl fishery as an example. He is building a multi-species, spatially-explicit, bio-economic model based on the population dynamics of a few typical groundfish species and will use this model to explore the effect of habitat segregation between species and to assess whether there is a management method based on habitat to reduce by-catch and increase yield (and/or profit). His simulation work

based on a two species (a productive and an unproductive stock), one dimensional habitat (linear array) model showed that discarding was the main factor influencing both the sustainability and the profitability of a two-species fishery, especially with increasing habitat overlap between the two species. The use of MPAs significantly reduced the profitability of the fishery and was not always able to maintain sustainability, depending on the mobility of the harvest species. Vessels trying to maximize their ability to catch their quota in an ITQ system increased their yield (at medium to high levels of overlap between species), but their profitability was less or the same compared to vessels focusing on maximizing their short-term profit. Kotaro will now expand his study to a two-dimensional habitat model with additional species based on information from the West Coast groundfish trawl fishery.

Ms. Carey McGilliard (UW Ph.D. student) is using simulation modeling to analyze the ability of several statistical catch-at-age models to estimate current biomass after the implementation of a single, large no-take marine reserve. She is basing the analysis on an age- and sex-structured two-dimensional spatial operating model, with three patterns of ontogenetic movement to represent the "true" underlying population dynamics. Results show that assessing populations as a single stock without accounting for the no-take marine reserve results in severe underestimation of biomass for two of the three patterns of movement considered in the simulations. Performing separate assessments for fished and protected areas leads to improved estimation performance in the absence of movement between assessment areas, but can severely overestimate biomass otherwise. Performing a three-area assessment with estimation of movement parameters between areas is the best method for assessing a species with non-directed, low movement rates and for situations where movement patterns were unknown. The three-area assessment model with estimation of movement parameters is unable to estimate movement for two of the three movement patterns, but correctly estimates current biomass in the absence of a marine reserve. Applying the same configuration of the assessment method when there is a marine reserve shows that the marine reserve informs many of the movement parameters.

The series of regular (generally bi-weekly) UW/NWFSC/AFSC Fisheries Think Tanks continued during the reporting period, coordinated by Ms. Chantel Wetzel (UW Ph.D. student). NMFS scientists and UW faculty and students participate in these workshops, the purpose of which is to increase collaboration among scientists working on west coast groundfish issues. A list of the Fisheries Think Tanks that took place during the reporting period is given at: *http://fish.washington.edu/news/miniworkshop/index.html.*

Bowhead Whale Feeding in the Western Beaufort Sea: Passive Acoustic Survey Component

PI
Kathleen M Stafford, UW — Applied Physics Laboratory

Task III

NOAA Contact
Catherine Berchok

NOAA Goals
Resilient Coastal Communities & Economies, Healthy Oceans

Description
As part of a larger, Minerals Management Funded Study on the feeding behavior of bowhead whales in the vicinity of Barrow, Alaska, an acoustic recording component was incorporated with other sampling regimes undertaken by the National Marine Mammal Laboratory, the University of Alaska at Fairbanks and the Woods Hole Oceanographic Institution.

Passive acoustic detection and tracking is a proven tool for assessment of large whales in Alaskan seas (Moore et al. 2006). This may be the best method to effectively monitor seasonal occurrence over large spatial and temporal scales. Specifically, acoustic detection has proven a key addition to the census of bowhead whales during their spring migration past Barrow (Clark and Ellison 2000) and in relation to oil and gas development activities offshore Prudhoe Bay (Greene et al. 2004). More recently, gray whale calls have been detected year-round near Barrow on long-term recorders deployed in collaboration with the NSF/Shelf-Basin Interaction Study (Stafford et al. in press); this was the first evidence of gray whale occurrence in winter near Barrow. An array of moored passive acoustic receivers east and west of the study area will be able to detect bowhead calls as the whales enter and use the waters of the western Beaufort Sea. Year-round deployment will provide previously unattainable assessment of the seasonal occurrence of bowheads in the study area.

Objectives
1. ***Assess the seasonal occurrence of bowhead calls in the study area during the third field season (mid-August 2010 to mid-August in 2011) .***
2. ***Assess the annual occurrence of bowhead whale calls in the study season year-round starting in August 2010.***
3. ***Correlate bowhead occurrence with results from oceanographic and prey sampling (e.g., temperature, salinity, florescence, and annual ice cover) to establish predictive variables for bowhead occurrence.***

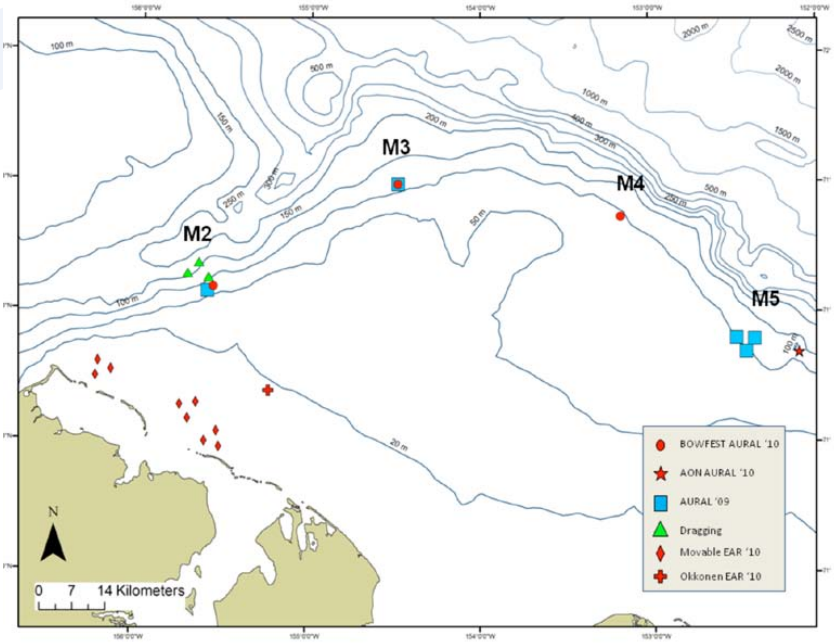


Figure 1. Locations of passive acoustic recorders during the 2010 BOWFEST field season.

Accomplishments

Only data from the site at M3 were available for 2008-2010 due to instrument loss in 2009. The seasonal pattern of bowhead calls at this site can be seen in Figure 2, which shows the detections of bowhead whales from 2008-10. No bowhead whales were detected from mid-November 2008 to mid-April 2009. The fall onset of ice arrival seems to drive the decrease in calls (i.e. the movement of whales out of the area). In spring, however, bowhead whales are heard even in nearly 100% ice concentration. This suggests that differ drivers, be they physiological or environmental, may be influencing migratory behavior in fall and spring.

In addition to bowhead whales, bearded seal beluga whale calls were detected at M3 from 2008-2010. At all sites, bearded seals (Figure 3) were vocally active year-round, peaking in the spring, which coincided with mating season and preceding sea ice break-up. The fewest calls were detected in August, when sea ice concentration was at its lowest, and calls increased with the formation of pack ice in the winter. A similar seasonal pattern was observed for both years, but daily call counts were lower in 2009-2010. Fall pack ice formed later in 2009 but spring sea ice concentration was similar for both years. Like bowhead whales, beluga whales were not detected mid-winter (Figure 4).

In addition to bowhead whales, bearded seal beluga whale calls were detected at M3 from 2008-2010. At all sites, bearded seals (Figure 3) were vocally active year-round, peaking in the spring, which coincided with mating season and preceding sea ice break-up. The fewest calls were detected in August, when sea ice concentration was at its lowest, and calls increased with the formation of pack ice in the winter. A similar seasonal pattern was observed for both years, but daily call counts were lower in 2009-2010. Fall pack ice formed later in 2009 but spring sea ice concentration was similar for both years. Like bowhead whales, beluga whales were not detected mid-winter (Figure 4).

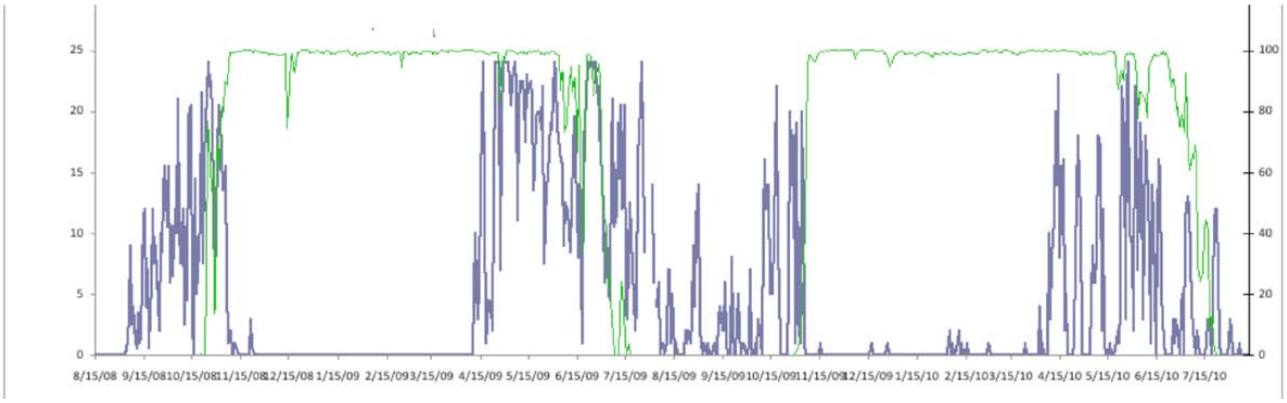


Figure 2. Bowhead whale detections (blue) with ice concentration (green) 2008-2010.

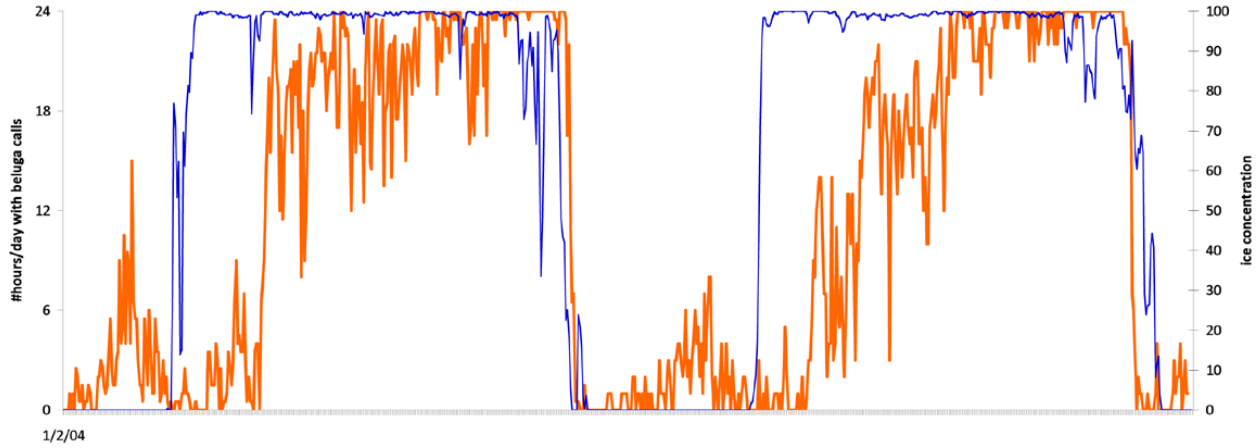


Figure 3. Bearded seal detections (orange) and ice concentration (blue).

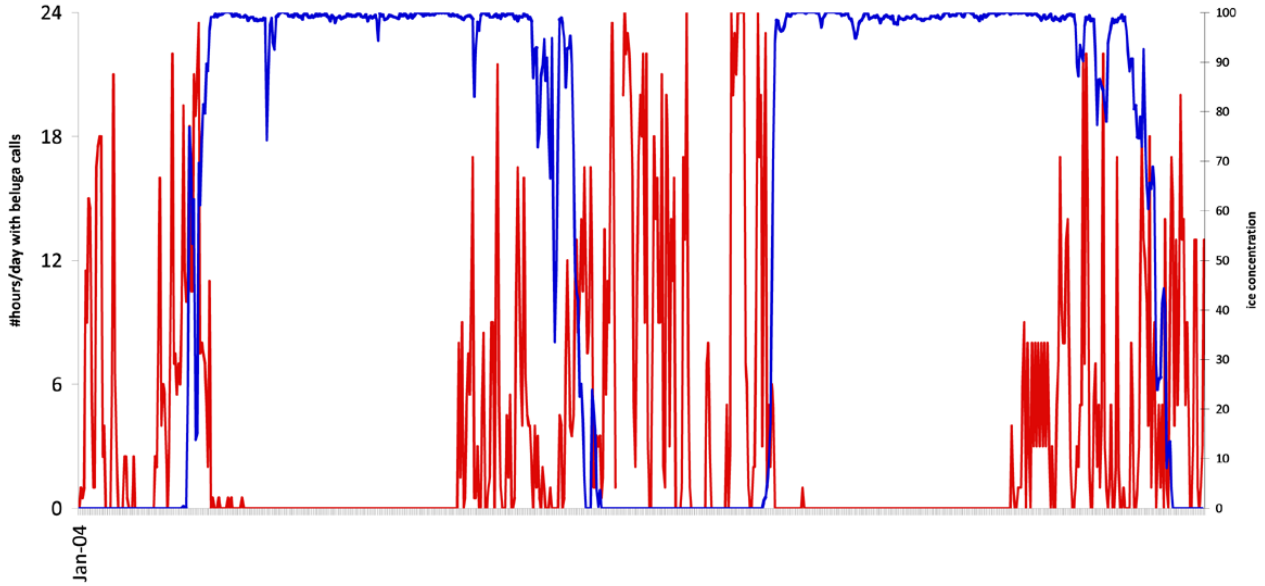
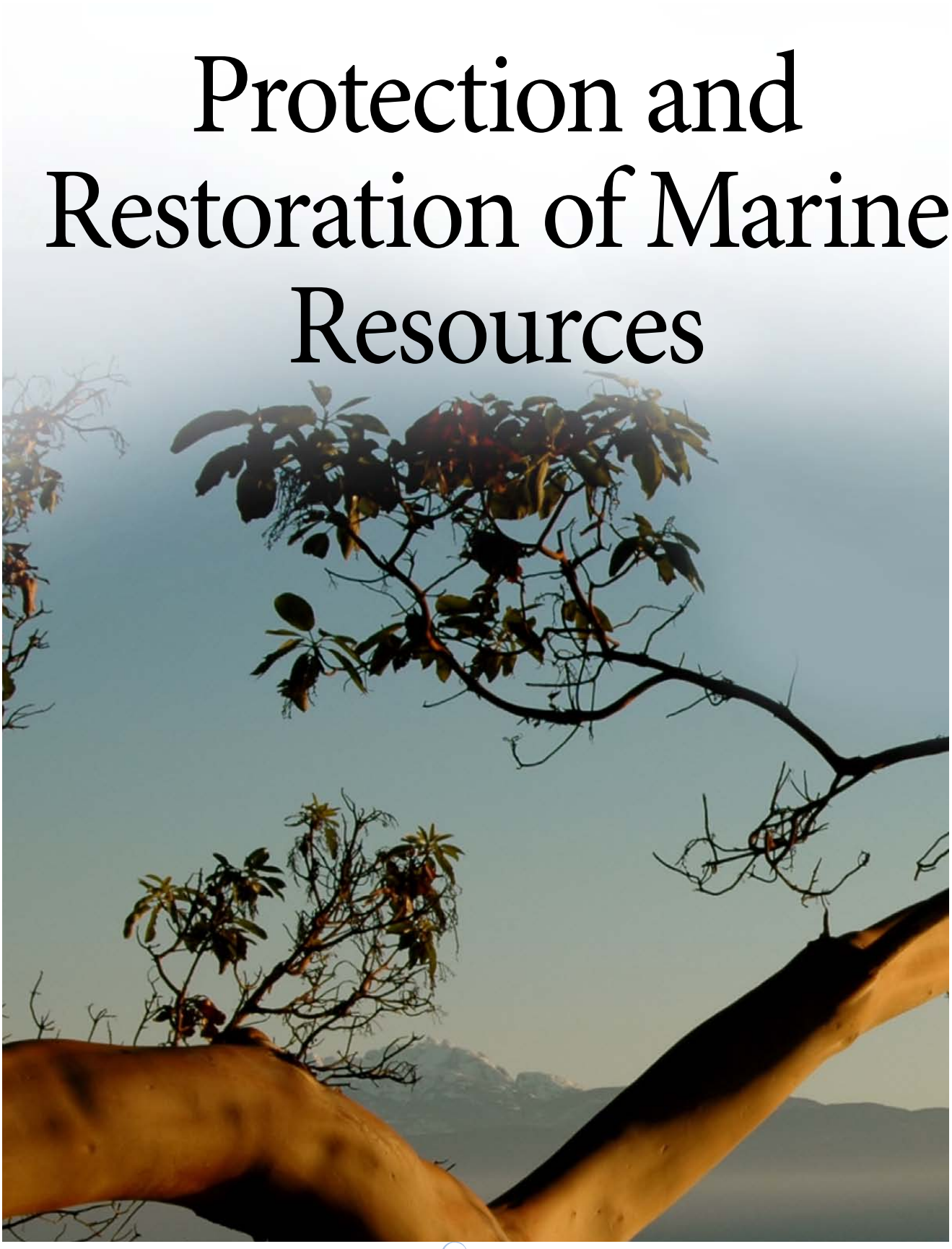


Figure 4. Beluga whale detections (red) and ice concentration (blue).

Protection and Restoration of Marine Resources



Development of a Prediction System for the California Current Integrated Ecosystem Assessment

PI
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Other UW Personnel
Albert Hermann JISAO, Jan Newton, Applied Physics Laboratory

NOAA Personnel
Isaac Kaplan, William Peterson, Northwest Fisheries Science Center

Task II

NOAA Contact
Dr. Kenric Osgood, Fisheries and the Environment (FATE)

NOAA Goals
Healthy Oceans, Resilient Coastal Communities & Economies

Description
A coastal ocean prediction system for the Pacific Northwest is being developed through a new collaborative project involving scientists at JISAO and NOAA's Northwest Fisheries Science Center (NWFSC). This system is being designed to provide quantitative forecasts of physical, chemical and biological (through lower-trophic levels) ocean properties on time horizons of ~9 months. These forecasts will be tailored towards NOAA and other operational stakeholders. The forecasts will be based on numerical ocean model simulations using a high-resolution (grid spacing ~5 km) version of the Regional Ocean Modeling System (ROMS) with a component that accounts for nutrient and plankton distributions. The initial and boundary conditions for the ROMS simulations are to be provided by a global coupled atmosphere-ocean model, the Coupled Forecast System (CFS), currently being run operationally by NOAA/NCEP/CPC for seasonal weather prediction. The ROMS output will be post-processed to yield specific properties crucial to the ecosystem including but not limited to coastal upwelling, currents and trajectories of water parcels, mixed layer depths, oxygen concentrations, pH, and plankton community types.

Objectives
The marine ecosystem of the Pacific Northwest coast is subject to large variations in physical forcing. While effort is being devoted to real-time assessment and short-term forecasts of upper ocean properties, and on probable future trends on decadal time scales, predictions for the marine ecosystem of the region on time scales of months to a year are lacking. Skillful predictions on these time scales would be of substantial benefit to managers and coastal communities and appear to be feasible using existing resources and tools. The present project represents a first step towards achieving these predictions on an operational basis.

Accomplishments
1. This project has just begun. A review of the applicants for a post-doctoral research associate position with JISAO is underway; a hiring will be made in spring 2012. Preliminary work has been carried out on the details in the configuration of the ROMS model to be run, with an emphasis on the handling of freshwater input at the coast. Early plans have been made on how the model output will be hosted on the Northwest Association of Networked Ocean Observing Systems (NANOOS) website.
2. JISAO scientist Nicholas Bond presented a review of the forecast system at the Pacific Northwest Weather Workshop in Seattle, WA on 3 March 2012.

Northwest Fisheries Science Center and University of Washington Undergraduate Intern Program

PI
Janice DeCosmo, UW — Academic Affairs

Other UW Personnel
Tracy Nyerges, Center for Experiential Learning & Diversity

Task III

NOAA Contact
Kathleen Jewett, Northwest Fisheries Science Center

NOAA Goal
Healthy Oceans; Resilient Coastal Communities and Economies

Description
This project is an educational collaboration between Undergraduate Academic Affairs at the University of Washington (UW) and the NOAA Northwest Fisheries Science Center (NWFSC) to provide education and training to undergraduates interested in fisheries research. This project is designed to engage undergraduates from a range of scientific and other relevant disciplines in internships with scientists and leaders at the NWFSC to develop their research interests and skills. These research experiences extend and enhance students' classroom learning at the UW. At the same time, it provides scientists at NWFSC opportunities to prepare promising students for careers in fisheries science research.

Objectives
1. ***Provide Internships for Undergraduates****:* Between 5-12 internship positions are anticipated annually under this project, for UW students to work with NWFSC's several research divisions. These academic year internships will also offer summer quarter option, with varying number of hours. One of the internships will also include fieldwork and travel during the summer. Selected interns will commit between 10 and 19.5 hours per week during the academic year and up to forty hours per week during summer and interim periods to their research projects. The number of total interns engaged in the program annually will depend upon the time commitment each intern is able to make to the experience and the type of research in the host lab. For instance, some research requires longer blocks of time and occasional field work.
2. ***Provide Professional Development****:* In addition to providing internships that give undergraduates experience in fisheries science research, the program also aims to provide other professional development for interns, such as learning how to network with other scientists, presenting their projects in poster format at NWFSC and/or at the UW undergraduate research symposium.
3. ***Prepare Undergraduates for Graduate School****:* Anticipated outcomes of this program include undergraduate interns moving on to graduate study in biological, marine, fisheries, or related science fields and/or developing career aspirations related to the learning and skills acquired during their internship experiences.

Accomplishments
This year nine students participated in the internship program. Four of the interns presented their research results at the annual UW undergraduate research symposium in May, 2011. All of the interns participated in networking activities and poster sessions at NWFSC.

Name	Major	Start date
David Berman	Aquatic and Fishery Sciences	1/11/2011
Stanley Biryukov	Pre-Science	7/30/2010
Kyle Frischkorn	Biochemistry	6/2/2009
Brian Harmon	Aquatic and Fishery Sciences	12/22/2010
Sarah K. Hu	Aquatic and Fishery Sciences	1/4/2010
Sarah Aspens	Aquatic and Fishery Sciences	4/1/2011
Andrew Ostericher	Chemistry (ACS)	6/23/2010
Juliana Stephan	Aquatic and Fishery Sciences, Biology (Physiology)	12/10/2009
Evan Yount	Microbiology	8/5/2010

Biological Removal of Petroleum Hydrocarbons in Marine & Aquatic Ecosystems to Determine the Fate of Deepwater Horizon Oil

PI
Russell P. Herwig, UW — School of Aquatic and Fishery Sciences

NOAA Personnel
Glen (Bushy) Watabayashi, Alan Mearns, and Christopher Barker, NOS/ORR

NOAA Contact
Glen (Bushy) Watabayashi, NOS/ORR

NOAA Goals
Resilient Coastal Communities, Healthy Oceans

Description
The NOAA Office of Response and Restoration (OR&R) is the federal agency responsible for responding to hazardous spills that occur in U.S. estuarine and marine waters. OR&R Emergency Response Division is located in Seattle, Washington. This agency was involved in evaluating damage, controlling dispersion, and determining the fate and transport of crude oil that was released into the Gulf of Mexico following the *Deep Water Horizon* well disaster in 2011. OR&R has mathematical models to predict the fate and distribution of hazardous chemicals, including crude oil that are discharged into marine and estuarine environments. In November 2011, Dr. Russell Herwig, Research Associate Professor in the School of Aquatic and Fishery Sciences, began working with OR&R to provide environmental microbiology expertise. Dr. Herwig provided preliminary biodegradation rate information that OR&R could use in their fate and transport models. This information was derived from reviewing the literature of biodegradation of crude oil and its different fractions in environmental and laboratory observations.

Dr. Christopher Barker, an oceanographer and oil spill modeler, requested biodegradation rate data for the following seven crude oil fractions for medium weight crude oil: small saturates, large saturates, aromatics, large aromatics, resins, asphaltenes, and waxes. Each one of these fractions contains many different compounds. Dr. Herwig estimated the following biodegradation half-life rates, reported in units of days. A half-life is the amount of time required to decrease the quantity of a specific oil fraction in half. Here are the estimated half-lives for the different oil fractions:

Table 1. Half-lives for the major fractions found in medium weight crude oil.

Oil Fraction	Half-life (days)
Small saturates	7
Large saturates	21
Aromatics	7
Large Aromatics	60
Resins	90
Asphaltenes	300
Waxes	600

Dr. Chris Barker used these biodegradation parameters for Gulf of Mexico crude oil and obtained the results summarized in the following Trajectory Analysis Planner (TAP) graphical figure presented below. The hypothetical spill of medium weight crude oil occurred near Cuba in the Florida Straits.

In addition, Dr. Herwig contributed to the Oil Spill Science (SOS) workshop that OR&R organizes several times each year by presenting biodegradation lectures. With his participation in the instructional workshop, it was the first time that NOAA OR&R discussed biodegradation in their workshop.

With additional funding, Dr. Herwig will continue to collaborate with OR&R, providing expertise in biodegradation and environmental microbiology.

Objectives
1. ***After a thorough examination of the literature, describe the biodegradation rates for the different fractions of compounds associated with crude oil spillage in nearshore marine and estuarine environments.***
2. ***After a thorough examination of the literature, describe research that is missing or needs to be completed for understanding the biodegradation of the different fractions associated with crude oil spillage in nearshore marine and estuarine environments.***

Accomplishments

1. Dr. Herwig performed a thorough examination of the technical literature, including reports and peer-reviewed papers. All citations to biodegradation-related publications were entered into an EndNote literature database.
2. Biodegradation rates were estimated for seven crude oil fractions.
3. Areas for future biodegradation and microbiology research were described. Biodegradation of the more recalcitrant fractions (resins, asphaltenes, waxes) of crude is poorly understood.

The following figure was generated by a computer model (Trajectory Analysis Planner [TAP]) of a deep-water medium weight oil spill occurring near the coast of Cuba in the Florida Straits. The model projections strongly suggest that biodegradation is the major route of removal after 20 days when evaporation of the volatile fractions occurs. In other words in the longer time frame, *biodegradation matters*.

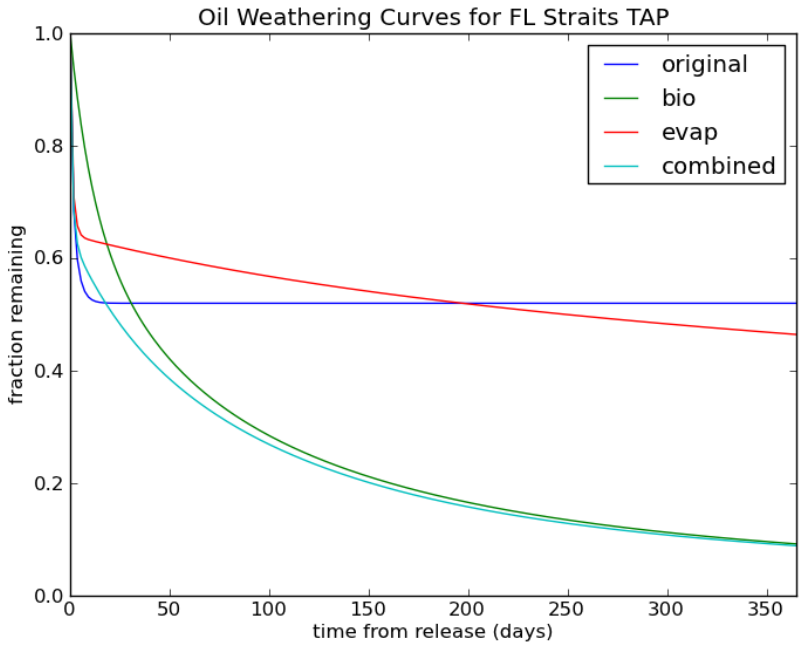

Figure 1. Output results from the Trajectory Analysis Planner (TAP) model for medium weight crude oil spilled near Cuba in the Florida Straits.




Fish Productivity and Fishing Impacts Compared Across a Range of Marine Ecosystems

PIs
Ray Hilborn, UW — School of Aquatic and Fishery Sciences (SAFS)

Other UW Personnel
Matt Baker, School of Aquatic and Fishery Sciences

NOAA Personnel
Anne Hollowed, Alaska Fisheries Science Center (AKFSC), M. Elizabeth Clarke, NWFSC

Task III

NOAA Contact
Anne Hollowed, NMFS, Alaska Fisheries Science Center

NOAA Goal
Resilient Coastal Communities and Economies

Description
To determine how fishing affects the productivity of fish stocks and ecosystems as a whole by investigating: (i) mean ecosystem trophic level changes according to catch, survey and stock assessment data and whether the trophic level of catch reflects changes in the ecosystem; (ii) shifts in community structure from trawl surveys; and (iii) the extent to which environmental changes or fishing impacts drive productivity. This project provides a comparative analysis across ecosystems with the key tools being databases on catch, trawl surveys and fisheries stock assessments in four U.S. ecosystems; the NE U.S. Continental Shelf, the California Current, the Gulf of Alaska, and the Eastern Bering Sea.

Objectives
1. ***Compare shifts in mean trophic level across ecosystems in surveys, stock assessments and catches.***
2. ***Evaluate the correlation between species, trophic levels and functional groups and productivity over time.***
   Analyses will investigate:
   i. Temporal trends and variability in productivity of individual stocks as well as production for the ecosystem as a whole.
   ii. The correlation structure of surplus production, either by species, trophic levels, or functional group (pelagic/demersals).
   iii. Variability in productivity within and among species and functional groups for the four focal ecosystems as well as productivity summed over all stocks within an ecosystem.
3. ***Assess extent to which environmental changes or impacts of fishing drive productivity.***
   Analyses will evaluate:
   i. Environmental impacts on productivity.
   ii. The extent to which productivity has been driven by abundance, environmental regime changes, or random fluctuations.
   iii. The extent to which productivity is explained by changes in abundance, environmental regime shifts or a mixed model for each unit of analysis (e.g. stock, trophic level or functional group).
   iv. The correlation in breakpoints across species or groups for significant regime shifts.
   v. Correlations between productivity units of analysis (i.e. determine whether fishing pressure causes productivity to shift from demersal stocks to pelagic stocks or from high trophic levels to low trophic levels).
   vi. Evidence for ecosystem-wide changes in productivity (i.e. determine whether productivity is impacted by fishing and whether surplus production of fisheries responds to increasing fishing pressure).

Accomplishments

1. Compilation and utilization of multiple data sources from NOAA trawl survey databases, acoustic databases, and stock assessments
2. Assignment of species into functional guilds based on diet analyses and functional role in the eastern Bering Sea, Gulf of Alaska, Aleutian Islands and California Current systems and comparison of trophic level status within functional guilds
3. Characterization of trends in biomass and abundance for individual species and aggregate functional guilds
4. Development of contour plots of relative distribution of all major species in the system according to depth, temperature and substrate type as well as relative density distributions for specific life stages of the dominant species within these ecosystems.
5. Development of correlation matrices of species abundance trends within functional guilds
6. Computation of variance ratio tests to determine evidence for compensation related to inter-species competition within functional guilds
7. Development and application of centroid-based clustering methods to distinguish correlated abundance trends in species at small-spatial scales as a means to identify sub-populations within aggregate stock complexes
8. Application of non-metric multidimensional scaling to identify discrete habitats within large marine ecosystems and evaluation of the stability of those boundaries as related to dynamic physical forcing mechanisms such as bottom temperature and the differences in stability of these boundaries across large marine ecosystems
9. Initial development of multivariate autoregressive models to determine relative influence of species-specific density dependence, inter-species compensation, climate and fishery extraction in productivity trends
10. Participation in conference and workshops related to the impact of large scale oceanic and atmospheric oscillations on marine productivity, regimes, and community dynamics - Woods Hole Oceanographic Institution (May 2011)
11. Presentation of preliminary analyses at the American Fisheries Society (September 2011)
12. Presentation of analyses at the Alaska Marine Science Symposium (January 2012)
13. Presentation of poster at Western Groundfish Conference (February 2012)
14. Development of manuscript on eastern Bering Sea for Deep Sea Research II

Fisheries Acoustic Research

PI
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NOAA Personnel
Janet Duffy-Anderson, NMFS, Alaska Fisheries Science Center (AKFSC); Patrick Ressler, AKFSC; Christopher Wilson, AKFSC

Task III

NOAA Contact
Russ Nelson, Alaska Fisheries Science Center (AKFSC)

NOAA Goal
Healthy Oceans

Description
This project partially supports a faculty position at the University of Washington, School of Aquatic and Fishery Sciences (SAFS). Activities include research, supervision of graduate students and postdoctoral associates, and service. Research activities examine acoustic reflectivity properties of north Pacific and Bering Sea fish species, develop visualization tools to increase the understanding of using sound to examine fish populations, and investigate equipment and methods used to acoustically enumerate, size, and map fish distributions. Supervision of graduate students includes those employed by RACE and REFM divisions at the Alaska Fisheries Science Center (AKFSC) and Postdoctoral Associates working with RACE scientists. Service activities include fostering collaboration between the SAFS and the AKFSC, co-organizing and administering the SAFS-AKFSC summer internship program, acoustic training of students and government scientists, and participating in academic committees at the School of Aquatic and Fishery Sciences

Objectives
1. ***To support graduate student and postdoctoral associate research programs***
2. ***To determine stage-dependent early life history distributions of walleye pollock in warm and cold years***
3. ***To classify acoustic backscatter groups in mixed aggregations using multifrequency data***

Accomplishments
1. A total of eight graduate students (4 Masters, 4 PhDs) and two postdoctoral associates were active during the reporting period. Steven Barbeaux defended his Ph.D. dissertation entitled, "Scientific acoustic data from commercial fishing vessels: eastern Bering Sea walleye pollock (*Theragra chalcogramma*)", which examined the spatial and temporal dynamics of walleye pollock through the winter commercial fishing season. Sam Urmy defended his Master's thesis entitled, "Temporal variability and the bio-physical coupling in the pelagic fauna of Monterey Bay." The first chapter, "Measuring the vertical distributional variability of pelagic fauna in Monterey Bay" has been published in the ICES Journal of Marine Science. Dr. Tracey Smart completed her postdoc and has two papers in press: Influence of environment on walleye pollock eggs, larvae, and juveniles in the southeastern Bering Sea (Deep-Sea Research), and Alternating Temperature States Influence Walleye Pollock (*Theragra chalcogramma*) Early Life Stages in the Southeastern Bering Sea (Marine Ecology Progress Series). Dr. Mathieu Woillez completed his postdoc appointment and has published the first paper on multifrequency acoustic data analysis entitled, "Multifrequency species classification of acoustic-trawl survey data using semi-supervised learning with class discovery" in the Journal of the Acoustical Society of America.
2. Water temperatures in the southeastern Bering Sea influence the density of walleye pollock *Theragra chalcogramma* early life stages, potentially influencing spatial distributions and the phenology of reproduction and development. We quantified stage-specific changes in spatial and temporal distributions under cold- and warm-water conditions using generalized additive models. Analyses showed that walleye pollock egg and yolksac larval

spatial distributions were unaffected by temperature, suggesting that spawning locations are stable. Mean centers of distribution for egg, yolksac larvae, preflexion larvae, late larvae, and juvenile stages were located closer to the continental slope than the mean locations in cold years (Fig. 1), similar to spatial shifts observed in distributions of subadults and adults. Differences in the timing of density peaks supported the hypothesis that the timing of spawning, hatching, larval development, and juvenile transition are temperature-dependent and delayed under cold conditions. The current analysis represents the best support available for the importance of temperature to walleye pollock in determining early life stage development and population trends in eastern Bering Sea. Our data indicate that future changes in water temperatures could influence the early life stages of an ecologically dominant member of the Bering Sea community by changing phenology and habitat use in the first several months of life.

3. Acoustic surveys often use multifrequency acoustic backscatter data to discriminate species and to estimate fish and plankton abundance. Direct samples, usually nets, are used to validate species classification of acoustic backscatter, but samples may be sparse or unavailable for non-targeted species. A generalized Gaussian mixture model was developed to classify multifrequency acoustic backscatter when not all species classes are known. The classification, based on semi-supervised learning with class discovery, was applied to data collected in the eastern Bering Sea during summers 2004, 2007, and 2008. Walleye pollock, euphausiids, and two other major classes occurring in the upper water column were identified. The next steps are to extend the algorithm to include non-acoustic data streams for use in classification and to develop methods to estimate proportions of species in mixed species classes.

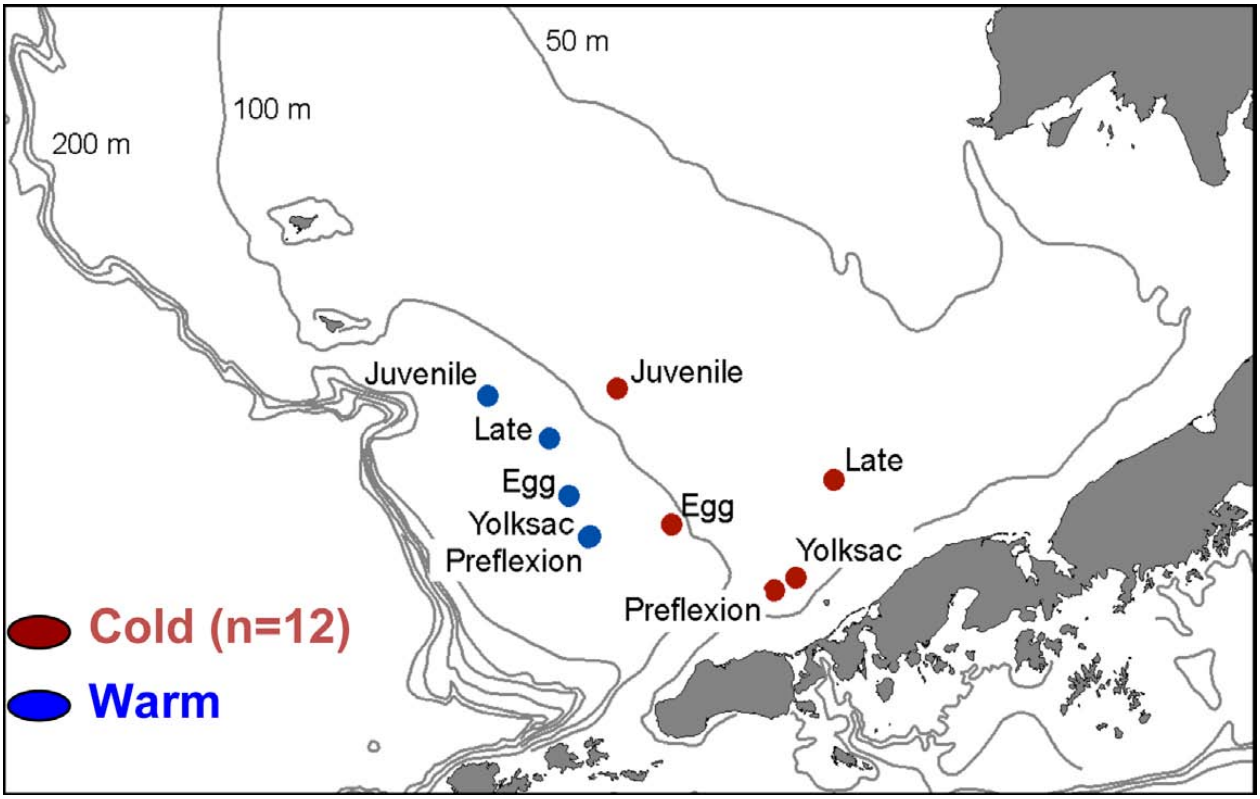

Figure 1. Mean centers of distribution for egg, yolksac, preflexion larvae, late larvae, and juvenile stages of walleye pollock (*Theragra chalcogramma*) in the eastern Bering Sea. All stages are transported closer to the continental slope during warm years relative to the positions during cold years.

Marine Biological Interactions in the North Pacific — Fish Interactions

PI
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Other UW Personnel
Todd TenBrink, R. Hibpshman , George A. Whitehouse, K. Holsman, S. Rohan, C. Robinson, and K. Sawyer, JISAO

NOAA Personnel
Kerim Aydin, Stephan Zador, Alaska Fisheries Science Center

Task II

NOAA Contact
Kerim Aydin, NMFS, AKFSC, Resource Ecology and Fisheries Management Division

NOAA Goals
Resilient Coastal Communities & Economies, Healthy Oceans

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. ***Investigations of the feeding ecology of North Pacific fishes***
2. ***Assist in collecting stomach, plankton or benthic samples in the field***
3. ***Use groundfish food habits data to develop or improve multispecies models for fisheries management***
4. ***Refine, update, and expand the Ecosystem Considerations report***
5. ***Develop a top predator index for the eastern Bering Sea and investigate relationships with environmental indices***

Accomplishments
1. ***Investigations of the Feeding Ecology of North Pacific Fishes. A total of over 5,000 groundfish stomachs were analyzed in the laboratory.***

2. ***Assistance collecting stomach, plankton or benthic samples in the field.*** Collection and shipboard analysis of groundfish stomachs during the time period was over 10,000 samples.

3. ***Accomplishments for multispecies modeling: Multispecies Statistical Model modifications:*** This year we substantially modified a previous version of a multispecies statistical catch at age model for the Bering Sea (MSM). Updates to the model included adding a third predator species such that the model now calculates catch and biomasss at age, as well as predation mortality (M2) for walleye Pollock, Pacific cod, and now, arrowtooth flounder. Additionally, we modified the model to include temperature- and size-dependent bioenergetic-based estimates of daily ration for each predator in the model. This modification allowed us to project the model forward under various climate scenarios (82 in total), to derive multispecies biological reference points (i.e., multispecies proxies for unfished biomass and FMSY). We further developed a set of control rule scenarios to evaluate with MSM and compared the sensitivity of emergent parameters (e.g., predation mortality, harvest rate, unfished biomass) to climatic variability and management strategies. Results of this work have been presented at a variety of workshops, seminars, and symposia (8 in total), including the American Fisheries Sciences meeting in Seattle. Two manuscripts are in progress that (i) detail the MSM model update and control rule results and (ii) outline the bioenergetics and foraging models used to derived predator rations.

As part of a working group of NOAA's Comparative Analysis of Marine Ecosystem Organization Program, we also collaborated with international experts in the field of fisheries management to evaluate how inclusion of trophic and environmental covariates in traditional surplus production models might influence subsequent estimates of biological reference points. Catch and biomass data for cod and herring species from 13 northern latitude ecosystems were analyzed using generalized linear models with and without covariates for a suite of environmental indices (i.e. temperature, wind) and models were compared using an information theoretic approach. Results of this project were presented at the AFS meeting in Seattle, and a manuscript of our results has been accepted for publication in an upcoming issue of Marine Ecology Progress Series.

4. Refine, update, and expand the Ecosystem Considerations report: The Ecosystem Considerations report is produced annually for the North Pacific Fishery Management Council as part of the Stock Assessment and Fishery Evaluation (SAFE) report. The goal of the Ecosystem Considerations report is to provide an overview of marine ecosystems in Alaska through ecosystem assessments and tracking time series of ecosystem indicators. The ecosystems currently under consideration are the eastern Bering Sea, the Aleutian Islands, and the Gulf of Alaska.

   The 2011 report includes both new and updated sections. The section describing ecosystem and management indicators includes updates to 44 individual contributions and presents 7 new contributions. These include: (1) Phytoplankton biomass and size structure during late summer to early fall in the eastern Bering Sea, (2) Gulf of Alaska chlorophyll a concentration off the Alexander archipelago, (3) Long term zooplankton trends in Icy Strait, southeast Alaska, (4) Forecasting pink salmon harvest in southeast Alaska, (5) Biodiversity (evenness) of the groundfish and invertebrate community for the eastern Bering sea slope, (6) A multivariate seabird index for the eastern Bering Sea, and (7) Indicators of Alaska-wide community regime shifts.

   The ecosystem assessment section includes a new Aleutian Islands Ecosystem Assessment developed by a multidisciplinary team of experts during a workshop in September 2011. The team was tasked with choosing a suite of indicators that together provide a comprehensive view of the Aleutian Islands ecosystem reflecting across trophic levels from the physical environment to top predators and humans, as well as both the nearshore and offshore. Numerous gaps in available time series were noted and discussed. Following presentations and review of existing physical and biological data, the team concluded that the significant variability in the island chain ecosystem warranted structuring the assessment by three ecoregions: Western, Central, and Eastern. Although a single suite of indicators were chosen for the entire ecosystem, not all are available or applicable in each of the three ecoregions. The assessment will be updated annually, and the suite of indicators will be re-evaluated every few years.

   The updated eastern Bering Sea ecosystem assessment is included in this report, as well as a new section evaluating the predictions made in last year's ecosystem assessment. An assessment of the Gulf of Alaska ecosystem is not included, but the development of a new assessment following the methods of the eastern Bering Sea and Aleutian Islands assessments is planned in coming years.

   The ecosystem assessment section also includes a Hot Topics subsection, which was designed to present a succinct overview of potential concerns for fishery management, including endangered species issues and early warnings of potential future fishery management interest. Last year, Hot Topics were presented for the first time as part of the new eastern Bering Sea assessment. This year, they extend to all three ecosystems. The topics for the eastern Bering Sea include endangered short-tailed albatross bycatch that occurred during fall in the Pacific cod longline fishery and recent increases in jellyfish seen in both summer and fall scientific surveys. For the Gulf of Alaska, the topics include the recent increased prevalence of "mushy' halibut syndrome and the controversial finding of infectious salmon anemia. For the Aleutian Islands, the topics include a discussion of fishery changes in the western and central ecoregions in

2011 and the release of the new Aleutian Islands risk assessment, which evaluates shipping traffic and oil spill trends.

Findings from the Ecosystem Considerations report were presented to the NPFMC joint plan teams in September and November and to the Science and Statistical Committee in December. To see the chapter in its entirety, see the website at: *http://access.AKFSC.noaa.gov/reem/ecoweb.*

5. ***Develop a top predator index for the eastern Bering Sea and investigate relationships with environmental indices:*** The project goal was to explore the use multivariate statistics to create a simplified index of top predator trends in the eastern Bering Sea. The project was successful in using principle components analysis (PCA) to reduce 19 individual time series of seabird and fur seal biological parameters into 2 leading principal components that together explained 62.2% of the variation within these parameters. Time series analysis of the seabird-only principal components indicated that there are significant lagged effects of summer bottom temperature and prey supply on seabird reproductive efforts. The new indicators based on the seabird PCA were incorporated into the 2011 Ecosystem Considerations report and in the next update to the eastern Bering Sea ecosystem assessment contained in the report. A manuscript on this study is in progress.

Coastal Observation and Seabird Survey Team (COASST)

PI
Julia K. Parrish, UW — School of Aquatic and Fishery Sciences

Other UW Personnel
Jane Dolliver, Anne Woods, Charles Wright, School of Aquatic and Fishery Sciences

Task III

NOAA Contact
Kim Rivera, NMFS Alaska Region

NOAA Goals
Resilient Coastal Communities & Economies, Healthy Oceans

Description
COASST is a citizen-science program in which trained volunteers collect monthly, or more frequent, data on beached marine birds at standard sites throughout the North Pacific (Eureka, CA to Kotzebue, AK). With 700 volunteers at over 300 sites distributed comprehensively throughout its range, and over 25,000 carcasses of over 150 species identified to date, COASST is the largest program of its kind in the world. COASST is also the only program to individually mark carcasses, allowing quantification of persistence and scavenging rates, as well as double checks of species identification. Advanced protocols allow volunteers to make provisional cause of mortality estimates, including bycatch mortality and photographic confirmation of gear type.

Objectives
1. ***Maintain and expand beached bird data collection on beaches in the North Pacific.***
2. ***Provide annually: analyzed data on deposition, persistence, and scavenging by location and month; reports on threatened and endangered species; estimates of mortality from bycatch and other anthropogenic sources; special reports on mass mortalities; and copies of all scientific publications.***

Accomplishments
1. Maintained monthly volunteer coverage on over 300 COASST sites throughout the North Pacific.
2. Conducted ten training and refresher sessions to train new volunteers and refresh skills of current volunteers.
3. Provided data to all state and federal agencies and other interested groups or individuals via the COASST website or, in the case of specific requests, by contacting us directly.
4. Analyzed existing data for fishery mortality trends, and trends in beaching rates of species known to be bycatch in North Pacific fisheries.

Diane Winterboer readies a Pelagic Cormorant for COASST processing on Beverly Beach Campground North, near Newport, Oregon. Photo credit: M. Winterboer

Annotated Checklist of Bottom-Trawled Macroinvertebrates of Alaska, with an Evaluation of Identifications in the Alaska Fisheries Science Center Bottom-Trawl Survey Database

PI
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Other UW Personnel
David Drumm, Katherine P. Maslenikov, SAFS

NOAA Personnel
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Additional Personnel
Robert Van Syoc, California Academy of Sciences

Task II

NOAA Primary Contact
James W. Orr, AKFSC

NOAA Goal
Healthy Oceans

Description
The primary goal of this project is to produce an annotated checklist of the marine macroinvertebrates of Alaska. The Alaska Fisheries Science Center has conducted annual bottom-trawl surveys of the Alaska continental shelf and upper slope since 1975. These surveys are the most comprehensive of their kind, conducted across the continental shelf and upper slope and are well established for the management of commercially significant fishes and crabs. The potential for using these surveys as indices of invertebrate distribution and abundance is also immense. Yet, while invertebrates have generally been identified to the species level during these surveys, the quality of invertebrate identifications, with the exception of commercially important crabs and shrimps, has been suspect and inconsistent through the years in part because of the lack of a consistent reference to the complex nomenclature and known distribution of invertebrates. With the availability of recent field guides, gaps in our knowledge are increasingly evident. This project entails the preparation of an annotated checklist of the marine macroinvertebrates of Alaska and the evaluation of the historical bottom-trawl survey database. Collaborators will participate in surveys for the observation and collection of data and photographs of specimens at sea, examine significant specimens from historical collections in national museums, survey taxonomic and other biological literature, and publish an annotated checklist of the marine macroinvertebrates of Alaska. With these comprehensive data at hand, we will conduct a retrospective analysis of the bottom-trawl survey database to assess levels of confidence for each invertebrate species over survey years.

Objectives

1. ***A comprehensive annotated checklist of Alaskan invertebrates to be submitted for publication in the NOAA Professional Papers, a series available digitally over the internet and with a worldwide print distribution.***
2. ***The results of the AKFSC survey database assessment to be published in the local Technical Memorandum series, also freely available over the internet.***
3. ***Synthesized results of this analysis will be incorporated into research publications planned for the primary literature.***

Accomplishments

The checklist has been nearly completed for five out of the six classes of Mollusca (Aplacophora, 11 species; Polyplacophora, 54 species; Scaphopoda, 10 species; Cephalopoda, 32 species). This list includes the higher classification down to species name, synonyms, common names (if applicable), type locality, geographic distribution, and depth distribution. All of the bivalve species have been listed (205 species), along with the rest of the information except type locality. The original source for most of the species will need to be examined to extract this information. Work is under way on the Gastropoda, by far the largest group of invertebrates represented in Alaskan waters. Other groups completed are the Porifera (203 species), Hydrozoa (156 species), Asteroidea (127 species), Ophiuroidea (66 species), Echinoidea (24 species), Holothuroidea (39 species), Crinoidea (7 species), Polychaeta (375 species), Bryozoa (233 species), Brachiopoda (7 species), Tunicata (42 species), Pycnogonida (60 species), Decapoda (195 species), Mysida (41 species), Lophogastrida (5 species), Euphausiacea (12 species), Amphipoda (308 species), Isopoda (63 species), Cumacea (25 species) and Tanaidacea (37 species). We are in the final stages of preparing a manuscript for publication on the northern range extensions, as well as biological notes for three decapods in the eastern North Pacific. The post-doc appointee (Drumm) collaborated with a Japanese graduate student and is a coauthor of a manuscript in press (Plankton and Benthos Research) entitled "Genetic divergence of deep-sea crangonid shrimps, *Argis lar* and its sibling *A. hozawai* from the Sea of Japan." Drumm and Orr also collected five of the six species of *Argis* found in Alaskan waters and this material will be used in a collaborative molecular phylogenetic study led by the same student.

Drumm has been working with specimens collected since the early 1990s by the AKFSC to determine confidence levels for invertebrate taxa. During this work, he has discovered that many crangonid and pandalid shrimps have been misidentified at the genus and species level. In addition, several species of *Spirontocaris* shrimp appear to have a high degree of character overlap with one another, and taxonomic references are not consistent in the characters used to distinguish them. The taxonomy of some species of *Crangon* is also complicated by a lack of diagnostic morphological characteristics, making accurate identification difficult. These uncertainties give impetus to revisionary work and the application of DNA barcoding data to resolve these issues.

The post-doc appointee (Drumm) attended and presented at the 38th Annual Meeting of the Alaska Chapter of the American Fisheries Society, November 14-18 in Girdwood, Alaska. The title of the oral presentation was: Marine Macroinvertebrates of Alaska – Annotated Checklist. Drumm also presented a poster with the same title at the 2012 Marine Sciences Symposium beginning 16 January. Outreach posters with photos of all species of seastars and shrimps of Alaska have been completed.

Floodplain Diversity and Spawning Area Productivity in the Yakima River, Part III: Multiscale Habitat Associations – Supplement

PI
Christian Torgersen, USGS/UW — School of Forest Resources

NOAA Personnel
Andrew Dittman, George Pess

Task III

NOAA Contact
Andrew Dittman, Kathleen Jewett NWFSC

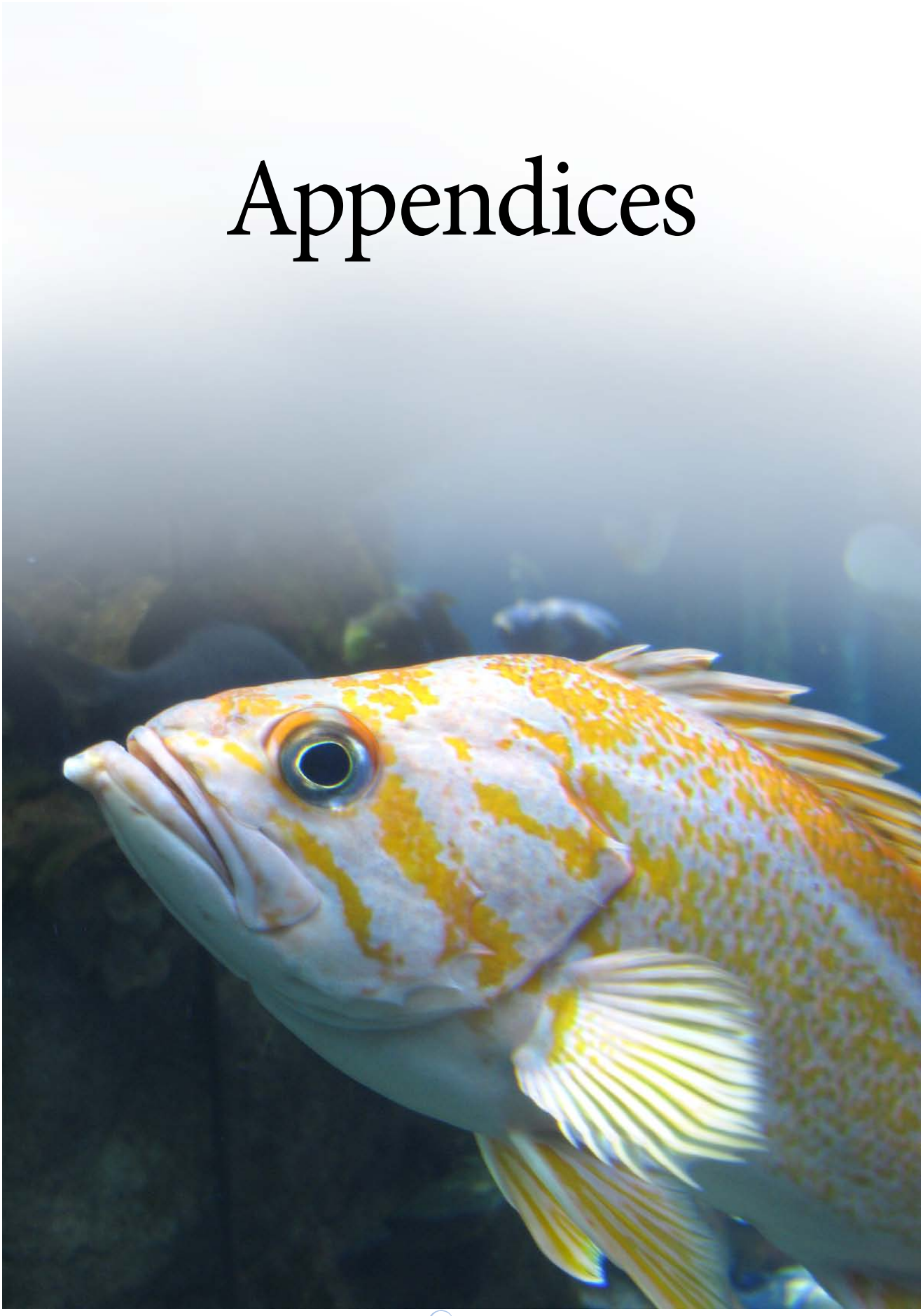
NOAA Goal
Healthy Oceans

Description
Ryan Klett successfully defended his Master's thesis (see citation below), and Jeremy Cram had the first chapter of his dissertation accepted for publication (see list of publications in project information document). Presentations at the national meeting of the American Fisheries Society in Seattle, WA were given by Jeremy Cram, Ryan Klett, and Andy Dittman, and a poster was presented by Darran May. At this meeting, Christian Torgersen co-organized the special symposium on riverscape ecology in which Jeremy Cram and Ryan Klett gave their presentations. In fall 2011, Christian Torgersen and Andy Dittman hosted a visiting scientist from Canada (Dr. Michel Lapointe, McGill University) to discuss potential collaboration and exchange information about salmonid homing and habitat ecology in rivers of the Pacific Northwest and northeastern Canada. Additional field data on redd distribution in the Yakima River were collected in fall 2011.

Objectives
1. ***Assess and identify physical and biological indicators of highly productive versus unproductive areas for critical salmon life history stages***
2. ***Develop predictive models of spawning site selection that incorporate different life history habitat requirements***
3. ***Assist with spawner surveys and analysis of redd distribution data. The graduate students and technician on the project conducted research to meet these objectives by presenting their results at a national meeting and by writing up the results for a thesis, a dissertation, and a peer-reviewed journal.***

Accomplishments
All stated objectives were met, and the students are progressing in the preparation of dissertation chapters (Jeremy Cram) and manuscripts for peer-reviewed journals (Jeremy Cram and Ryan Klett). Data entry and analysis for redd surveys are proceeding according to schedule (Darran May).

Appendices



Appendix 1

JISAO Senior Fellows and Council Members*

University of Washington

*Ackerman, Thomas, Professor, Atmospheric Sciences, Director, JISAO

Armstrong, David, Professor and Director, Aquatic and Fishery Sciences

Battisti, David S., Professor, Atmospheric Sciences

Bretherton, Christopher, Professor, Atmospheric Sciences/ Applied MathematicsCharlson, Robert J., Professor Emeritus, Atmospheric Sciences

Covert, David S., Research Professor Emeritus, Atmospheric Sciences

Emerson, Steven R., Professor, Oceanography

Eriksen, Charles C., Professor, Oceanography

Fleagle, Robert G., Professor Emeritus, Atmospheric Sciences

Friedman, Carolyn, Professor, Aquatic & Fishery Sciences

Fu, Qiang, Professor, Atmospheric Sciences

Gammon, Richard H., Professor, Oceanography and Chemistry

*Hartmann, Dennis L., Professor, Atmospheric Sciences

Hilborn, Ray, Professor, Aquatic & Fishery Sciences

Horne, John, Professor, Aquatic & Fishery Sciences

Jaeglé, Lyatt, Professor, Atmospheric Sciences

Jaffe, Dan, Professor, Interdisciplinary Arts & Sciences, Adjunct Professor, Atmospheric Sciences

Lettenmaier, Dennis P., Professor, Civil and Environmental Engineering

Mantua, Nathan, Associate Professor, Aquatic and Fishery Sciences, Co- Director, Center for Science in the Earth System and Climate Impacts Group

McDuff, Russell, Professor, Oceanography

*Miles, Edward L., Professor, Marine and Environmental Affairs, Climate Impacts Group

Murray, James W., Professor, Oceanography

*Punt, Andre E., Professor, Aquatic and Fishery Sciences

Quay, Paul D., Professor, Oceanography

Rhines, Peter B., Professor, Oceanography and Atmospheric Sciences

Ruesink, Jennifer, Associate Professor, Biology

Thompson, LuAnne, Professor, Oceanography, , Director, Program on Climate Change

Wallace, John M., Professor, Atmospheric Sciences

NOAA Pacific Marine Environmental Laboratory

Baker, Edward T., Supervisory Oceanographer, Ocean Environment Research Division, Affiliate Professor, Oceanography

Bates, Timothy S., Research Chemist, Ocean Climate Research Division, Affiliate Associate Professor, Oceanography

Bullister, John, Oceanographer, Ocean Climate Research Division, Affiliate Associate Professor, Oceanography

Cronin, Meghan, Oceanographer, Ocean Climate Research Division, Affiliate 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

*Johnson, Gregory C., Oceanographer, Ocean Climate Research Division, Affiliate 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

*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, Director, Pacific Marine Environmental Lab, Affiliate Assistant Professor, Oceanography

Stabeno, Phyllis, Supervisory Oceanographer, Ocean Climate Research Division

Titov, Vasily, Oceanographer, Project Leader for NOAA Center for Tsunami Research, Affiliate Assistant Professor, Earth and Space Sciences

***2011-2012 Council Members**

Appendix 2

Events and Visitors

Events

1. **The Second Annual Climate Science Conference** (Sept 2011) – CIG hosted the conference and is a member of its organizing committee

2. **CIG Briefing – World Affairs Council** (delegates from SE Asia) on CIG and PNW climate impacts, June 30, 2009

3. **CIG Briefing – World Affairs Council** (delegates from Europe) on CIG and PNW climate impacts, Spring 2010

4. **July 27 – 28, 2011:** ***A Workshop on Climate Change, Fish, and Fish Habitat Management in the North Cascadia Ecosystem***

5. **October 5 – 7, 2011:** ***"Axial Seamount Ocean Observatories Initiative Regional Scale Nodes Science Planning"*** workshop with 75 participants from the U.S. and Canada, at the Mountaineers Program Center. The workshop was organized by David Butterfield and colleagues and funded by the National Science Foundation and NOAA/PMEL.

6. **October 20 – 21, 2011:** ***NOAA West Coast/Pacific Tsunami Conference*** Held at NOAA Western Regional Center, Building 9, 90 attendees

   Attendees: NOAA Tsunami Warning Center administrators and watch-standers, NOAA Center for Tsunami Research staff, JISAO Tsunami Modeling Group, JISAO Tsunami Software Development Team, and Tsunami Program Managers

   Theme: Education, Awareness, and Preparedness on the Tsunami threat to the U.S. West Coast, Alaska, Hawaii, and Pacific Territories as part of building a "Weather-Ready Nation."

   This meeting was put together as an overview of tsunami forecasting capability provided by the JISAO tsunami research group to the NOAA Tsunami Warning Centers. An explanation of the theory and numerical modeling behind the SIFT (Short-term Inundation Forecasting for Tsunamis) forecast system was presented, and extensive testing procedure was performed to bring the system into operational testing status

   During the meeting, SIFT was promoted from Developmental to Operational Testing status, and work continues with NOAA's Tsunami Warning Centers to bring SIFT to full operational compliance.

7. **November 2, 2011:** ***The 15th annual Pacific Northwest Climate and Water Workshop: the 2012 Water Year*** (this year held as a webinar) – around 100 participants were federal, state, and local water managers, public utility district managers, NGOs, academics, and fish and wildlife managers.

8. **November 7 – 8, 2011:** ***Workshop on Climate Change Adaptation for Vegetation Management in the North Cascadia Ecosystem***

9. **November 30 – December 1, 2011:** ***Workshop on Climate Change, Hydrology, and Access in the North Cascadia Ecosystem***

10. **March 7, 2012:** ***CIG Briefing to US EPA Region X***

Visitors

1. **July 6, 2009:** U.S. Rep. Brian Baird for a presentation on the Climate Impacts Group and ocean acidification.

2. **June 24, 2009:** State Rep. Larry Seaquist for a presentation on the Climate Impacts Group and Pacific Northwest impacts.

3. **June 30, 2011:** Antonio Busalacchi – Seminar speaker, ESSIC, CMNS-Atmospheric & Oceanic Science, University of Maryland

4. **January 28, 2012:** James Morrison – CIG Strategic Planning Retreat, Regional Climate Change Coordinator, USFS Northern Region, Montana

5. **March 2, 2012:** Adam Bourassa – Seminar speaker Assistant Professor, Department of Physics and Engineering Physics from the University of Saskatchewan. A short bio (PDF) can be found at *http://www.usask.ca/physics/isas/Exec.Bios/BOURASSA.pdf.*

   Seminar Title: OSIRIS on Odin: A Decade of Limb Scattered Sunlight Measurements
   Abstract: The Canadian built Optical Spectrograph and Infrared Imaging System (OSIRIS) has been measuring limb scattered sunlight spectra from the Odin satellite since launch in 2001. These measurements are used in combination with a successive orders spherical radiative transfer forward model to retrieve vertical profiles of trace gas concentration and stratospheric aerosol extinction coefficient. This talk highlighted several aspects of the OSIRIS measurements, including the development of the radiative transfer model for limb scatter, details of the Multiplicative Algebraic Reconstruction Technique (MART) retrieval algorithm, and recent results from the stratospheric aerosol extinction retrievals, which show increased levels over the past decade due to several minor volcanic eruptions, including the recent eruption of the Nabro volcano in North Africa.

Appendix 3

Project List by Task and Project

Task #	Principal Investigator	Department	Title of Project	Award Amount
I	Ackerman, Thomas	JISAO	JISAO Task I	$200,100
I	Branch, Trevor	JISAO	Bevan Lecture Series	$10,000
II	Ackerman, Thomas	JISAO	JISAO Task II PMEL Projects	$7,637,344
II	DeCosmo, Janice	URP	Northwest Fisheries Science Center and University of Washington Undergraduate Intern Program	$55,650
II	Doyle, Miriam	JISAO	Links between the early life history dynamics of fish and climate and ocean conditions in the Gulf of Alaska and southeast Bering Sea	$66,986
II	Herwig, Russell	SAFS	Biological Removal of Petroleum Hydrocarbons in Marine and Aquatic Ecosystems to Determine the Fate of Deepwater Horizon Oil	$41,785
II	Miller, Bruce	SAFS	Marine Biological Interactions in the North Pacific – Fish Interactions Task	$326,254
II	Punt, Andre	SAFS	An Evaluation of Management Strategies for Implementation of Annual Catch Limits for Alaska Groundfish	$42,355
III	Ackerman, Thomas	JISAO	A Quasi-Operational Prediction System for the Coastal Ocean of the Pacific NW	$103,986
III	Aliseda, Alberto	Mech Engineering	ADIOS3: Physical mechanism of droplet formation for immiscible fluids injected into water through a high Reynolds number jet. Modeling droplet breakup to determine the Fate of Deepwater Horizon Oil	$175,000
III	Armstrong, David	SAFS	Partnership with NWFSC and AFSC To Develop Increased Capacity In the School of Aquatic And Fishery Sciences to Enhance Teaching and Research	$302,000
III	Baker, Joel	UW Tacoma	Standardization of methods to quantify marine microdebris: Laboratory intercomparison and the development of polymer composition, size, and shape as indicators of sources of marine microplastics	$93,469
III	Burgstahler, Sheryl	DO-IT	NOAA Scholar Funding	$19,528
III	Cooper, Joyce	Mech Engineering	Life Cycle Assessments for the Improvement of Aquaculture Systems	$92,037
III	Doherty, Sarah	JISAO	IGAC Core Project Office - NOAA	$96,428
III	Essington, Timothy	SAFS	Improving ecosystem-based stock assessment and forecasting by using a hierarchical approach to link fish productivity to environmental drivers	$178,385
III	Hermann, Albert	JISAO	Assessing the Atlantic Meridional Overturning Circulation (AMOC) in climate models	$30,000
III	Hermann, Albert	JISAO	Using HPCC Techniques to Power User Tools for Ecosystem Models: the Bering Sea example	$23,400
III	Hilborn, Ray	SAFS	Fish productivity and fishing impacts compared across a range of marine ecosystems	$85,089

Task #	Principal Investigator	Department	Title of Project	Award Amount
III	Holzworth, Robert	ESS	Lightning Studies	$150,000
III	Horne, John	SAFS	Fisheries Acoustics Research	$74,998
III	Horne, John	SAFS	Forecasting walleye pollock recruitment in a Bayesian framework	$50,279
III	Lettenmeier, Dennis	CEE	Development of an experimental national hydrologic prediction system	$75,000
III	Lindsay, Ronald	APL	A New Unified Sea Ice Thickness Data Set	$114,955
III	Lundquist, Jessica	CEE	Mountain Hydrometeorology for Weather and Climate Forecasting Applications	$25,000
III	Mass, Cliff	Atm Sci	Advanced Research in High-Resolution Data Assimilation in Support of NWS Regional Forecast Systems	$75,000
III	Parrish, Julia	SAFS	Coastal Observation and Seabird Survey Team (COASST)	$7,491
III	Percival, Don	APL	Evaluation of Detiding Algorithms and Statistically-Based Selection of Sources for the SIFT Application	$60,000
III	Pietsch, Theodore	SAFS	Archival and Dissemination of Specimens and Data for the Northeast Pacific	$191,370
III	Punt, Andre	SAFS	Development of a package of functions to facilitate the development of custom stock assessment models including size-based crab models	$135,774
III	Punt, Andre	SAFS	West Coast Groundfish Stock Assessment	$158,154
III	Rigor, Ignatius	APL	International Arctic Buoy Programme (IABP) – Monitoring the Eurasian Basin of the Arctic Ocean	$50,000
III	Riser, Steven	Oceanography	Argo: Global Observations for Understanding and Prediction of Climate Variability	$3,046,768
III	Snover, Amy	CIG	Methods of Assessing Fisheries Vulnerability to Climate Change (International)	$50,000
III	Snover, Amy	CIG	Preparing for Climate Change: A Workshop on Assessing and Planning for Climate Change Impacts on West Coast Fisheries	$26,951
III	Stafford, Kate	APL	Bowhead Whale Feeding in the Western Beaufort Sea: Passive Acoustic Survey Component	$65,000
III	Steinemann, Anne	CEE	California NIDIS Pilot	$103,255
III	Torgersen, Christian	SFR	Floodplain diversity and spawning area productivity in the Yakima River, Part V: Linking variation in spawner phenotype with habitat characteristics	$97,612

Appendix 4

JISAO Awards Funded Outside the Cooperative Agreement

Project Title	Principal Investigator	Award Amount	Awarding Agency
Validation and Application of MISR Cloud Retrievals	Ackerman, Thomas	$131,713	JPL
A Multi-Scale Observational and Modeling Study of Cirrus and Boundary Layer Clouds Using A-Train Data	Ackerman, Thomas	$6,145	PNNL
Evaluating and Improving Cloud Processes in the Multi-Scale Modeling Framework	Ackerman, Thomas	$174,209	DOE
Collaborative Research: Modeling coastal oxygen production and carbon sequestration	Ackerman, Thomas	$27,851	NSF
Evaluating Dynamical States, Radiation Budgets and Cloud Properties in the NCEP CFS-R and ECMWF ERA Interim Output	Ackerman, Thomas	$75,000	NOAA
A Multi-Scale Observational and Modeling Study of Cirrus and Boundary Layer Clouds Using A-Train Data	Ackerman, Thomas	$50,000	PNNL
CMG Collaborative Research: Spatio-temporal Reconstruction of Dispersal Strategies in Marine Organisms	Bond, Nicholas	$145,681	NSF
Water Column Profiler Data Processing Project	Bond, Nicholas	$40,000	IPHC
Projections of Ocean Properties along the Washington Coast Related to Environmental Health	Bond, Nicholas	$87,830	WA Sea Grant
Tsunami Hazard Modeling for U.S. Coastlines	Bond, Nicholas	$170,100	NRC
BC and other light-absorbing impurities in North American Great Plains snow: sources, deposition rates, impacts and a comparison with north China snow	Doherty, Sarah	$1,113,002	EPA
Climate model studies to investigate how climate state affects the efficiency of forcing by black carbon in snow	Doherty, Sarah	$81,306	DOE
International Global Atmospheric Chermistry	Doherty, Sarah	$96,199	NASA
Exploring temporal and spatial variability in Gulf of Alaska groundfish dynamics with integrated biophysical models	Hermann, Albert	$92,264	NPRB
Analysis of the NASA/GEWEX Surface Radiation Budget Products	Hinkelman, Laura	$60,122	NASA
Landscape Genetics	Littell, Jeremy	$21,917	USFS

Project Title	Principal Investigator	Award Amount	Awarding Agency
Climate change, vegetation models, and decision making in the face of uncertainty: a proposed short course	Littell, Jeremy	$65,000	USFS
NPS Climate	Littell, Jeremy	$13,791	DOI
PNW CSC Extremes	Littell, Jeremy	$150,000	DOI
FWS Hatcheries	Mantua, Nathan	$12,852	USFWS
PNW Guidebook	Mantua, Nathan	$241,000	USFS
Atmospheric Classification for the Analysis of ARM Observations and Global Climate Models	Marchand, Roger	$167,271	DOE
CloudSat Global Summary and Geometric Profile (GeoProf) Datasets	Marchand, Roger	$14,820	JPL
Development of an Adaptive Vertical Grid Scheme for Large Scale Models	Marchand, Roger	$106,593	NOAA
Collaborative Research: Impact of sea-ice on bottom-up and top-down controls of crustacean zooplankton and the mediation of carbon and energy flow in the eastern Bering Sea	Mordy, Calvin	$467,207	NSF
NOAA-ECOHAB	Salathe, Eric	$59,955	NOAA
Updating the Puget Sound Partnership Action Agenda & Biennial Science Work Plan to Include Climate Change	Snover, Amy	$40,000	EPA
PNW CSC FWS/CESU	Snover, Amy	$26,340	USFWS
PNW CS Conference USGS/FRESC	Snover, Amy	$10,000	USGS
Skagit Climate Science Consortium (SC2) workshop	Snover, Amy	$9,000	MacIlroy
In-Situ Biological Carbon Fluxes in the Pacific Ocean	Sonnerup, Rolf	$86,362	NOAA
A Sulfur Hexafluoride section in the North Pacific Ocean: Application of a dual tracer approach	Sonnerup, Rolf	$10,815	NSF
Solomon Sea high-resolution diagnostics for SWOT planning: glider analysis & ROMS development	Zhang, Dongxiao	$102,021	NASA-JPL

Appendix 5

Graduate Students

Student Name	Academic Unit	Degree	Degreee Advisor
BIKSON, CARIE L.	School of Aquatic and Fishery Sciences	M.S.	Theodore Pietsch
CRAM, JEREMY M	School of Forest Resources	Ph.D.	Christian Torgersen
DEGNIN-WARNER, MICHELLE	School of Aquatic and Fishery Sciences	M.S.	Theodore Pietsch
DIESBURG, STEVEN P	Mechanical Engineering	M.S.	Joyce Cooper
DILMEN, DERYA ITIR	Earth And Space Sciences	Ph.D.	Vasily Titov, Joanne Bourgeois
FASSBENDER, ANDREA J	School of Oceanography	Ph.D.	Chris Sabine
GRAY, ALISON R.	School of Oceanography	Ph.D.	Cliff Mass
HARBITZ, CAROLINE R	School of Oceanography	Ph.D.	Stephen Riser, Peter Rhines
HASKELL, DANIEL	Civil and Environmental Engineering	M.S.	Joel Baker
HENNON, TYLER D.	School of Oceanography	Ph.D.	Stephen Riser, Matthew Alford
JACQUES, DALE A.	School of Aquatic and Fishery Sciences	M.S.	John Horne
MADAUS, LUKE E	Department of Atmospheric Sciences	M.S.	Cliff Mass, Greg Hakim
MCGILLIARD, CAREY	School of Aquatic and Fishery Sciences	Ph.D.	Ray Hilborn
MONNAHAN, COLE C	Quantitative Ecology & Resource Mgmt	M.S.	Trevor Branch
ONO, KOTARO	School of Aquatic and Fishery Sciences	Ph.D.	Ray Hilborn
PELLAND, NOEL	School of Oceanography	Ph.D.	Charles Eriksen
PURKEY, SARAH M.	School of Oceanography	Ph.D.	Gregory Johnson
RALEIGH, MARK S.	Civil and Environmental Engineering	Ph.D.	Jessica Lundquist
RUTTER, JEFFERY D	Quantitative Ecology & Resource Mgmt	Ph.D.	Andre Punt
SHAMBERGER, KATHRYN E.	School of Oceanography	Ph.D.	Richard Feely
SPIRANDELLI, DANIELE J	Urban Ecology	Ph.D.	Marina Alberti
STACHURA, MEGAN M.	School of Aquatic and Fishery Sciences	M.S.	Nathan Mantua, Ray Hilborn
WAGNER, CHERIE A.	School of Marine & Environmental Affairs	M.S.	Patrick Christie
WAYAND, NICHOLAS E	Civil and Environmental Engineering	M.S.	Jessica Lundquist
WENEGRAT, JACOB O	School of Oceanography	M.S.	Mike McPhaden
WHITEHOUSE, GEORGE A.	School of Aquatic and Fishery Sciences	M.S.	Tim Essington
WILLIAMS, NANCY L.	School of Oceanography	M.S.	Richard Feely, Chris Sabine
WU, MOTOKI	School of Aquatic and Fishery Sciences	M.S.	Andre Punt

Appendix 6

JISAO Awards and Honors 2011-2012

Ackerman, Thomas – Elected a Fellow of the American Geophysical Union (AGU).

Bellman, Scott – The manager of UW DO-IT (Disabilities, Opportunities, Internetworking, and Technology) was presented the Spotlight Award for his efforts in supporting the goals of the DO-IT Center's projects.

Branch, Trevor – Won the Ecological Society of America 2011 Sustainability Science Award given annually to the authors of the paper that makes the greatest contribution to the science of ecosystem and regional sustainability through the integration of ecological and social sciences.

Burgstahler, Sheryl – The DO-IT founder and director won the Strache Leadership Award acknowledging her leadership in the field of disability and technology with an emphasis on continuing education.

Burgstahler, Sheryl – Won the AHEAD Professional Recognition Award in honor of her contributions to the field of higher education and disability.

Butterfield, David – Appointed to the NEPTUNE Canada Science User Committee, charged with guiding and promoting science from this cabled seafloor observatory.

Butterfield, David – Guest editor for special issue of *Economic Geology* on mineralization at submarine volcanic arcs.

Climate Impacts Group (CIG) – Won the 2011 UW College of the Environment Outstanding Community Collaboration Award.

Essington, Tim – Awarded a Pew Fellowship in Marine Conservation.

Hinkelman, Laura – Nominated for the UW Distinguished Staff Award (winner will be announced in June 2012).

Littell, Jeremy – Won the Early-career Poster Award at the World Climate Research Program's Open Science Conference in Denver.

Littell, Jeremy – Won a USFS Excellence in Wilderness Stewardship Research Award for the paper he co-wrote titled "Climate Change and Wilderness Fire Regimes."

Raleigh, Mark – A graduate student with Jessica Lundquist, Mark won the Western Snow Conference James E. Church Memorial Award for best paper and presentation.

Raleigh, Mark – Won a CH2M HILL Engineers Without Borders Graduate Scholarship Award.

Snover, Amy – Won the Editor's Award from the Bulletin of the American Meteorological Society (BAMS).

Whitely Binder, Laura – Nominated for the UW Distinguished Staff Award (winner will be announced in June 2012).

Zaragoza, Jake – A JISAO intern in summer 2011, Jake has been accepted into the SOARS research mentoring program at the National Center for Atmospheric Research (NCAR) in Boulder, CO.

Appendix 7

Personnel Count

Category	Number	B.S.	M.S.	Ph.D.
Faculty	1			1
Research Scientist	67	12	25	30
Visiting Scientist	0			
Postdoctoral Fellow**	9			9
Research Support Staff	6	6		
Administrative	0			
Total (> or = 50%)	83	18	25	40
Undergraduate Students	3			
Graduate Students	28			
Employees receiving less than 50% NOAA support	42			
Located at Lab	73 (PMEL), 1 (AFSC), 2 (NWFSC)			
Obtained NOAA employment within the last year	2			

**an additional 2 PostDocs received less than 50% support

Appendix 8

Postdoctoral Research Associates

BAKER, MATTHEW R
HAGERMAN, SHANNON M
HOLSMAN, KIRSTIN
JOHNSTONE, JAMES A
KLEISS, JESSICA MARIE **
LIQUE, CAMILLE EMILIE
MISHRA, VIMAL **
SIEDLECKI, SAMANTHA A
USLU, BURAK
WOILLEZ, MATHIEU
ZHOU, HONGQIANG

**Received less than 50% support from JISAO

Appendix 9

Publications Count

JISAO Lead Author	*10-11*	*11-12*
Peer-reviewed	66	89
Non-Peer-reviewed	1	6
Total	**67**	**95**

NOAA Lead Author	*10-11*	*11-12*
Peer-reviewed	16	20
Non-peer-reviewed	0	2
Total	**16**	**22**

Other Lead Author	*10-11*	*11-12*
Peer-reviewed	83	75
Non-peer-reviewed	11	4
Total	**94**	**79**

TOTAL	**10-11**	**11-12**
Peer-reviewed	**165**	**184**
Non-peer-reviewed	**12**	**12**
Total	**177**	**196**

Appendix 10

Publications April 1, 2011 – March 31, 2012

Not Previously Reported

1. Branch, T. A., R. Watson, E. A. Fulton, S. Jennings, C. R. McGilliard, G. T. Pablico, D. Ricard, and S. R. Tracey (2010), The trophic fingerprint of marine fisheries, *Nature*, *468*(7322), 431-435.
2. Dougherty, A., C. Harpold, and J. Clark (2010), Ecosystems and Fisheries-Oceanography Coordinated Investigations (Eco-FOCI) Field Manual, edited by Alaska Fisheries Science Center NOAA National Marine Fisheries Service, AFSC Processed Report 2010-02, p. 213, US Department of Commerce, Seattle, Washington.
3. Furtado, J. C., E. Di Lorenzo, N. Schneider, and N. A. Bond (2010), North Pacific Decadal Variability and Climate Change in the IPCC AR4 Models, *Journal of Climate*, *24*(12), 3049-3067.
4. Kleiss, J. M., and W. K. Melville (2010), The Analysis of Sea Surface Imagery for Whitecap Kinematics, *Journal of Atmospheric and Oceanic Technology*, *28*(2), 219-243.
5. Kruse, G., G. Eckert, R. Foy, R. Lipcius, B. Sante-Marie, D. Stram, and D. Woodby (Eds.) (2010), Biology and Management of Exploited Crab Populations under Climate Change, Alaska Sea Grant College Program, University of Alaska, Fairbanks.
6. Lindsay, R. (2010), New Unified Sea Ice Thickness Climate Data Record, *Eos Trans. AGU*, *91*(44).
7. Mass, C., A. Skalenakis, and M. Warner (2010), Extreme Precipitation over the West Coast of North America: Is There a Trend?, *Journal of Hydrometeorology*, *12*(2), 310-318.
8. McGilliard, C. R., A. E. Punt, and R. Hilborn (2010), Spatial structure induced by marine reserves shapes population responses to catastrophes in mathematical models, *Ecological Applications*, *21*(4), 1399-1409.
9. Niklason, P., P. Stitzel, H. Barnett, R. Johnson, and M. Rust (2010), Montlake Process for Utilization of Salmon Waste in Alaska, paper presented at A Sustainable Future: Fish Processing Byproducts, Portland, OR, Feb 25-26, 2009.
10. Shukla, S., A. C. Steinemann, and D. P. Lettenmaier (2010), Drought Monitoring for Washington State: Indicators and Applications, *Journal of Hydrometeorology*, *12*(1), 66-83.

Published

11. Abdul-Aziz, O. I., N. J. Mantua, and K. W. Myers (2011), Potential climate change impacts on thermal habitats of Pacific salmon (Oncorhynchus spp.) in the North Pacific Ocean and adjacent seas, *Canadian Journal of Fisheries and Aquatic Sciences*, *68*(9), 1660-1680.
12. Adames, A. F., M. Reynolds, A. Smirnov, D. S. Covert, and T. P. Ackerman (2011), Comparison of Moderate Resolution Imaging Spectroradiometer ocean aerosol retrievals with ship-based Sun photometer measurements from the Around the Americas expedition, *J. Geophys. Res.*, *116*(D16), D16303.
13. Alford, M. H., M. F. Cronin, and J. M. Klymak (2011), Annual cycle and depth penetration of wind-generated near-inertial internal waves at Ocean Station Papa in the Northeast Pacific, *Journal of Physical Oceanography*, *doi: 10.1175/JPO-D-11-092.1*.
14. Arcas, D., and Y. Wei (2011), Evaluation of velocity-related approximations in the nonlinear shallow water equations for the Kuril Islands, 2006 tsunami event at Honolulu, Hawaii, *Geophys. Res. Lett.*, *38*(12), L12608.
15. Arcas, D., and H. Segur (2012), Seismically generated tsunamis, *Phil. Trans. R. Soc. A*, *370*(1964), 1505-1542.
16. Arthur, C., and J. Baker (2011), Proceedings of the Second Research Workshop on Microplastic Marine Debris. NOAA Technical Memorandum NOS-OR&R-39.
17. Baker, M. R., N. W. Kendall, T. A. Branch, D. E. Schindler, and T. P. Quinn (2011), Selection due to nonretention mortality in gillnet fisheries for salmon, *Evolutionary Applications*, *4*(3), 429-443.
18. Baker, E. T., J. E. Lupton, J. A. Resing, T. Baumberger, M. D. Lilley, S. L. Walker, and K. H. Rubin (2011), Unique event plumes from a 2008 eruption on the Northeast Lau Spreading Center, *Geochem. Geophys. Geosyst.*, *12*, Q0AF02.
19. Banobi, J. A., T. A. Branch, and R. Hilborn (2011), Do rebuttals affect future science?, *Ecosphere*, *2*(3), art37.

20. Barbeaux, S. (2011), Scientific acoustic data from commercial fishing vessels: eastern Bering Sea walleye pollock (Theragra chalcogramma), University of Washington, Seattle.
21. Beal, L. M., W. P. M. De Ruijter, A. Biastoch, and R. Zahn (2011), On the role of the Agulhas system in ocean circulation and climate, *Nature*, *472*(7344), 429-436.
22. Biancamaria, S., F. Hossain, and D. P. Lettenmaier (2011), Forecasting transboundary river water elevations from space, *Geophys. Res. Lett.*, *38*(11), L11401.
23. Boldt, J. L., S. C. Bartkiw, P. A. Livingston, G. R. Hoff, and G. E. Walters (2012), Investigation of Fishing and Climate Effects on the Community Size Spectra of Eastern Bering Sea Fish, *Transactions of the American Fisheries Society*, *141*(2), 327-342.
24. Bond, N. A. (2011), The Coastal Gulf of Alaska Program: Progress and perplexity, *Current, The Journal of Marine Education*, *27*(2), 15-18.
25. Bourbonnais, A., M. F. Lehmann, D. A. Butterfield, and S. K. Juniper (2012), Subseafloor nitrogen transformations in diffuse hydrothermal vent fluids of the Juan de Fuca Ridge evidenced by the isotopic composition of nitrate and ammonium, *Geochem. Geophys. Geosyst.*, *13*, Q02T01.
26. Branch, T. A., O. P. Jensen, D. Ricard, Y. Ye, and R. A. Y. Hilborn (2011), Contrasting Global Trends in Marine Fishery Status Obtained from Catches and from Stock Assessments Contraste de las Tendencias Globales en el Estatus de las Pesquerías Marinas Obtenido de Capturas y Evaluación de Reservas, *Conservation Biology*, *25*(4), 777-786.
27. Branch, T. A., J. D. Austin, K. Acevedo-Whitehouse, I. J. Gordon, M. E. Gompper, T. E. Katzner, and N. Pettorelli (2011), Fisheries conservation and management: finding consensus in the midst of competing paradigms, *Animal Conservation*, *DOI: 10.1111/j.1469-1795.2011.00502.x*, n/a-n/a.
28. Butterfield, D. A., K.-I. Nakamura, B. Takano, M. D. Lilley, J. E. Lupton, J. A. Resing, and K. K. Roe (2011), High SO_2 flux, sulfur accumulation, and gas fractionation at an erupting submarine volcano, *Geology*, *39*(9), 803-806.
29. Cheung, K. F., Y. Wei, Y. Yamazaki, and S. C. S. Yim (2011), Modeling of 500-year tsunamis for probabilistic design of coastal infrastructure in the Pacific Northwest, *Coastal Engineering*, *58*(10), 970-985.
30. Chiodi, A., and D. Harrison (2012), Determining CO_2 airborne fraction trend with uncertain land use change emission records, *J Intl Climate Change: Impacts and Responses*, *3*(1), 79-88.
31. Chotamonsak, C., E. P. Salathé, J. Kreasuwan, S. Chantara, and K. Siriwitayakorn (2011), Projected climate change over Southeast Asia simulated using a WRF regional climate model, *Atmospheric Science Letters*, *12*(2), 213-219.
32. Climate Impacts Group (2012), An analysis of the pre-workshop interviews: Laying the Foundation for Integrating Climate Change Impacts and Adaptation into Fishery Management Decisions: SARP Project Report.
33. Cronin, M. F. (2011), NOAA buoy deployed in the Agulhas Return Current. South African Environmental Observation Network, *SAEON e-Newsletter*, *http://www.saeon.ac.za/enewsletter/archives/2011/april2011/doc04*.
34. Cronin, M. F., R. A. Weller, R. S. Lampitt, and U. Send (2012), Ocean reference stations, Chapter 9, in *Earth Observation*, edited by R. B. Rustamov and S. E. Salahova, pp. 203-228, In Tech, ISBN: 978-953-307-973-8. Available from: *http://www.intechopen.com/articles/show/title/ocean-reference-stations*.
35. Danielson, S., E. Curchitser, K. Hedstrom, T. Weingartner, and P. Stabeno (2011), On ocean and sea ice modes of variability in the Bering Sea, *J. Geophys. Res.*, *116*(C12), C12034.
36. Darby, D. A., W. B. Myers, M. Jakobsson, and I. Rigor (2011), Modern dirty sea ice characteristics and sources: The role of anchor ice, *J. Geophys. Res.*, *116*(C9), C09008. doi:09010.01029/02010JC006675.
37. Das, T., D. W. Pierce, D. R. Cayan, J. A. Vano, and D. P. Lettenmaier (2011), The importance of warm season warming to western U.S. streamflow changes, *Geophys. Res. Lett.*, *38*(23), L23403.
38. de Ronde, C., et al. (2011), Submarine hydrothermal activity and gold-rich mineralization at Brothers Volcano, Kermadec Arc, New Zealand, *Mineralium Deposita*, *46*(5-6), 541-584.
39. Duffy-Anderson, J., D. Blood, and K. L. Mier (2011), Stage-specific vertical distribution of Alaska plaice (Pleuronectes quadrituberculatus) eggs in the eastern Bering Sea, *Fishery Bulletin*, *109*(2), 162-169.

40. Dulière, V., Y. Zhang, and E. P. Salathé (2011), Extreme Precipitation and Temperature over the U.S. Pacific Northwest: A Comparison between Observations, Reanalysis Data, and Regional Models, *Journal of Climate*, *24*(7), 1950-1964.
41. Emerson, S., C. Sabine, M. F. Cronin, R. Feely, S. E. Cullison Gray, and M. DeGrandpre (2011), Quantifying the flux of $CaCO_3$ and organic carbon from the surface ocean using in situ measurements of O_2, N_2, pCO_2, and pH, *Global Biogeochem. Cycles*, *25*(3), GB3008.
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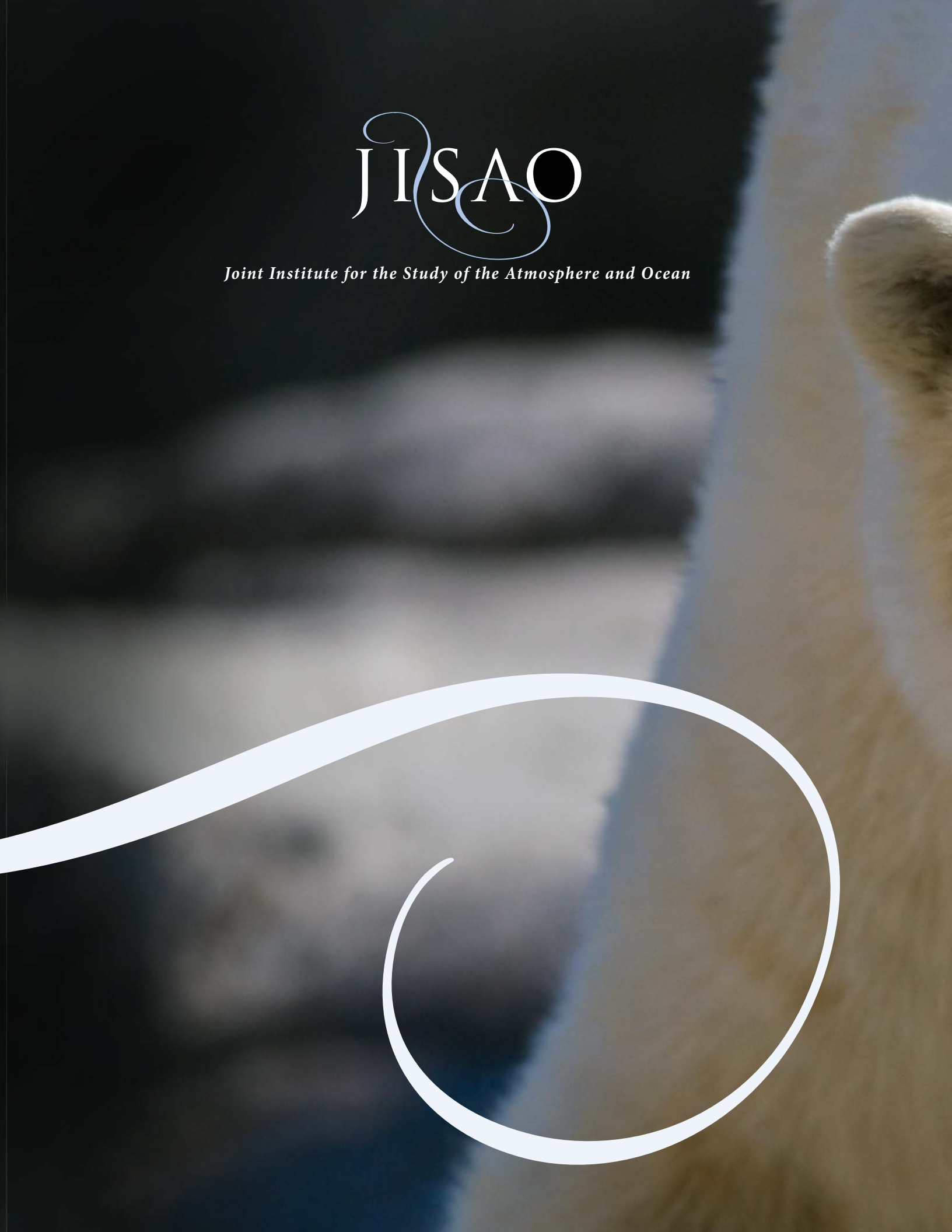
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