
Joint Institute for the Study of the Atmosphere and Ocean

University of Washington
3737 Brooklyn Ave NE
Box 355672
Seattle, WA 98105-5672

206.685.6548
206.685.3397 fax
jisao@u.washington.edu
jisao.washington.edu

Graphic Design – Robyn Ricks, Washington Sea Grant
## Contents

**Executive Summary** ................................................................. 1

**Climate Research and Impacts** .................................................. 15

**Environmental Chemistry** ......................................................... 43

**Marine Ecosystems** ................................................................. 57

**Ocean and Coastal Observations** .............................................. 91

**Protection and Restoration of Marine Resources** ...................... 99

**Seafloor Processes** ................................................................. 105

**Tsunamis Observations and Modeling** ...................................... 115

## Appendices ........................................................................... 135

**Appendix 1** JISAO Senior Fellows and Council Members ............ 136

**Appendix 2** Professional Awards, Funded Events and Visitors ........ 137

**Appendix 3** New Cooperative Agreement Awards Funded in 2012-2013 139

**Appendix 4** Awards Funded Outside the Cooperative Agreement .... 140

**Appendix 5** Graduate Students .................................................. 141

**Appendix 6** Personnel Count ..................................................... 142

**Appendix 7** Postdoctoral Research Associates ............................ 143

**Appendix 8** Publications Count .................................................. 144

**Appendix 9** Publications – 2013 .................................................. 145

**Appendix 10** Acronyms ............................................................. 142
Executive Summary
The Joint Institute for the Study of the Atmosphere and Ocean (JISAO) at the University of Washington (UW) is a NOAA Cooperative Institute that is at the forefront of research in atmospheric, oceanic and fishery sciences. JISAO promotes interdisciplinary collaborations between UW and NOAA scientists under 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

The breadth of this research reflects the range of scientific expertise represented at UW. JISAO’s unique collaborative structure provides easy access to exceptional resources and facilities at one of the nation’s preeminent institutions of higher education and research. Aligning well with NOAA’s goals and strategic plan, JISAO’s research, education and outreach programs provide the ability to form strong collaborations and partnerships with NOAA, as well as with other local and national organizations.

A short distance from the UW campus, NOAA’s Pacific Marine Environmental Laboratory (PMEL) serves as JISAO’s host laboratory. JISAO also works with the NOAA Alaska Fisheries Science Center (AFSC) and the Northwest Fisheries Science Center (NWFSC), among others.

Organizationally, JISAO is a unit under the innovative UW College of the Environment (CoEnv) whose mission includes the study of the earth’s land, water and atmospheric systems; the development and application of engineering and technological advances; 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 the financial and operations management of the Institute. 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 and Impacts

JISAO climate research, in collaboration with NOAA and other partners, spans a wide range of important topics and phenomena, including: climate prediction; impacts of climate variability and change; evaluation of water and energy cycles; and, polar research. Following are a few examples that provide a sampling of the scope and diversity of this work.

Even though a great deal of research has been devoted to the El Niño-Southern Oscillation (ENSO) phenomenon, the problem it presents has not been solved. JISAO and NOAA scientists are currently working on whether its character is liable to evolve in association with global climate change. Rigorous statistical analyses on a long record of reliable weather observations from Darwin, Australia reveal the lack of a systematic long-term trend. Perhaps more importantly, this work also demonstrates that long (multi-decadal) segments of this record appear to have statistically significant trends when considered in isolation. This work represents a cautionary note in our abilities to discern signals from the noise in the climate system.

While JISAO has a particular focus on the Pacific, there are considerable interests and expertise in other parts of the globe. Recent work pertaining to the Atlantic Meridional Overturing Circulation (AMOC), focuses on the fidelity with which it is represented in state of the art global climate models. The hindcast simulations from a new set of CMIP5 models that were developed for the upcoming 5th Assessment Report of the IPCC better match the observed properties of the AMOC during the 20th century than the simulations from a previous generation of climate models. The new models simulate an overall weakening of the AMOC during the 21st century in part due to changes in the fluxes of freshwater out of the Arctic. Diagnosis of the mechanisms responsible for this key driver of the global climate is continuing.

JISAO has productive Arctic research collaborations with NOAA scientists as well as with UW scientists in departments across campus. One of the locations of special interest is the Bering Strait. There appears to have been an increase as large as 50% in transports through the Bering Strait since 2001. Moreover, it has been found that direct measurements are the only effective way to monitor the flows in this region (remote sensing is insufficient) and ultimately how much heat and freshwater is entering the Arctic. This work is made possible through JISAO’s longstanding participation in the Russian-American Long-term Census of the Arctic program (RUSALCA).

The Old Weather project involves the creation of an online resource using crowd-sourcing to transcribe arctic weather data from historical ships’ logs going back 150 years. This data will eventually be used by scientists to construct Arctic climate history and study climate patterns from the past. The project has earned national attention.
Environmental Chemistry

Along the Washington-Oregon-California continental margin, ocean acidification, upwelling, biological productivity, and respiration processes in subsurface waters are major contributors to the variability in dissolved inorganic carbon (DIC) and pH. The persistence of corrosive water on the continental shelf off Washington and Oregon has been previously identified and could have profound ecological consequences for benthic and pelagic calcifying organisms such as mussels, oysters, abalone, echinoderms, and pteropods. During the late summer months of 2011 and 2012, the extent of acidification conditions was studied via shipboard cruises and profiling gliders in order to better understand the relationships among these natural and human-induced processes. Results show that 14-28% of the overall acidification experienced over the continental shelf during the summer upwelling season is derived from anthropogenic CO₂, 9-20% is derived from local respiration processes, and the remaining 59-74% is derived from the natural process of upwelling itself. These processes combine to maintain corrosive waters for calcifying organisms at depths ranging from 20 to 200 m over most of the continental shelf region during the late summer months.

The sources of cloud condensation nuclei (CCN) over the ocean must be accurately parameterized in global climate models. Reliable 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. The atmospheric chemistry group at JISAO and NOAA measured particles directly emitted from the ocean using a newly developed in situ particle generator (Sea Sweep). Although freshly emitted sea spray aerosols are enriched in organic matter, results from the Sea Sweep measurements show that these particles behave like an internal mixture of sea salt with a small organic component. It was also found that the effectiveness of sea spray aerosols as CCN is not related to local chlorophyll concentrations. These results are expected to ultimately improve our ability to model the distributions of marine clouds.

Marine Ecosystems

Groundfish fisheries of the eastern Bering Sea and Aleutian Islands, as well as the Gulf of Alaska regions of the North Pacific, are the subject of a project that is exploring the impacts of implementing management strategies that formally incorporate uncertainty into the harvest control rules. These strategies include a status-quo approach, methods based on simple rules related to standing stocks, and a more sophisticated approach that accounts for uncertainty in harvest totals that constitute overfishing. This work represents an extension of the previous framework for Management Strategy Evaluation (MSE) with the ultimate objective of determining the best way to establish catch quotas that result in both low probabilities of fisheries collapse and relatively high overall yields.

JISAO’s Seasonal Coastal Ocean Prediction Experiment (J-SCOPE) is a collaborative effort involving scientists at JISAO and NWFSC. Quantitative forecasts have begun to be produced of physical, chemical and biological (through lower-trophic levels) ocean properties on time horizons of ~9 months. These forecasts are tailored towards NOAA and other operational stakeholders. They are based on numerical ocean model simulations using a high-resolution (grid spacing ~3 km) version of the Regional Ocean Modeling System (ROMS) with a component that accounts for nutrient and plankton distributions. Because the marine ecosystem of the Pacific Northwest coast is subject to large variations in physical forcing, managers and coastal communities would benefit substantially from skillful predictions on time horizons of 6-9 months. This project represents a first step towards achieving these predictions on an operational basis, using existing resources and tools.

JISAO has been involved in an in-depth study showing that black carbon is the second largest man-made contributor to global warming, and its influence on climate has been greatly underestimated. The paper was published in January, 2013, in the Journal of Geophysical Research – Atmospheres. This paper has received a great deal of media attention and public interest.
A new project this year studies the effect of wind-driven mixing on observations of plastic marine debris in the ocean. The same engineered properties that contribute to the enormous utility of plastic, namely durability and resistance to degradation, also result in long residence times (decades to millennia) when plastic is introduced into the natural environment. The bulk of scientific measurements of plastics in the open ocean come from surface net tows. Because the surface ocean is a dynamic environment and plastic fragments act as passive particles, this plastic debris is subject to the physics of mixing within the ocean surface boundary layer, resulting in surface measurements that underestimate the total amount of plastic in the upper water column. Results of a new project team working in this area suggest that the surface ocean actually contains between 2 and 27 times the amount of plastic measured using surface net tows.

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.

Seabirds sometimes attack baited hooks deployed by long line fishing vessels of the US West Coast fleet. Scientists with the UW’s School of Aquatic and Fishery Sciences (SAFS) and Washington Sea Grant are working to minimize the incidental by-catch of seabirds by the fleet targeting sablefish, with a special emphasis on reducing the mortality of short-tailed albatross, a listed species under the Endangered Species Act (ESA). The key elements of this effort have involved measuring the sink rates of fishing lines, the frequency of seabird attacks by species on these lines, and recruiting and training liaisons to interact directly with commercial fishers. This project reflects the leveraging made possible by support provided by NOAA’s NMFS Northwest Region, the National Fish and Wildlife Foundation, and the Packard Foundation.

There is a great deal of recent interest and controversy on the extent to which commercial fishing impacts the mean trophic level of marine ecosystems. In other words, how much are we fishing down the food web? A group from SAFS and NOAA NWFSC and AFSC is at the forefront of this debate through a comparative analysis based on catch data and fisheries stock assessments for four regional ecosystems ranging from the northeastern US continental shelf to the eastern Bering Sea. The analysis features accounting for environmental variability in addition to fishing pressure, and state-of-the-art techniques for evaluating the interactions among species. The research is ongoing but among its other accomplishments, Dr. Matt Baker of SAFS received an ICES Early Career Scientist award.

JISAO is proud of its commitment to providing opportunities for undergraduates from across the US to gain research experience as part of its summer internship program (summarized below in this report). This is by no means the only opportunity of this type. In particular, 6-9 undergraduate internships are made available each year through a collaboration between UW Undergraduate Academic Affairs and NOAA NWFSC. These interns are active participants in laboratory and field activities under the mentorship of scientists at NWFSC. This enhances their undergraduate learning experience and helps provide a jump start to their professional careers.
Seafloor Processes

The Vents Group of JISAO and NOAA/PMEL are world leaders in the exploration of submarine volcanoes and hydrothermal vents. Among the many projects underway has been the long-term monitoring at the Axial Seamount of the Juan de Fuca Ridge. This effort has recently featured the collection of biological materials with antibiotic properties that have gained the interest of the pharmacology research community. The Vents Group develops innovative instrumentation and equipment for sampling in the harsh environments represented by submarine volcanoes. The direct measurements and samples acquired are being used to create and test models linking physical effects to the biogeochemistry in the vicinity of these exotic locations. It bears emphasizing that these places are not just incredibly beautiful but also potentially crucial as a source of trace metals to the world’s oceans. Scientists with this group are key members of a large multi-team effort to determine how the contributions of trace metals and other chemical constituents associated with hydrothermal activity compare with riverine and atmospheric inputs.

Tsunami Observations and Modeling

JISAO is part of the NOAA Center for Tsunami Research (NCTR). Measurement technology, forecast modeling tools and dissemination capabilities are developed and transferred to operational agencies to provide the nation and the world with the best possible predictions of tsunami impacts. JISAO tsunami research is recognized throughout the world and continues to set the standard in tsunami detection and forecasting. In light of the near-field devastating effects of recent tsunamis (Japan, 2011 and Chile, 2010) JISAO’s tsunami scientists, in conjunction with NCTR, have recently identified the problem of near-field tsunami forecasting as one of their primary areas of research. JISAO scientists are currently studying the potential of new technology, such as Differential Global Positioning Systems (GPS), in providing initial deformation conditions for tsunami forecast models. This real-time reporting of ground motion during an earthquake may make it feasible to run models that could provide almost immediate information for evaluating the threat of a tsunami from a nearby earthquake. Another technology under study is the use of a new generation of near-field Deep-ocean Assessment and Reporting of Tsunami (DART) sensors with a much higher sampling frequency than existing units. This will permit efficient filtering of seismic and tsunami waves and will allow for deployment of these DART units much closer to the earthquake generation area.
Education and Outreach

“The opportunity to work closely with very skilled scientists, to have them as mentors and teachers, was extraordinary. I now have an idea of what research, and graduate school, is like. This internship has cemented my interest in this field, as well as opened up new possibilities for me.”

~Isabel McCoy, 2012 JISAO Intern

JISAO’s Education and Outreach (E&O) Program continues to make important contributions by advancing environmental literacy at all levels of our society and educating and 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 Undergraduates (REU). The REU program began with one student in 2008 and has expanded to include 23 students since 2009. Nine former interns have graduated and four of them are currently in graduate school at Pennsylvania State University; University of California, Davis; and University of Washington (2). In December 2012, Laura Vogel was our first intern to receive a graduate degree earning an MS in Environmental Engineering from Stanford University. In past years, JISAO’s REU program has received additional funding support from NOAA’s Office of Oceanic and Atmospheric Research (OAR) and the NOAA Center for Atmospheric Research (NCAS) at Howard University. Outstanding interns have returned a second summer to work with mentors who valued the work they performed during their initial internship.

JISAO’s prominent presence in the local and national environmental science communities is reflected in the growth of the E&O Program and its many successful events as follows:

- **JISAO Summer Research Experience for Undergrads (REU)**
  - JISAO welcomed six undergraduate students in summer 2012. Students were matched with mentors in the UW School of Oceanography, the UW Atmospheric Sciences department, and the Alaska Salmon Research Program near Dillingham, AK. Student web pages and videos are displayed in the Outreach section on JISAO’s website. The interns and their universities are listed below:
    - Abby Ahlert, University of Maryland
    - Karimar Ledesma Malondano, University of Puerto Rico
    - Shirley Leung, University of Pennsylvania
    - Isabel McCoy, New Mexico Institute of Mining and Technology
    - Bianca Santos, Stony Brook University
    - Ricky Vargas, Rutgers University

JISAO Interns
2013 to continue the research she did as an intern with Dr. Andreas Muhlbauer.

- JISAO’s internship program was named “One of Seattle’s coolest internships” by Seattle Met magazine in their January 2013 issue.

### Pacific Science Center (PSC) Partnership

- **Scientist Spotlights**
  Science Communication Fellows Guillaume Mauger, Karin Bumbaco, and Drew Hamilton presented hands-on activities related to their work on designated weekends at Pacific Science Center. Science Communication Fellows are professionals who have been certified by PSC as current science ambassadors and excellent communicators.

- **Paws-On Science: Husky Weekend**
  Seattle families visited 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 as they got to meet and talk with polar researchers. JISAO’s Mick Spillane and Edison Gica staffed a booth titled “Tsunami Alert”. Over 10,000 area residents and visitors to Seattle attended the event.

### K-12 Events

- **Orca Bowl:**
  JISAO scientists, Fred Menzia and Morgan Orstendorff, were judges and Scott McKeever was a score-keeper at Washington Sea Grant’s 2012 Orca Bowl. 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. This year’s winner was Garfield High School. They will go on to compete at nationals in Milwaukee, WI.

- **NOAA Science Camp:**
  - JISAO scientists led sessions and participated in the 2012 NOAA Science Camp at the Pacific Marine Environmental Laboratory.
  - This was the seventh 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.
  - JISAO researchers also participated in the camp’s Speed Networking event giving students a chance to meet scientists doing many different kinds of science.
• **DO-IT Scholars Program:**
  DO-IT works with high school students with disabilities who have the potential to pursue college studies and careers and develop leadership skills yet face significant challenges because of their disabilities. JISAO provides support for one student to attend the program who wants to pursue education and a career in an area of research supported by NOAA.

• **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 3rd Annual Science Day.
  - They also served as judges for the school’s science fair in May 2012.

• **Skype Visit:**
  Laura Hinkelman hosted a Skype session with students at Union City Community High School in Union City, IN. She gave a presentation on her research to an environmental science class of eight students.

• **Mercer Slough Environmental Education Center:**
  Karin Bumbaco talked with high schoolers in Bellevue, WA about career options in science and explained the climatology research she does with JISAO.

• **Scientists in the Classroom:**
  Lindsey Wright mentors a student at Sinagua Middle School in Flagstaff, AZ. They worked together on five tsunami-related projects: an Mp3 interview; PowerPoint presentation; research paper; a movie about climate change; and a final presentation schedule for May 2013.

• **Microplastic Debris Collecting:**
  Joel Baker visited the Saghalie Middle School Math and Science Academy where he taught 150 students about collecting and analyzing beach debris.

**College Events**

• **Seattle University visit to PMEL:**
  Eight students from a pilot conservation class at Seattle University visited PMEL in February 2013. Nick Bond and Jim Overland talked with the students about their research and Paul Freitag gave them a tour of the TAO lab.

• **Northwest Fisheries Science Center (NWFSC) Undergraduate Intern Program:**
  - A collaboration between UW and NWFSC, the program provides training to undergraduates interested in fisheries research.
  - Six students participated in 2012 and three more have been selected for 2013.

• **JISAO researchers gave talks about their research at the following colleges and universities:**
  - University of Washington
  - Pacific Lutheran University
  - UW Bothell
  - Central Washington University
  - Everett Community College
  - Western Washington University
  - UW Tacoma
  - Central Washington University

**Conferences and Career Fairs**

• **SACNAS (Advancing Hispanics, Chicanos and Native Americans in Science) National Conference in Seattle, WA:**
  - Jed Thompson, JISAO’s Education and Outreach Coordinator, represented JISAO and the College of the Environment and distributed applications for JISAO’s internship program.
  - Former JISAO intern Jake Zaragoza was in attendance and gave a talk at the conference.

• **AISES National Conference:**
  - The American Indian Science and Engineering Society (AISES) held their 2012 national conference in Anchorage, Alaska from November 1-3.
  - Daniel Hernandez, a former JISAO intern and current graduate student in the UW School of Aquatic and Fishery Sciences, represented JISAO and spoke with students from tribal colleges about opportunities to apply for JISAO’s summer internship program.
• **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.
  ° JISAO also had a booth on UW’s Red Square staffed by Jed Thompson and Todd Mitchell.

• **International Conference on Climate Change:** JISAO researchers attended the 2012 conference from July 12-13 at the University of Washington in Seattle.

• **8th International Cloud Modeling Workshop:** JISAO’s Andreas Muhlbauer co-chaired the event in Warsaw, Poland in July 2012.

• **AeroCom Workshop:**
  AeroCom is an open international initiative of scientists interested in advancing the understanding of global aerosol and its impact on climate. JISAO sponsored and hosted the event on the UW campus in September 2012.

### Outreach Communication

• **JISAO website:**
  Its design represents a standard set by UW and the College of the Environment. It provides a more effective means to communicate institute activities to constituents with an improved, user-friendly format and organization. Over the years, JISAO has tracked media coverage of all JISAO scientists. Archives of past media coverage, as well as staff profiles, are easily accessible via links on the main page. The following events received notable media coverage in the past year:
  ° Old Weather project: Weather.com, New York Times, Outside magazine, Slate
  ° Tsunami forecasting: Seattle Times, MSNBC, Nature
  ° Acidity in the oceans: Seattle Times, Nature
  ° Exploring undersea volcanoes, Outside magazine, NOAA News
  ° Cloud’s effect on climate change: New York Times
  ° Conservation canines: New York Times

• **Outreach Section:**
  Significant improvements were made to the Outreach section of the JISAO website. New content is updated on a regular basis as events and activities occur.

• **Data Archives:**
  JISAO scientist Todd Mitchell provides content for JISAO’s data archives, which are viewed by more than 10,000 people per year.

• **Public Radio Segment:**
  JISAO scientist Nick Bond had a weekly segment on the regional weather and climate on Public Radio KUOW.

### Public Outreach

• **WA Department of Fish and Wildlife:**
  WA State Climatologist Nick Bond gave a talk in Olympia, WA, titled Climate Variability of the Pacific Northwest.

• **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. Other Sound Waters events include:
    ° University for a Day: JISAO’s Cynthia Peacock and Adrienne Sutton went to Whidbey Island for an ocean acidification presentation.

• **Climate Lecture Series:**
  ° Nick Bond and Karin Bumbaco gave a series of lectures for the Beachwatchers 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”

• **JISAO researchers also volunteered their time for the following programs and organizations:**
  ° UW Undergraduate Research Symposium
  ° Expanding Your Horizons
  ° JISAO summer intern seminars
  ° Boy Scouts of America
  ° Sound Experience, Women in Science Cruise
  ° Center for Urban Waters
Financial Management and Administration

Over the years, JISAO has restructured and refined its business operations to meet the Institute’s needs during a period of growth and change. Due to a recent downsizing effort, a smaller group now manages and supports JISAO’s research, education, and outreach programs. In addition, UW has streamlined many of its services, employing more cost-effective methods for providing centralized support to UW departments. The infrastructure provided by both UW and CoEnv ensures that the JISAO administration can continue to operate as efficiently as possible, to maintain and improve compliance systems and procedures, employ best practices and manage finances and operations well. JISAO and PMEL administrators have formed a strong partnership that works well and contributes to the success of the Institute.

A management team meets once per week for planning purposes and to discuss issues related to budgets/grants, human resources and daily operations. The team includes:

- 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/Administrative Specialist

JISAO’s Executive Council meets when there are agenda items that require higher-level policy reviews and decisions. Meetings are held either at UW or NOAA once per quarter for JISAO employees. NOAA scientists attend some of these meetings if they are involved with the topic. These meetings 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 and the Administrative Specialist hold 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. Additional postdoctoral funding was provided this year by Chris Sabine, PMEL Director.
- 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 research associates, Samantha Siedlecki, from the University of Chicago, and Camille Lique, from Laboratoire de Physique des Océans, Plouzané, France. Lique finished her appointment with JISAO and took a position with the University of Oxford, Oxford, England. Siedlecki accepted a position with JISAO as a research scientist. The JISAO Research Associate Search Committee has chosen three new post docs who will begin work with JISAO and NOAA/PMEL this year. They are Bonnie Chang from Princeton University, Kim Martini from the University of Alaska, and, Joel Pedro from the University of Tasmania.

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 important 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 principal investigators in research projects 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.

The JISAO/NOAA Cooperative Agreement funding for the period ending on March 31, 2013 totals $13,305,805. JISAO’s funding exclusive of the Cooperative Agreement for the last 12 months amounts to another $2,875,426. The charts that follow break down Cooperative Agreement funding by tasks and themes awarded in 2012 - 13.
The JISAO administration continued to work on the following initiatives over the past year to improve and strengthen JISAO as an organization:

- **JISAO Education and Outreach Program**
  - Continued to strengthen and broaden the success of the E&O program (see section above for details of the year’s activities)

- **JISAO Staff Recognition Program**
  - Recognized outstanding research, papers, honors and awards on JISAO website
  - Presented UW service awards to JISAO employees
  - Two JISAO employees were nominated for the annual UW Distinguished Staff Award

- **Strengthening Communications**
  - Continued joint quarterly meetings with JISAO and NOAA employees
  - Held the annual all-staff meeting on UW campus that includes all JISAO employees at UW and those who work at NOAA facilities; NOAA scientists also attended
  - JISAO assistant director and the administrative specialist continued to hold weekly office hours at NOAA/PMEL, improving communications and collaboration between NOAA and UW personnel
  - Website evolution continued with improvements in information presented and user friendliness
  - Continued to work on developing Science in 180 video series
  - Participated on both the NOAA and UW CoEnv communications teams to regularly share information and best practices
  - Worked with NOAA Communications and others 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
  - Continued 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 served the College in various capacities in the past year
  - Several JISAO staff worked on university-wide initiatives and on committees addressing financial, human resources, communications and safety matters
Climate Research and Impacts
Life Cycle Assessments for the Improvement of Aquaculture Systems

PI

Joyce Cooper — UW Mechanical Engineering/Design for Environment Laboratory

Other UW Personnel

Alaric Babej, Steven Diesburg — UW Mechanical Engineering/Design for Environment Laboratory

NOAA Personnel

John Colt — Northwest Fisheries Science Center, National Marine Fisheries Service

Task III

NOAA Primary Contact

John Colt — Northwest Fisheries Science Center, National Marine Fisheries Service

NOAA Goal

Resilient Coastal Communities & Economies

Description

This study is for the purpose of improving aquaculture systems using Life Cycle Assessments (LCA) by quantifying and understanding the life cycle impacts of aquaculture systems under current and growing production rates; identifying opportunities to optimize aquaculture life cycles on the basis of regional resource availability and the potential to generate environmental, economic, and social value from aquaculture co-products; and contributing to the data available for the development of LCAs on aquaculture systems for NMFS research and beyond.

Objectives

1. Assess Alaskan Salmon Processing Waste Alternatives — Demonstrate the use of LCA in aquaculture for the development of process improvement and dissemination recommendations. The project will assess the “Montlake Processes” described by Nicklason, et al. (Nicklason 2010) as a case study. The Montlake Processes are a modification of current salmon processing intended to reduce life cycle impact through the use of a waste product in the place of virgin resources.


Accomplishments

1. Life cycle data were developed in support of objective 1, Assess Alaskan Salmon Processing Waste Alternatives, which both demonstrate the use of LCA in process comparison and provide useful results. The final results will provide insight pursuant to discharge regulations in Alaska and the evaluation of “Best Available Technologies” for salmon processing, noting that discharge results in large anoxia areas and serious impacts on benthic animals.

Offal grind and discharge, conventional offal processing, Montlake fresh offal processing, and Montlake stabilized offal processing 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). Figure 1 depicts the four offal management processes modeled.

Given the four offal processing data sets, preliminary LCAs have been developed. Supporting life cycle data prepared represent the life cycles of diesel production and use in Sitka; phosphoric acid, propionic acid, and sodium hydroxide production in the lower 48 and transport to and use in Sitka. Preliminary results representing the life cycle contributions to climate change, acidification, and eutrophication are depicted in Figures 1-2. As shown, alternatives to offal grind and ocean discharge are estimated to reduce contributions to all life cycle impacts assessed.
Finalization of the LCA results requires some additional data collection (some data gaps still exist in select datasets throughout the life cycles) and sensitivity analyses to test modeling assumptions.

2. Life cycle data were reviewed and a case study is in progress in support of objective 2, Assess Alternative Feeds for Aquaculture Systems, which identifies important data needs and modeling considerations for LCAs comparing aquaculture feeds.

A review of aquaculture feed LCAs revealed misinterpretations based on how growth rate is modeled. A case study is being developed to demonstrate the correct treatment of growth rate in LCAs comparing feeds (e.g., fish vs. plant-based feeds) coupled with a critique of existing studies within the context of minimizing life cycle environmental, economic, and social impacts.
Figure 2. Preliminary LCA results
Assessing the Atlantic Meridional Overturning Circulation (AMOC) in Climate Models

PI
Al Hermann — UW Joint Institute for the Study of Atmosphere & Ocean

Other UW Personnel
Wei Cheng, Dongxiao Zhang — UW Joint Institute for the Study of Atmosphere & Ocean

Non-UW/Non-NOAA Personnel
John Chiang — University of California, Berkley

Task III

NOAA Primary Contact
James Todd — NOAA Climate Program Office

NOAA Goal
Resilient Coastal Communities & Economies

Description
The purpose of this study is to assess the Atlantic Meridional Overturning Circulation (AMOC) in Coupled Model Intercomparison Project Phase 5 (CMIP5) models.

Objectives
1. Analyze the (AMOC) in CMIP5 models.
2. Attend workshops to present the results.
3. Submit a paper to the Journal of Climate.
4. Develop a new proposal based on this work.

Accomplishments
1. As part of the community effort to evaluate the new generation climate models used for the Intergovernmental Panel on Climate Change’s fifth assessment report (AR5), we examined the AMOC simulated by ten CMIP5 models for the historical (1850-2005) and future climate.
2. We found that the mean states of AMOC in CMIP5 historical simulations are closer to observations than those of the CMIP3. All CMIP5 models examined predict a weakening of the AMOC in the 21st century, but the rates of weakening differ between the models.
3. In CMIP5 historical simulations, the multi-model ensemble mean AMOC exhibits a multidecadal variability with a ~60-year periodicity. This variability is associated with external climate forcing.
Lightning Studies

PI
Robert H. Holzworth — UW Department of Earth & Space Sciences

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

Task III

NOAA Primary Contact
Steven J. Goodman — NOAA NASA Goddard – GOES-R Satellite

NOAA Goal
Climate Adaptation & Mitigation

Description

This is the second 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.

2. To use data assimilative techniques to add lightning location data in to the WRF model.

Objectives

1. Provide expertise and data on global lightning as part of the NOAA GOES-R prelaunch planning for the GLM (Global Lightning Mapper) instrument.

2. Develop and validate the technology to assimilate lightning into lightning forecasting models.

Accomplishments

1. Shared real time WWLLN lightning data with NOAA investigators in the effort to develop pre-launch validation criteria for NOAA/GOES-R/GLM mission.

2. Presented papers at scientific meetings, including one at the GOES-R Science Week in Huntsville, Alabama in September, 2012, and three at the AMS Annual Meeting in Austin, Texas January 5-10, 2013.

3. The lightning activity during periods of cold-air outbreaks was examined, using the World Wide Lightning Location Network (WWLLN) data for the 2009-2010 winter seasons over the Pacific Ocean from about 160E to the coast and north of 20N. The synoptic characteristics of events with significant lightning were compared to events without significant lightning activity. We found that cold air outbreaks that progressed sufficiently south of about 40°N tended to have much more lightning activity than events when the cold air remained north of about 40°N. The lightning activity was particularly pronounced when comma clouds developed and grew in spatial extent. This work, conducted over the last 1.5 years, culminated in the talk (above) at the AMS meeting by McMurdie.

4. Working with Clifford Mass, UW Atmospheric Sciences, the UW WWLLN data assimilation project, will be testing the assimilation of lightning with a series of experiments of increasing sophistication. All will examine the use of lightning to improve data assimilation using the Weather Research and Forecasting (WRF) model. A major question is the best approach to assimilating lightning: using a nudging technique that pushes the model state towards one consistent with lightning in a continuous progressive way, or making use of sophisticated ensemble-based data assimilation that applies realistic ensemble-based covariance structures (EnKF). An alternative is to use a hybrid EnKF/nudging approach. We also have a variety of ways of pushing the model towards a lightning-consistent state: using humidity profiles, heating profiles, or microphysical species profiles are possibilities.

The simplest approach is to nudge the model humidity fields towards a saturated state where lightning is occurring, and this was done first as a baseline to which we will compare other approaches. Specifically, WWLLN data has been assimilated into the WRF model using the WRF observation-nudging capability to modify vertical moisture profiles where lightning was detected. Assimilation experiments have been performed for short-range forecasts of several severe weather events over the continental United States. These experiments used initial and boundary conditions from the Global Forecast System (GFS), and were run at a resolution sufficient to resolve convection without the use of a cumulus parameterization scheme (3 km). The results of these experiments demonstrate the value of lightning data in improving the model representation of severe convection.

Figures 1a-c show the impact of this lightning assimilation technique on the forecast of a severe derecho event that occurred in June 2012. The model was initialized at 0600 UTC June 29, 2012, and run 24 hours through 0600 UTC June 30, 2012. Assimilation of lightning data occurred between 1300 UTC and 1600 UTC June 29, 2012. The model is configured with a grid spacing of 3 km, makes use of a 6-class microphysical scheme, and does not use a cumulus parameterization scheme.

Figure 1a shows the model-simulated radar reflectivity at 2200 UTC for the forecast with no lightning assimi-
lation, while Figure 1b shows the model-simulated radar reflectivity at the same time using the lightning data assimilation technique described above. Figure 1c shows the composite radar reflectivity over Ohio at 2200 UTC from the National Mosaic and QPE (NMQ) project. At six hours after the assimilation period, there are clear improvements to the location and appearance of the squall line using lightning data. Substantial improvements are found at other times as well, and with other events we have tested so far. During the next few months we will extend this collection of test cases, and move on to more sophisticated approaches (e.g., nudging heating rates and microphysical species-e.g., graupel/ice).
Figure 1c

**Figure 1:** Simulations without (a) and with (b) lightning data assimilation and a composite radar image at the same time (c).
A New Unified Sea Ice Thickness Climate Data Record

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

Other UW Personnel
Mark Wensnahan — UW Applied Physics Laboratory

Task III

NOAA Primary Contacts
William Murray — Climate Program Office, Climate Observations and Monitoring Program

NOAA Goal
Climate Adaptation & Mitigation

Description

This project has created a new unified sea ice thickness climate data record to better intercompare different ice thickness measurements, to better evaluate the changing state of the ice pack, and to better evaluate sea ice models. It will greatly improve the usefulness of these valuable data for the entire polar research community.

While ice extent is well-measured by satellite, monitoring ice thickness has been and remains a challenge. However, the amount of ice draft, airborne, and satellite data available in the last few years from both polar regions has increased markedly, providing a large and growing resource. Existing observations of ice thickness span a variety of methods, accuracies, and temporal and spatial scales, and are archived in a variety of different locations and in different formats. Each has its own strengths in terms of sampling or accuracy. The uncertainties are documented to various levels of detail for the different data sources, but the documentation in general is spread throughout the literature. A concerted effort to collect as many observations as possible in one place, with consistent formats and clear and abundant documentation, will allow the community to better utilize what is now a considerable body of observations. With a variety of data in one location and a common format, it will be much easier to compare the different sources with each other and with model output. The increased space and time coverage of a unified dataset will facilitate improved analyses of how and where sea-ice thickness has changed over the last three decades.

All of the data 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, airborne electromagnetic measurements, airborne laser altimeter measurements, coastal fast ice stations, and ICESat laser altimeter measurements. The mooring data come from 27 different locations and now represent 967 station-months. The submarine data come from 34 different cruises and represent 109,000 km of track. The Airborne EM data come from 15 different campaigns and represent 13,000 km of track. The IceBridge laser altimeter data come from four spring seasons and represent 27,000 km of track.

Objectives

In order to create this new data set we:

1. Acquire data from different data providers.
2. Decode all of the observations that often are in different formats even from the same data provider.
3. Perform quality control and remove duplicate data.
4. In some cases wrote point data files for the data base.
5. Average the data over one month time intervals for the moorings and cluster the data in 50 km regions for the submarines, airborne, and satellite measurements.
6. Determine 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 and IceBridge.
7. Determine the distributions of draft, freeboard, or thickness.
8. Write all of the data in standard formats.
9. Construct a metadata record. We have 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.
10. The objectives of the project are not only to provide the data to the wider community, but also to use the data set to evaluate model simulations and better determine the variability and trends in sea ice thickness and volume.

Accomplishments

1. The new data set, debuted at the Portland AGU Ocean Sciences Meeting in February of 2010, was highlighted in a poster at the Fall 2011 AGU Meeting, and was announced in an EOS article (Lindsay, 2010). The web site is psc.apl.washington.edu/sea_ice_cdr.
2. In our fourth and final year of this project we added more data to the sea ice thickness climate data record (the Sea Ice CDR), publicized the data set, and participated in three publications using the data.
3. This year we began to include the very extensive airborne ice thickness observations from NASA Operation IceBridge (OIB). We now have OIB data for 2009 through 2012. The entire data set currently contains 26,831 averaged observations representing over 561 million point measurements. The maps in the figure below show the locations of all of the non-satellite observations currently in the database.

4. Four significant publications were published 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). The Sea Ice CDR plays a prominent role 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 compared 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). Finally this year we published a paper on the seasonal prediction of sea ice extent using data from the Sea Ice CDR (Lindsay et al, 2012).

5. This year we will submit the data and metadata to the National Snow and Ice Data Center for archival. We have already been in contact with a representative of NSIDC to establish the best means to do this. The project will conclude in June this year, but we will continue to maintain the data set and add additional data as they become available. Hopefully we will be able to easily update the data set at NSIDC in years to come.

![Figure 1](image_url). Locations of all submarine, moored, airborne, and coastal observations in the Sea Ice CDR. The right panel shows the temporal distribution of the observations from 1970 to 2012. The ICESat observations (2005-2007) are not included.
Mountain Hydrometeorology for Weather and Climate Forecasting Applications

PI
Jessica Lundquist — UW Department of Civil & Environmental Engineering

Other UW Personnel
Mark Raleigh, Brian Henn, Nic Wayand, Shara Feld and Alex Fisher — UW Department of Civil & Environmental Engineering

NOAA Personnel
Marty Ralph, Mimi Hughes, Paul Neiman and Allen White — OAR/ESRL-Physical Sciences Division

Task III

NOAA Primary Contact
Marty Ralph — NOAA Boulder Office

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 the performance of a distributed hydrologic model?

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
1. We deployed and retrieved 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.

2. We evaluated low-cost humidity sensors and their utility as key hydrologic forcing for river prediction and then used them to assess best methods for estimating atmospheric moisture in complex terrain (Feld et al., submitted).

3. 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., in press).

4. We evaluated the utility of MODIS for detecting fractional snow covered area under different densities of forest cover (Raleigh et al. 2013). These three addressed the project objective of evaluating advanced observations.

5. 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 (Wayand et al., in press). This addressed the project objective of assessing the best forcings for river prediction.

Awards Received
Graduate student Raleigh was awarded the James E. Church Award for best student paper and presentation at the 2011 Western Snow Conference. Raleigh was also recently awarded a CH2MHill Engineers without Borders USA Scholarship.
International Arctic Buoy Programme (IABP) – Monitoring the Eurasian Basin of the Arctic Ocean

PI
Ignatius Rigor — Polar Science Center, Applied Physics Laboratory

Other UW Personnel
Mark Ortmeyer, Jim Johnson — Polar Science Center, Applied Physics Laboratory

NOAA Personnel
Pablo Clemente-Colón, Bethany McDonald — National Ice Center

Task III

NOAA Primary Contact
Janet Intrieri — NOAA Arctic Research Program

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.

Our ability to predict weather and sea ice conditions requires in situ observations of surface meteorology and sea ice motion. These observations are assimilated into Numerical Weather Prediction (NWP) models that are used to forecast weather on synoptic time scales, and into the many long-term atmospheric reanalyses (e.g. NCEP/NCAR Reanalysis) that are used for innumerable climate studies. The impact of these in situ observations can be seen in Fig. 1 where Inoue et al. (2009) shows that the standard deviation in gridded sea level pressure (SLP) reanalyses fields over the Arctic Ocean was over 2.6 hPa in areas where there were no buoy observations to constrain the reanalyses, and this uncertainty in the SLP fields spreads to cover the entire Arctic when the observations from buoys are removed from the reanalyses. The buoy observations also help constrain estimates of wind and heat.

Figure 1. Standard deviation (SD) of sea level pressure measurements from various atmospheric reanalyses. The SD is low in areas where there are buoy observations (left). The spread increases to cover the whole Arctic when the observations from the buoys are removed from the reanalyses (right). [Inoue et al. 2009]
Figure 3. Time series of temperature from the various sensors. This figures show that the measurements from NWS station at Barrow (grey), are as much as 20 degrees warmer than the measurements from the Barrow Climate Reference Network (CRN) station at Barrow (pink). The observations from the Portable Weather Station (PWS, blue), MetOcean SVP (green), and Pacific Gyre SVP (grey) are also shown.
nal cycle was due to solar heating of the hull. However, there were still alarming differences between all the measurements taken in the Barrow area. Comparison of the NWS station and the NOAA Climate Reference Network (CRN) station were different by as much as 20C. We expected some differences across the 10 km. domain, but not this large. Since the AON requires accurate measurements of pressure, temperature, and wind, we plan to perform a rigorous assessment of the sensors we use to measure these variables. We can perform an Arctic Observing eXperiment (AOX) in Spring 2013 using funds already provided to the USIABP.

b. We are planning to perform AOX at the DOE/ARM station near Barrow, where we will deploy a cluster of buoys and other instruments that we routinely use for the AON. This cluster of buoys has been collected using funds already provided to the USIABP, and contributions from our international partners in the IABP. In particular, Chris Marshall who heads the MetAreas program for Environment Canada, has agreed to provide a Minimet SVP, and ICEXAIR buoys to assess during AOX. Our overarching goal is to understand the performance and quantify the errors of our fundamental AON instruments. We will also collaborate with Dorothy Hall and Son Nghiem at NASA to compare the retrievals of temperature from satellites.

c. The PAWS and four SVP were deployed at the PSC/ APL/UWs North Pole Environment Observatory http://psc.apl.washington.edu/northpolg in April 2012, along with other buoys purchased by collaborators in the IABP to establish an “Automated Drifting Station (ADS)” which measures a myriad of physical parameters.

d. PI Ignatius Rigor deployed two AXIB buoys from the Arctic Domain Awareness flights in August and September 2012 (Fig. 4). These were deployed with AXCTD probes for the Seasonal Ice Zone Reconnaissance Surveys (SIZRS).

e. Co-PI Clemente-Colón, was onboard the Coast Guard ice breaker Healy overseeing the deployment of the IABP buoys during the summer of 2012. One AXIB was deployed in September 2012, however, the second AXIB failed predeployment tests and will be returned to the manufacturer for repair and deployed during the summer of 2013. We also collaborated with LCDR John Woods to develop the Naval Academy “IceGoat” buoy (Fig. 5) which was tested at Barrow and recently deployed by Clemente-Colón from the Healy. The remaining SVP buoys were deployed in the large expanses of open water of the Beaufort, Chukchi and Bering seas.

f. The data from all USIABP buoys are released to the research and operational communities in near real-time through the WMO/IOC Global Telecommunications System. As part of this grant we QA/QC the data from the Arctic buoys for the WMO/IOC GTS. All the meteorological, and oceanographic data posted on to the GTS by the IABP may be viewed at http://www.jccommops.org/dbcp/network/maps.html, and http://osmc.noaa.gov/Monitor/OSMC/OSMC.html.

g. Research quality fields of ice motion, sea level pressure (SLP) and surface air temperature are also analyzed and produced by the APL-UW; these fields can be obtained from the IABP web server at http://iabp.apl.washington.edu, and have been archived at various data centers.

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. There are currently 71 buoys reporting in the IABP array (Fig. 6). 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 and 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.

a. Press Interviews and Articles (reverse chronological order):


b. 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. 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 science interest (currently, it features an exhibit on ocean vents). The exhibit space comprises: 1) 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 work 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.

c. 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, and helped deploy buoys during the BROMEX experiment.

Figure 6. Map of buoys reporting from the Arctic Ocean on February 12, 2013. There are currently 71 buoys reporting in the IABP observing network.
Methods of Assessing Fisheries Vulnerability to Climate Change (International)

PI
Amy Snover — Climate Impacts Group

Other UW Personnel
Lara Whitely Binder — Climate Impacts Group

Task III

NOAA Primary Contact
Roger Griffis — Marine Ecosystems Division, NOAA Fisheries Service

NOAA Goal
Climate Adaptation & Mitigation

Description
This project has been partially on hold, pending sponsor decision on whether additional funding will be made available to implement a workshop on vulnerability assessment methods. In the interim, we have performed the groundwork for a literature review, identifying and characterizing key publications describing methods for rapid assessment of fisheries vulnerability to climate change. We are convening relevant experts for a forum on “Climate Ready Marine Resource Management,” April 3-4, 2013, at the National Adaptation Forum in Denver, to present and discuss methods and approaches, to identify collaborative opportunities with broader international efforts to assess methods, and to develop guidance for analyzing fisheries impacts/vulnerability to climate change.

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
1. Foundation laid for literature review – identified and characterized key publications describing methods for rapid assessment of fisheries vulnerability to climate change.
2. Work on objectives 2 and 3 has not begun, and is contingent on receipt of additional funding.
Preparing for Climate Change: A Workshop on Assessing and Planning for Climate Change Impacts on West Coast Fisheries

PI
Amy Snover — UW Climate Impacts Group

Other UW Personnel
Lara Whitely Binder — Climate Impacts Group

NOAA Personnel
Penny Dalton — Washington Sea Grant; Jon Stein, 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

Task III

NOAA Primary Contact
Penny Dalton — Washington Sea Grant

NOAA Goals
Climate Adaptation & Mitigation
Resilient Coastal Communities & Economies

Description

The Climate Impacts Group (CIG) hosted a workshop in May 2011 to assess the vulnerability of three West Coast fisheries to climate change in partnership with West Coast 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 Sectoral Applications Research Program (SARP) 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

1. To increase understanding of the vulnerability of fisheries to climate change and implications for marine users and managers.
2. To articulate 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. To identify research and information gaps.
4. To provide an opportunity for discussion among, and for collaboration between, participants coming from a range of backgrounds in fisheries, including research, management, and commercial fishing.

Accomplishments

1. 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.
2. 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.
3. Research and information gaps were identified, and have been described in the final draft white papers.
4. 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 participants in identifying and discussing opportunities for collaboration.

![Final Participant Breakdown by Fishery Breakout Group](image1)

![Final Participant Breakdown by Professional Category](image2)

*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.
California NIDIS Pilot

Objectives
1. Design California NIDIS pilot and implementation strategy.
2. Evaluate California NIDIS pilot and process.
3. Evaluate drought indicators, triggers, and early warning system.

Accomplishments
1. Design of California NIDIS Pilot and Implementation Strategy
   a. Assisted in development of process for elicitation of potential NIDIS Pilot projects. Four Pilot Activities were selected through group processes and criteria developed during planning meetings.
   b. Communicated with personnel in other NIDIS Pilots and the NIDIS Program Office to obtain insights, experiences, and lessons. Coordinated with other Pilot Activity leaders to determine objectives and processes for the Pilot to ensure that the four Pilot Activities will generate synergies and opportunities for cross-learning, with lessons and resources that can be transferred to other regions and states.
   c. Provided advice and coordination for the meetings and the selection process. Designed roundtable discussions, including questions to be asked, format for eliciting input, intended outcomes from meetings, and follow-up procedures. Identified participants to be included at meetings and in NIDIS Pilot activities, and communicated with participants. More than one hundred stakeholders have been involved in the California NIDIS Pilot, with about half in the Southern California Pilot Activity.
   d. Assisted in development of criteria for NIDIS Pilot and Pilot Activities. Synthesized stakeholder input and refined list of criteria. Presented revised list of criteria to stakeholders, and incorporated additional feedback.
   e. Identified critical drought issues for focus of NIDIS Pilot Activities. Identified stakeholders to be involved, along with goals, processes, and expected outcomes. Together with Pilot Activity leaders, determined objectives for Pilot, and ways to develop results and resources that would be useful to the rest of the country.

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

Task III

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

NOAA Goal
Climate Adaptation & Mitigation

Description
My work with the California NIDIS Pilot spans the design, development, implementation, and evaluation of drought early information resources and strategies, working closely with both the producers and users of drought information, including agencies, industries, institutions, tribes, and other major stakeholders. The Pilot is implemented through four Pilot Activities, each of which explore important and distinctive phenomena of drought: (1) Southern California, complexities of urban droughts in a well-plumbed system, heavily reliant on imported water; (2) Russian River, hydrologic extremes with droughts draining reservoirs and precipitation events filling reservoirs; (3) Central Valley, remote sensing to assess the extent of fallowed land; and (4) Klamath Basin, integrated hydroclimate information system in a complex water environment. To date, the California Pilot has held eight meetings across the state, engaged more than 100 stakeholders, and identified drought information uses, needs, partners, and concrete ways that the NIDIS could help decision-makers to reduce drought impacts. Results from the California Pilot will include the following: early warning information capabilities for a range of decisions, user communities, temporal scales and spatial scales; real-time on-the-ground use of NIDIS information, demonstrating ways that early warning capabilities can reduce drought costs and impacts; and products, resources, and lessons that can be transferred to the rest of nation. The results of my work and the overall project, including summaries from stakeholder meetings and the four Pilot Activities, are detailed on the California NIDIS Pilot website: http://www.drought.gov/drought/regional-programs/california/california-home.
2. Evaluation of California NIDIS Pilot and Process
   a. Conducted both a Pilot evaluation and process evaluation. The Pilot evaluation focused on the California NIDIS Pilot, its progress, and its results and the Process evaluation focused on the overall process and individual steps for the design, selection, and implementation of the NIDIS Pilot.
   b. Developed protocols to document activities in each stage of implementation. Developed evaluation criteria, metrics, and methods for data collection and analysis. Currently collecting data on the use and potential value of NIDIS Pilot Activities and information. A primary finding is that stakeholders can identify specific and needed applications of NIDIS drought early warning information, and the economic and societal benefits of using that information.
   c. Performed first-phase evaluation of NIDIS Pilot. Dimensions include the following: What would make a successful pilot? How do the Pilot Activities each contribute to that success? How would NIDIS drought information be used and integrated into decision-making? What are the net benefits of the use of that information to reduce drought impacts and costs? What can NIDIS provide decision-makers that wouldn't otherwise be possible? What resources and lessons can be transferred from California to the rest of the county? Stakeholders indicated that NIDIS offers a valuable and needed resource that doesn't otherwise exist, and it could provide a centralized, authoritative, integrated, and usable source of drought information.
   d. Performed first-phase evaluation of NIDIS Process. Dimensions included the following: What is a successful process for the NIDIS Pilot Activities? What are criteria for evaluation? Were the processes fair, efficient, participatory, and supportive? What do stakeholders think? What recommendations can we provide for future NIDIS Pilot efforts? Stakeholders indicated that the NIDIS Pilot Activity processes and meetings have been inclusive and valuable, and cite specific benefits of the meetings and the overall NIDIS process and goals.

3. Evaluation of Drought Indicators, Triggers, and Early Warning System
   a. Compiled and compared the range of drought indicators used by decision-makers (e.g., water managers) in each of the pilots, and links with drought decisions. Nearly half of the agencies rely on the U.S. Drought Monitor for assessing and triggering drought, even though they note its limitations for regional and local drought assessment.
   b. Developed criteria for drought indicator evaluation. For instance, what is a “good” drought indicator and early warning system? In the absence of a gold standard for drought, design ways to assess indicator performance. For instance, one set of criteria relate to an indicator providing early warning, without false alarm or false assurance.
   c. Determined possible indicators for integrated NIDIS drought information resources, including indicators for varying types of decisions and early warning time frames, drought supplies, drought demands, temporal and spatial scales, historic analogs, climatologies, and formats. Stakeholders indicated the value of a percentile-based system, which can be used to compare different indicators and varying temporal and spatial scales, and for messaging to the public in a way that is understandable and useful.

Meetings and Presentations
   e. U.C. Irvine, Presentation of California NIDIS Pilot, Irvine, CA, June 1, 2012.
   g. Russian River Pilot Activity, planning meeting, Santa Rosa, CA, March 14, 2012.
   i. Southern California Pilot Activity, all-participant meeting, San Diego, CA, January 20, 2012.
Arctic Climate Change Program

PI
Muyin Wang — UW Joint Institute for the Study of Atmosphere & Ocean

Other UW Personnel
Nicholas A. Bond, Kevin Wood — UW Joint Institute for the Study of Atmosphere & Ocean

NOAA Personnel
Jim Overland, Phyllis Stabeno, Sigrid Salo, Nancy Soreide — Pacific Marine Environmental Laboratory

Task II

NOAA Primary Contacts
John Calder — Arctic Research Office, (retired Dec, 2012)
Janet M. Intrieri — Earth System Research Laboratory

NOAA Goal
Climate Adaptation & Mitigation

Description
The Arctic Climate Change project has been part of the EcoFOCI group for the past decade, and will continue to maintain close ties with ecosystem research. Our main focus of climate research is in the Arctic region, including sub-Arctic seas, such as the Chukchi Sea, and the Bering Sea.

Objectives

1. Build and maintain a suite of Arctic climate observing networks (ocean, sea ice, and atmosphere) in association with national and international partners.
   a. JISAO scientist, Kevin Wood, participated in the 2012 RUSALCA cruise to the Bering Strait to service the mooring, and helped plan the recovery of three moorings.
   b. Using balloon sounds and wave-glider, a major project entitled "Linkage of Arctic Sea Ice Loss, Increased Ocean Heat Storage, and Regional and Far-Field Winds" began in late 2012 with the support of the Office of Naval Research led by Nicholas Bond.

2. Provide data and analysis to climate assessment activities, and the international science community.
   a. JISAO scientists take an active role in studies of Arctic climate and climate change, based on their collected data from stations and climate models. The research results have been published in peer-referred journals, as well as presented in meetings and workshops (Wang, Wood, Bond).

3. Support and enhance NOAA’s mission in climate variability and ecosystem impacts in the Pacific sector of the Arctic.
   a. JISAO scientists are involved in an effort to apply simulations of future climate (IPCC AR4 and AR5) to issues related to Arctic and North Pacific marine ecosystems. The output from these models is being used to force regional ocean models of the North Pacific Ocean and Bering Sea, and to make projections based on empirical methods. This is a collaborative work with scientists from EcoFOCI groups (Wang, Cheng, and Hermann).

4. Participate in public education and outreach, and making data and analysis results available to fishery management councils and other resource managers.
   a. JISAO scientist Muyin Wang, is responsible for updating the Bering Climate Website, which is a collection of physical and biological variables for the Bering Sea studies. This web site has been a popular source for ecosystem study communities.
Climate Research and Impacts

Accomplishments

1. Arctic Sea Ice – JISAO scientist, Wang, in collaboration with James 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) a new record low sea ice extent at the end of the melt season in 2012, which for the first time in satellite era reached below 4 million km², (2) all-time minimum sea ice coverage for the months of October and November, 2012, and (3) record warm temperatures and major surface melt in Greenland glacier during 2012. 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 scientist Tracey Nakamura towards the development and maintenance of the web interface.

2. CMIP5 model assessment and sea ice projection (led by Wang) – A comprehensive assessment of the CMIP5 models resulted in several publications by Wang and Overland. They updated their analysis based on CMIP5 models, and have published three related journal publications.

3. Arctic observation using balloon sounds and wave-glider (led by Bond) – A major project entitled “Linkage of Arctic Sea Ice Loss, Increased Ocean Heat Storage, and Regional and Far-Field Winds” began in late 2012 with the support of the ONR. This project consists of both a retrospective analysis of the relationships between sea ice distributions, and regional atmospheric circulation patterns and field work from ships and research aircraft. The research carried out in the former category showed that year-to-year variations in sea ice are strongly related to concomitant variations in the Northern Annular Mode (NAM) atmospheric pattern, with the recently identified Arctic Dipole (AD) pattern of secondary significance. The field phase of this project will commence in late summer 2013. An atmospheric profiling system was purchased for this purpose, and will be used to make weather balloon soundings and cloud measurements, along with simultaneous ocean profile measurements, in the marginal ice zone of the Beaufort Sea. Under the auspices of this project, Wood led the preparation of a journal article ( provisionally accepted by Polar Research) on the atmospheric and upper ocean anomalies that have occurred north of Alaska during recent summers. This work took advantage of new technology, specifically a remotely-operated waveglider, to map out the volume of a plume of warm, fresh water in the coastal zone that is crucial to the seasonal melting of sea ice.

4. Old Weather/Arctic Rediscovery project (led by Wood) – Established an intern program at the National Archives and at the New Bedford Whaling Museum to help with the organization and imaging of ship log-books that contain huge quantities of new-to-science Arctic climate and environmental data. A beta version of Old Weather – Arctic web site was designed and implemented for user interface (UI), and was successfully tested until the Old Weather – Arctic was ready for launch (www.oldweather.org). A press event about “Old Weather – Arctic” was launched at the National Archives hosted by the NOAA Administrator and the Archivist of the United States (see blog.oldweather.org). Another project website (www.pmel.noaa.gov/arctic/rediscover) is under design and testing. This was done with funding support from a successful proposal to NPRB, which allows us to continue this project through 2013. Meanwhile, Wood submitted a third proposal for an additional extension/expansion.

5. K-12 Events – Wood led the Arctic Rediscovery project, in which students from Commack High School in New York designed a replica thermometer screen based on one used to measure air temperature during the stay of the HMS Plover at Point Barrow, Alaska from 1852 to 1854. With the help of NOAA’s Global Monitoring Division and some volunteer technical support, the replica thermometer screen was equipped with a modern platinum resistance thermometer and installed at the Barrow Observatory, where parallel data have been collected. The students will use this data to estimate the bias associated with the replica thermometer screen design and evaluate how historical and modern measurements may be compared.
RUSALCA: The Pacific Gateway to the Arctic – Quantifying and Understanding Bering Strait Oceanic Fluxes

PIs
Rebecca Woodgate, Ron Lindsay — UW Applied Physics Laboratory

Other UW Personnel
James Johnson — UW Applied Physics Laboratory
Cynthia Travers, Cecilia Peralta Ferriz — UW School of Oceanography

Task III

NOAA Primary Contacts
John Calder, Kathy Crane — NOAA Arctic Research Program

NOAA Goals
Climate Adaptation & Mitigation
Healthy Oceans

Description

The Bering Strait, a narrow (~ 85 km wide), shallow (~50 m deep) strait at the northern end of the Pacific, is the only ocean gateway between the Pacific and the Arctic. Although the flow through the strait is small in volume (~0.8 Sv northward in the annual mean), due to its remarkable properties (high heat and freshwater content, low density, high nutrients) it has a startling strong influence, not only on the Chukchi Sea and the Arctic Ocean, but also on the North Atlantic overturning circulation and possibly world climate. Draining the Bering Sea shelf to the south, the Bering Strait throughflow is an integrated measure of Bering Sea change. The comparatively warm, fresh throughflow contributes ~ 1/3rd of the freshwater input and possibly ~ 1/5th of the oceanic heat input to the Arctic, and provides the most nutrient-rich waters entering the Arctic Ocean. Furthermore, the low density of these waters keeps them high in the Arctic water column, giving them a key role in upper ocean ecosystems and physical processes including ice-ocean interactions.

A joint NSF-NOAA effort has supported observational work in the strait region since 2007, with funding for the deployment of moorings from summer 2009 to 2010, the ship-time and clearance support for field work and work in Russian waters in all years, and data quality control, archiving and analysis, especially as regards quantification of the oceanic fluxes of volume, heat and freshwater. For the period from April 1, 2012 to March 31, 2013, this work has included working for Russian clearances for an 11-day cruise on the research vessel Professor Khromov in July 2013 (which serviced NSF funded moorings in US waters), and data analysis efforts.

Objectives

1. To measure the velocities and water properties of the Bering Strait throughflow from 2009-2010, in conjunction with the Arctic Observing Network vision of basin-scale Arctic system observations, and to quantify (with uncertainty estimates) oceanic fluxes of volume, freshwater, heat, and nutrients through the strait.
2. To design an optimum monitoring system for oceanic fluxes through the Bering Strait.
3. To place recent records in a multi-year context (from 1990 through to 2013).

Accomplishments

1. The proposed mooring deployments in 2009 and recoveries in 2010 were successfully accomplished. The data are quality controlled and available via our website http://psc.apl.washington.edu/BeringStrait.html. Cruise results are recorded in our cruise reports, e.g., (Woodgate, 2009; Woodgate and RUSALCA12ScienceTeam, 2012; Woodgate et al., 2010b), also available at the website.
2. Data analysis has resulted in quantification of recent changes in the strait (Woodgate et al., 2010a), including measurement of a ~ 50% increase in the Bering Strait fluxes from 2001 to present (Woodgate et al., 2012). The full abstract of this most recent 2012 Geophysical Research Letters paper is: “Mooring data indicate the Bering Strait throughflow increases ~50% from 2001 (~0.7Sv) to 2011 (~1.1Sv), driving heat and freshwater flux increases. Increase in the Pacific-Arctic pressure-head explains two-thirds of the change, the rest being attributable to weaker local winds. The 2011 heat flux (~5x10^20 J) approaches the previous record high (2007) due to transport increases and warmer lower layer (LL) temperatures, despite surface temperature (SST) cooling. In the last decade, warmer LL waters arrive earlier (1.6±1.1 days/yr), though winds and SST are typical for recent decades. Maximum summer salinities, likely set in the Bering Sea, remain remarkably constant (~33.1 psu) over the decade, elucidating the stable salinity of the western Arctic cold halocline. Despite this, freshwater flux variability (strongly driven by transport)
exceeds variability in other Arctic freshwater sources. Remote data (winds, SST) prove insufficient for quantifying variability, indicating interannual change can still only be assessed by \textit{in situ} year-round measurements.”

3. Results from the work have also appeared as part of other journal articles and are in demand by various observational and modeling studies (Beszczynska-Möller et al., 2011; Clement Kinney et al., in press; Zhang et al., 2012).

4. Data analysis has resulted in a monitoring system design for the strait, which consists of three moorings in US waters – one in the center of the US channel, one in the Alaskan Coastal Current and one at a mid-strait site just north of these straits. These sites allow a quantification of the oceanic fluxes of volume, heat, and freshwater through the strait.

5. Russian permissions were obtained for working in the strait for all years except for 2011. In 2012, two cruises took place – one entirely in US waters, one (under separate funding and the oversight of Kathy Crane) entirely in Russian waters.

6. While the project has been very successful in UW-Russian mooring operations and data analysis, there have been some complications with access to Russian waters during the field work. Specifically, in 2011, no field work was accomplished in Russian waters, and three moorings deployed in Russian waters in 2010 had to be left in the water for an extra year. In 2012, again the main mooring cruise took place only in US waters, but the three moorings in Russian waters were recovered on a separate field work effort.

\textbf{Reproduced from Woodgate et al, 2012:}

\textit{Figure 1.} (a) A Bering Strait summer satellite (MODIS) Sea Surface Temperature (SST) image marking moorings (black dots) and NCEP wind points (X) [from Woodgate et al., 2010].
(b-h) Bering Strait annual mean (AM) time-series from 1991 – 2011 of:

b) transport calculated from A3 (blue) or A2 (cyan), adjusted for changes in instrument depth (black) with error bars (dashed) calculated from variability;

c) near-bottom temperatures from A3 (blue) and A4 (magenta-dashed), and the NOAA SST product (red diamonds);

d) salinities from A3 (blue) and A4 (magenta);

e) heat fluxes: blue - from A3 only; red – including ACC correction (1×10^20 J) and contributions from surface layer of 10m (lower bound) or 20m (upper bound) at SST, with black x indicate heat added from 20m surface layer;

f) freshwater fluxes: blue – from A3 only; red – including 800-1000km^3 (lower and upper bounds) correction for stratification and ACC;

g) transport attributable to NCEP wind (heading 330º, i.e., northwestward) at each of 4 points (coloured X in (a)) and the average thereof (black); and

h) transport attributable to the pressure-head term from the annual (black) or weekly (green) fits.

Uncertainties are order 10-20%. Red lines on (g) and (h) indicate best fit for 2001-2011 (trends=m(er), in Sv/yr, er being the 95% confidence limit from a 1-sided Student’s t-test).
Synthesis of Arctic Research (SOAR) and Applied Physics Laboratory Collaborative Projects

PI
Rebecca Woodgate — UW Applied Physics Laboratory

Other UW Personnel
Bonnie Light, Kristin Laidre, Kate Stafford, Kay Runciman — UW Applied Physics Laboratory

NOAA Personnel
James Overland — Pacific Marine Environmental Laboratory
Catherine Berchok, Megan Ferguson — National Marine Fisheries Service

Non-NOAA and Non-UW Personnel
Robert Suydam, Craig George — North Slope Borough
Matt Druckenmiller — National Snow & Ice Data Center
Chris Clark — Cornell University
David Hannay — JASCO Research
Susannah Blackwell — Greeneridge Associates
Brenda Norcross — University of Alaska, Fairbanks
John Citta — Alaska Department of Fish & Game
Janet Clarke — Science Applications International Corporation

Task III

NOAA Primary Contacts
Phyllis Stabeno — Pacific Marine Environmental Laboratory
Sue Moore — NOAA Science & Technology

NOAA Goals
Climate Adaptation & Mitigation
Healthy Oceans

Description

The Synthesis of Arctic Research (SOAR) aims to bring together a multidisciplinary group of Arctic scientists and Alaskan coastal community representatives to explore and integrate information from completed and ongoing marine research in the Pacific Arctic Region. The goal of the SOAR project is to increase scientific understanding of the relationships among oceanographic conditions, benthic organisms, lower trophic pelagic species (forage fish and zoo-plankton), and higher trophic species (seabirds and marine mammals) in the Pacific Arctic, with particular emphasis on the Chukchi Sea Lease Sale Areas. The SOAR project is supported by the Bureau of Ocean Energy Management and NOAA, and led by Dr. Sue Moore, Dr. Phyllis Stabeno, and an 11-member Science Steering Committee.

The major deliverable of SOAR will be a collection of peer-reviewed scientific publications in a special issue or theme section of an appropriate journal. Science themes and questions appropriate for synthesis were developed at a science workshop held in Anchorage, Alaska from March 14-16, 2012. The potential impact of the effects of annual variability of sea ice in the Pacific Arctic and the associated variability in primary production was one of the questions discussed under the theme of Responses to Step Change in Physical Drivers of the Marine Ecosystem. The work proposed here will result in manuscripts on the topic of sea ice variability and primary production in a peer-reviewed journal. APL scientists contribute to various SOAR projects, as outlined below.

Objectives

1. Update estimates of shortwave solar flux into the Arctic from 2008 to present. Rebecca Woodgate and Bonnie Light are part of the SOAR project “Causes of Drastic Climate Change for the Pacific Arctic,” and with the support of scientific programmer Kay Runciman, will use remotely sensed sea ice concentration, adjusted shortwave down welling fluxes, and an albedo model for sea ice to estimate total absorbed shortwave fluxes in the Arctic Ocean.

2. Collaborate with marine mammal expert Kristin Laidre in body condition analyses, ecological interactions of Arctic marine mammals with sea ice habitat, and in general on whale ecology in the Arctic. She is working with other SOAR investigators to help develop and interpret quantitative models of bowhead whale body condition relative to changes in remotely sensed sea ice in Alaska.
3. Collaborate on the sound environments bowhead whales encounter in the Chukchi and Beaufort Seas throughout the year. Kate Stafford is working on this objective, contributing relevant data and providing scientific expertise pursuant to the development of a collaborative paper suitable for a peer-reviewed publication on bowhead whale call detections and the overall sound environment of the Chukchi and Beaufort seas for the period September 2009-2010. In support of co-authorship on the paper, this effort will include participation in a 3-day working meeting convened by the Bioacoustics Research Program at Cornell University in Ithaca NY. Support to attend the BRP meeting will be provided via Invitational Travel from NOAA’s PMEL.

4. Collaborate with investigators to address the relationship between beluga whales, Arctic cod, and oceanographic conditions in Barrow Canyon and at the shelf break of the western Beaufort Sea. Within this project, Stafford is helping develop a better understanding of how and why beluga whales use Barrow Canyon and the shelf break of the western Beaufort Sea by combining varied data sets including aerial surveys, satellite tracking, and dive data from tagged belugas of the eastern Chukchi Sea, fish trawls, passive acoustic monitoring, and oceanographic conditions.

Accomplishments

1. Solar shortwave flux to ocean – the data sets for this work have been collated, and the analysis is in progress. We are using the ERA-interim product for short wave flux and, to allow for comparison to older work, we must also quantify differences between this short wave product and the older ERA-40 product. When complete, the shortwave flux analysis will be used for a manuscript being led by James Overland at NOAA.

2. The data sets on bowhead whale body condition from the harvest in Barrow have been compiled, and an analysis has been started. The body condition data have been coded for accuracy and error checked and compiled into two condition models: a girth model and a volume model. Seasonal and interannual trends in bowhead whale body condition have been estimated with multiple regression models and data on timing of sea ice breakup and wind-driven upwelling are being compiled and added to the models as covariates. A draft manuscript is in progress.

3. A 3-day workshop was held at the Cornell Laboratory of Ornithology in Ithaca, New York, from November 6-8, 2012 with a follow-up meeting in Anchorage, Alaska on January 22, 2013. Prior to the November workshop, raw acoustic data from three APL instruments were sent to Cornell to be renamed and resampled so that ambient noise levels might be derived from those data. Data from all collaborators was collated and ambient noise levels extracted. For the follow-up meeting in Anchorage, all participants provided bowhead whale call detections to examine the seasonal movements of animals from the Bering, Chukchi, and Beaufort Seas. A draft manuscript is in progress.

4. The beluga whale project collaborators met in Anchorage in November 2012 to determine which datasets were available for this project and which geographic region to concentrate on. At present, data from aerial surveys, satellite telemetry, fish trawls and passive acoustic monitoring (PAM) are being contributed. The PAM data for beluga whale detections are processed and ready to contribute to a manuscript. This manuscript is being led by Robert Suydam of the North Slope Borough, Alaska.
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, UW School of Oceanography

Other UW Personnel
Jessica Maves, Caitlin Olive, Tina Houck, Troy Albom, Ryan Long, Lauren Reetz — Undergraduate Researchers

NOAA Personnel
Courtney Arthur, Marine Debris Program

Non-UW/Non-NOAA Personnel
Abigail Ahlert, JISAO Summer Intern, University of Maryland, Atmosphere and Ocean Sciences

NOAA Primary Contact
Courtney Arthur, Marine Debris Program

NOAA Goal
Resilient Coastal Communities & Economies

Description
This project continues exploring microplastic debris in the ocean, originally funded by NOAA’s Marine Debris Program in 2008. During this year, we have participated in many outreach programs; continued microplastic collection from surface waters, bed sediments, and beach material; finalized the interlab comparison project; applied FTIR method to SEA samples; and developed flow cytometry analysis for nanoplastics.

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

Accomplishments
1. Continued microplastic collection
   a. Over 300 surface water samples were collected throughout the Puget Sound by the University of Washington Tacoma, Service Education Adventure, Sound Experience, and Bellarmine Preparatory School under the supervision of UWT researchers.
   b. All samples were processed at the Center for Urban Waters laboratory.
   c. The mass of microplastics in field samples collected are related to the total dry mass of material collected.
   d. Bay location did not seem to have an effect on the amount of microplastics found, whether near an urban environment or remote. Tides and currents seem to be the drivers of concentration, and will be explored in the future using Puget Sound flow models.
   e. Methodical sample collection and laboratory analyses have ended, with continued sampling from environmental education partners into the future.
   f. Initial work of concentrating bed sediments showed the presence of microplastics in all samples analyzed. Five locations in Commencement Bay near Tacoma, WA were sampled and processed in the lab using physical heavy liquid separation (see Figure 1), allowing for the microplastics to float to the surface (see Figure 2). More bed sediments will be analyzed in the future and correlated with grain-size and basin locations.
Environmental Chemistry

A time series study of beach material was completed on Alki Beach in West Seattle, WA. Field methods developed by the Port Townsend Marine Science Center, and laboratory analyses by the Center for Urban Waters were utilized. Results of the time series showed a lot of variation of plastic concentration, plastic type, and distribution along a parallel transect of the beach face.

2. Interlab comparison project
   a. The methods manual is receiving final edits from the original authors, and will be available by June 2013.
   b. Known samples have been collected and prepared for shipment to participating labs.
   c. Labs will be given an allocated time to process the samples and report results to the Center for Urban Waters.
   d. All information will be processed and utilized to test the methods developed at the Center for Urban Waters.

3. FTIR method application
   a. During the summer of 2012, an undergraduate student from the JISAO internship program applied the FTIR method developed during last year.
   b. Samples collected from Sea Education Adventure, Woods Hole, MA were analyzed for type.
   c. A catalog of known plastic types was created to assist with flow cytometer work on nanoplastic debris.

4. Flow cytometer analysis
   a. Known plastic type and quantity were floated in saltwater using sonication. These plastics were dyed using Oil Red O stain for detection with the cytometer.
   b. Results showed detection of plastics in personal care products as compared to a controlled using forward scatter versus fluorescence.
   c. Future work will include applying this method to untreated and treated wastewater effluent.
5. Outreach programs
   a. Collected beach microplastic debris with 150+ STEM students from Saggiole Middle School's Math and Science Academy, Federal Way, WA.
   b. Taught microplastic concentration methods to researchers from Central Washington University, Edmonds, WA and Bellarmine Preparatory School, Tacoma, WA.
   c. Presented three microplastic projects at the University of Washington's Undergraduate Research Symposium, Seattle, WA.
   e. Demonstrated laboratory techniques for 60 Math, Science and Leadership Students (MSL), University of Washington Tacoma, WA.
   f. Taught sampling techniques to 35 girls on Sound Experience's Women in Science Cruise, 'Girls at the Helm' San Juan, WA.
   g. Trained Ben & Jerry's employees and Adventuress Crew on sampling microplastics in surface water, Center for Urban Waters, Tacoma, WA.
   h. Led discussion groups at the First Creek Middle School Environmental Science Summit, Tacoma, WA.
   i. Taught ocean debris course to 50 UWT freshmen including: exploring the problem, field sampling, and laboratory analysis, University of Washington Tacoma, WA.
Atmospheric Chemistry - Aerosol Program

PI
David Covert — UW Department of Atmospheric Sciences

Other UW Personnel
Drew Hamilton, James Johnson — UW Joint Institute for the Study of Atmosphere & Ocean

NOAA Personnel
Tim Bates — Pacific Marine Environmental Laboratory
Patricia Quinn, Derek Coffman, Kristen Schulz — Pacific Marine Environmental Laboratory

Task II

NOAA Primary 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.

Objective
To assess the regional climate and air quality impacts of atmospheric aerosol particles through measurements of their physical chemical, radiative, and cloud nucleating properties.

Accomplishments
1. We continued analysis of data from the May – June 2010 Climate and Air Quality CalNex cruise off the coast of California (see highlights below).
2. The Western Atlantic Climate Study (WACS), an ocean-derived aerosol cruise on R/V Brown from Boston to Bermuda in August 2012, was conducted. The purpose of this study was to measure the flux of ocean-derived aerosol to the atmosphere over biologically productive and non-productive waters. The data will be used to improve parameterizations of ocean-derived aerosols in climate models.
3. We conducted aerosol and snow measurements in Vernal, Utah as part of the Uintah Basin Winter Ozone Study (February 2013). 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.
4. We led an assessment on the impact of black carbon on Arctic climate (see highlights below).
5. We continued measurements of aerosol chemical composition at Barrow, AK.

Highlights
1. Ocean-Derived Aerosols: Reliable 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. In Bates et al. (2012), we reported measurements of particles directly emitted from the ocean using a newly developed in-situ particle generator (Sea Sweep). The Sea Sweep was deployed alongside R/V 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 to measure the physical, chemical, optical, and cloud nucleating properties of nascent particles.

Payoff: The sources of CCN over the ocean must be accurately parameterized in global climate models. Although freshly emitted sea spray aerosols are enriched in organic matter, results from the Sea Sweep measurements show that these particles behave hygroscopically like an internal mixture of sea salt with a small organic component. It was also found that the degree of organic enrichment and CCN activity of the sea spray aerosols are not affected by local chlorophyll concentrations. These results will improve source function parameterizations of sea spray aerosol.
2. The Impact of Black Carbon (BC) on Arctic Climate: The AMAP Short-Lived Climate Forcers Expert Group, co-chaired by Patricia Quinn, completed an assessment of the impact of black carbon on Arctic climate (Quinn et al., 2011). Main conclusions of the assessment included:

- Source regions and sources types that dominate the burden of BC in the Arctic are fairly well understood.
- Forest and Grassland Fire emissions dominate the contribution of Canada and Russia to the burden of BC in the Arctic atmosphere. Agricultural fires can also make a significant contribution if they become Forest/Grass fires.
- Diesel combustion emissions dominate the contribution of U.S. and Nordic countries to the burden of BC in the Arctic atmosphere.

Domestic (e.g., wood stove) sources within the Nordic countries and Russia make a substantial contribution to the burden of BC in the Arctic atmosphere. With further implementation of regulatory measures on transport emissions, the relative importance of domestic sources is likely to increase.

- Emissions in close proximity to or within the Arctic are more likely to be deposited to snow and ice surfaces and cause surface warming than emissions from further south.
- Extra-polar forcing likely results in a poleward transfer of heat energy, indicating the need to manage global emissions of BC and greenhouse gases.

Payoff: This assessment provides scientific advice that can be used by the Arctic Council to establish mitigation strategies for reducing the warming in the Arctic.
The International Global Atmospheric Chemistry (IGAC) Core Project Office

PI
Sarah J. Doherty — UW Joint Institute for the Study of Atmosphere & Ocean

Other UW Personnel
Megan L. Melamed, Steven Brey, June Ladenburger — UW Joint Institute for the Study of Atmosphere & Ocean

Task III

NOAA Primary Contact
Timothy Bates — Pacific Marine Environmental Laboratory

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.

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.

Objectives

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.

Accomplishments

Progress continues on current IGAC activities, including:

1. Atmospheric Chemistry & Climate (concluded 2012)
   a. AC&C sought to improve the representation of chemistry/climate interactions in models.

2. AC&C Model Intercomparison Project (ACCMIP)
   a. ACCMIP is providing extensive coordinated model simulations, diagnostics, and evaluations of the effect of short-lived species on climate, in coordination with the climate model intercomparison effort (CMIP5).

3. Atmospheric Chemistry & Health (AC&H)
   a. This initiative brings together the atmospheric chemistry and health communities to explore the various and multi-dimensional interactions between atmospheric chemistry and human health, with IGAC leading the atmospheric chemistry research needs.
4. Aerosols, Clouds, Precipitation, & Climate (ACPC)
   a. ACPC was established in 2007 to obtain a quantita-
      tive understanding of the interactions between aero-
      sol, clouds, and precipitation and their role in the
      climate system. ACPC is a coordinated effort encom-
      passing six strategic elements: (1) a focus on regimes
      where there are strong indications of aerosol-cloud-
      precipitation interactions; (2) an emphasis on statisti-
      cal characterizations of aerosol-cloud-precipitation
      interactions; (3) the development of approaches that
      leverage past and ongoing activities; (4) thorough
      integration of modeling and observational activi-
      ties; (5) a hierarchical approach to both modeling
      and data collection and analysis; and (6) continued
      development of measurement techniques.

5. Air-Ice Chemical Interactions (AICI)
   a. The goal of AICI is to assess the significance of these
      processes at local, regional, and global scales by
      bringing together the laboratory, field, and modeling
      communities.

6. Air Pollution & Climate: A Science-Policy Dialogue
   a. There is still a separation between air pollution and
      climate change in both the policy and scientific com-
      munities. The aim of the Air Pollution and Climate
      Initiative is to break down these divides and clarify
      the synergies and trade-offs of research and mitiga-
      tion efforts across a spectrum of air pollution and
      climate change policies.

7. African Monsoon Multidisciplinary Analysis - Atmos-
   pheric Chemistry (AMMA-AC) [Concluded 2012]
   a. AMMA was an international project launched in
      2002 to improve knowledge and understanding of the
      West African Monsoon, its variability, and its
      impact on West African nations. AMMA-AC during
      Phase I focused on the development of measurement
      networks of trace gases and aerosols throughout
      West Africa.

8. Chemistry-Climate Model Initiative (CCMI)
   a. CCMI is coordinating model evaluation and associ-
      ated modeling activities between the domains of
      chemistry and climate dynamics.

9. Deposition of Biogeochemically Important Trace Spe-
    cies (DEBITS)
   a. Phase I of DEBITS focused on the development of
      an international measurement network of stations
      to monitor the wet and dry deposition of bioge-
      chemically important trace species. In Phase II, the
      DEBITS science community has adopted a twofold
      approach to deposition flux measurements and
      impact studies.

10. Global Emissions Initiative (GEIA)
    a. For the past two decades, GEIA has provided access
       to various global and regional emission inventories
       in a consistent framework, organized workshops
       that bring together inventory developers and users,
       prepared state-of-the-science emission summaries,
       and provided these data to international scientific
       projects. The breadth of GEIA’s activities is now
       expanding to a forum for exchange of expertise and
       information that unites the scientific, regulatory, and
       operational emission communities.

11. Halogens in the Troposphere (HitT)
    a. The primary objective of the SOLAS/IGAC task
       HitT is to determine and quantify the importance of
       reactive halogen compounds (RHCs) in tropospheric
       chemistry and climate forcing.

12. 2012 IGAC Conferences and Workshops
    a. ACCMIP 2nd Workshop January 30 – February 1,
       2012, Pasadena, CA USA — The workshop further
       defined the experimental setup of the ACCMIP
       projects currently underway, along with the delivery
       schedule and format, while focusing primarily on
discussion of specific topics for analyses that would
be performed on the ACCMIP dataset.

b. Workshop on Health Impacts of Air Quality and
   Climate in Asia — April 8 - 11, 2012, Guangzhou,
   China — 72 participants from Asia, Europe, and the
   United States were brought together to build collabo-
   rations, exchange knowledge, and plan an interdisci-
   plinary framework for addressing science questions
   related to four themes: climate, air quality, health,
   and social vulnerability in Asia. The workshop enabled
   the interactions of experts from many diverse disci-
pines, including those from the atmospheric, health,
and social sciences.

   c. Developing Asian Megacities towards a Sustainable
   World, April 25 - 27, 2012, Zhangjiajie, China — To
   understand the mechanism of human impact on the
   geophysical/chemical processes and their feedbacks
   on the Earth System is the most important topic for
   global change research. In recent years, Monsoon
   Asia Integrated Regional Study (MAIRS) has been
   promoting research on the impacts of aerosol emis-
   sion and land cover change in megacities on the
   local/regional climate in the monsoon Asian region.
   The output of this workshop will be published as a
   “Strategic Plan of Asian Megacity Study.” It is mainly
   focused on five themes: Development of Asian
   Megacities; Climate and urbanization; Assessment
   of resilience and vulnerability of Asian megacities;
Vulnerability and resilience of Asian cities; Regional collaboration and future studies.

d. IGAC/SPARC Global Chemistry-Climate Modeling and Evaluation Workshop, May 21 - 24, 2012, Davos, Switzerland — Approximately 130 scientists from 16 different countries over four continents attended the workshop. Through a combination of invited talks, contributed talks, poster sessions and working group discussions, participants identified science questions relevant to chemistry-climate model evaluation, the specific physical or chemical processes associated with each question, the relevant observations, and the associated model diagnostics. The workshop participants recommended the creation of a joint IGAC/SPARC Chemistry-Climate Model Initiative (CCMI) to coordinate future IGAC and SPARC chemistry-climate model evaluation and associated modeling activities.

e. Atmospheric Chemistry in the Anthropocene, September 17 - 21, 2012, Beijing, China — The 12th IGAC Science Conference was held at the China National Convention Center in Beijing, with a theme of “Atmospheric Chemistry in the Anthropocene” to address the critical interactions between the atmosphere and human activities in an era when humans have fundamentally altered the composition and chemistry of our atmosphere. Greater than 500 scientists and students from more than 40 countries, including over 100 scientists from China, were in attendance.

f. A U.S./Japan Workshop on the Tropical Tropopause Layer, October 15 - 19, 2012, Honolulu, HI, USA — Here, 50 participants gathered at the East-West Center of the University of Hawaii to discuss the Tropical Tropopause Layer (TTL). Nearly 20 of the participants were graduate students and young scientists. The workshop summarized the current state of understanding of the TTL with tutorial presentations, summarized and formulated key questions surrounding the TTL, and discussed and coordinated observations planned over the next few years in the tropical Pacific region.

g. SOLAS/IGAC Workshop on the Role of Marine Gel for the Emission for Primary Organic Aerosols from the Ocean, December 11 - 13, 2012, Kiel, Germany — This workshop convened 15 participants to form a deeper understanding of the biogenic sources of primary organic aerosol from the ocean, their chemical composition and their physical properties. The attendees identified priority questions needing to be addressed by the community, some potential controversies on the topic, and a way forward to fill knowledge gaps.

h. SOLAS/IGAC Halogens in the Troposphere (HitT) Workshop, December 17 - 19, 2012, Kiel, Germany — For this workshop, 25 attendees assessed current knowledge surrounding the relevance and also atmospheric reaction cycles of natural chlorine in the troposphere. Participants identified areas where a deficit in understanding existed; discussed the potential for new advances in atmospheric detection, laboratory studies, and modeling; and designed observational strategies to improve understanding of photochemical processes and assess the impact of chlorine chemistry on the marine boundary layer.

13. Communication and Outreach

a. IGAC Newsletter — IGAC continues to produce a scientific newsletter on a four-month basis that is distributed internationally to more than 3000 scientists. While many peer-reviewed publications result from IGAC activities, the primary product resulting directly from this grant is the IGAC Newsletter. The printing and mailing of the newsletter is taken care of by Academia Sinica in Taipei, but Megan L. Melamed (funded under this grant), is fully responsible for planning newsletter issues, recruiting article authors, and editing the newsletter. A graphic designer at the UW Department of Atmospheric Sciences is paid under this grant to do article layout. All past issues of the newsletter (now numbering 49 in total) are downloadable from the IGAC web page.

b. IGAC Website http://igacproject.org/ — During the past grant cycle, a primary focus of the IGAC International Project Office was to redesign the IGAC webpage. The web site highlights IGAC’s current activities, conferences, workshops, and IGAC related events. It is our goal to create an interface that is more accessible for the international IGAC community.

c. IGAC Mailing List — IGAC has an email-based mailing list that gives individuals control over how much they want to hear from IGAC. Community members can choose to receive a hard or digital copy of our newsletter or can decide to keep in closer touch with the IGAC community by signing up to be notified of upcoming IGAC related conferences, workshops, and other grand gatherings.
Nutrients

PI
Calvin Mordy — UW Joint Institute for the Study of Atmosphere & Ocean

Other UW Personnel
Peter Proctor, Fred Menzia, Morgan Ostendorf — UW Joint Institute for the Study of Atmosphere & Ocean

NOAA Personnel
Eric Wisegarver — Pacific Marine Environmental Laboratory

Task II

NOAA Primary Contact
Dennis Moore — Pacific Marine Environmental Laboratory

NOAA Goal
Healthy Oceans

Description
The Repeat Hydrography CO₂/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 (CO₂), 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 CO₂/Tracer Program will reveal much about internal pathways and changing patterns that will impact the carbon sinks on decadal time scales.

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

The objectives of this project are:

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; and deep and shallow water mass and ventilation studies.

Accomplishments

1. The team was responsible for nutrient analysis on the Repeat Hydrographic Line A10 in the Atlantic Ocean, CLIVAR — Figure 1. Peter Proctor participated on the cruise, and conducted high precision shipboard analysis of phosphate, nitrate, nitrite and silicic acid on 2,736 samples collected from the CTD rosette at discrete depths (Figure 2). Quality control of the data set was completed, and the final data is available and archived at the CCHDO website: http://ushydro.ucsd.edu/cruise_data_links.htm.

2. These nutrient data have been compared with nutrient measurements made on earlier expeditions along the same section: an R/V Meteor cruise in 1992/1993, and an R/V Mirai cruise in 2003. Such comparisons 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 A10.

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

PI
Joseph Resing — UW Joint Institute for the Study of Atmosphere & Ocean

Other UW Personnel
Adrienne Sutton, Geoffrey Lebon, Sylvia Musielewicz, Cynthia Peacock, John Osborne — UW Joint Institute for the Study of Atmosphere & Ocean
Andrea Fassbender, Nancy Williams — UW School of Oceanography

NOAA Personnel
Richard Feely, Christopher Sabine, Simone Alin, Jeremy Mathis, Dana Greeley, Cathy Cosca, Dave Wisegarver, Stacy Jones, Randy Bott — Pacific Marine Environmental Laboratory

Non-UW/NOAA Personnel
Nina Bednaršek — National Research Council Postdoc

Task II

NOAA Primary Contact
Richard Feely — Pacific Marine Environmental Laboratory

NOAA Goals
Climate Adaptation & Mitigation
Healthy Oceans
Resilient Coastal Communities & Economies

Description
The Marine Carbon Program provides a mechanism for research collaboration between PMEL and JISAO scientists and other University of Washington staff with common interests in the marine carbon cycle and its interactions with atmospheric CO₂ and climate. The program focuses on multi-disciplinary research involving atmosphere-ocean CO₂ exchange fluxes, water column CO₂ distributions and transport, data interpretation and modeling, and ocean acidification. Special emphasis will be placed on the continuing effort to enhance our understanding of the role of the ocean in sequestering the increasing burden of anthropogenic carbon dioxide in the atmosphere and the changes that are occurring due to ocean acidification. Project goals include: (1) determining the air-sea exchange of CO₂ from measurements collected on research ships, volunteer observing ships and moorings; (2) determining the distribution and transport of CO₂ into the ocean interior from measurements collected onboard NOAA and UNOLS research ships; and (3) determining the extent of the chemical changes that are occurring in the oceans as a direct result of ocean acidification.

Objectives

1. Collect DIC and process data on A20/22 cruise: PMEL provided equipment and personnel for the A20/22 cruise which departed Woods Hole, MA on March 24, 2012.
2. Service 32 CO₂ moorings: In order to maintain sustained time series, the moored CO₂ systems need to be swapped out with new systems at least once per year. The schedules for servicing are different for each system.
3. Deploy new moored CO₂ systems: One new CO₂ mooring is planned for deployment during the year.
4. Perform required maintenance on underway CO₂ systems: We maintain four underway CO₂ systems that require regular servicing.
5. Prepare new underway CO₂ system: We have plans to install one new underway system on a ship during the year.
6. Collect and analyze discrete samples from the Pacific Northwest: We have continued working with a number of our colleagues around the Pacific Northwest to collect and analyze discrete carbon samples. This includes a cruise to the Washington-Oregon-California continental shelf margin in summer 2012.

Accomplishments

1. Conducted final DIC data processing for two legs of the CLIVAR/CO₂ Repeat Hydrography Section S4P in the Pacific and the A20/22 cruise in the Atlantic. All data have been submitted to the Carbon Dioxide Information Analysis Center.
2. Maintained five underway CO₂ systems.
3. Deployed and/or maintained 33 moored CO₂ systems.
4. We have continued analyzing discrete samples collected on a number of cruises conducted with our collaborators including a cruise along the West Coast of the U.S. sampling the Newport Hydrographic Line with OSU and NOAA/NMFS colleagues based in Oregon collecting and analyzing samples during mooring maintenance cruises with our colleagues at NOAA’s Olympic Coast Marine National Sanctuary. Additionally, samples were taken from ocean acidification surveys conducted by scientists at NOAA’s Pacific Islands Fisheries Science Center around many of the remote island chains in the Pacific Ocean.
Chlorofluorocarbon Tracer Program

PI
Rolf Sonnerup — UW Joint Institute for the Study of Atmosphere & Ocean

NOAA Personnel
John Bullister, David Wisegarver — Pacific Marine Environmental Laboratory

Task II

NOAA Primary Contact
John Bullister — Pacific Marine Environmental Laboratory

NOAA Goals
Climate Adaptation & Mitigation

Description

The concentrations of chlorofluorocarbons (CFCs), along with a number of other anthropogenic compounds like CO₂, increased significantly in the global atmosphere during the past century. Oceanic CFC concentrations can be modeled as functions of location and time, and their sea surface histories are fairly well understood. Studies of the entry of Chlorofluorocarbons (CFCs) from the atmosphere into the surface ocean and the subsequent transport of these compounds into the ocean interior provide a unique description of the time-integrated oceanic circulation and uptake of anthropogenic CO₂ and heat. These tracer data can be used to estimate the rates and pathways of ocean circulation and mixing processes, and as a means of testing and evaluating numerical models of ocean circulation. The development and testing of such models is critical for understanding the present state of the ocean-atmosphere system, quantifying the role of the oceans in the uptake of climatically important trace gases such as CO₂, and improving predictions of climate change for the upcoming century. The tracer data have made important contributions to data-based estimates of oceanic uptake of anthropogenic CO₂, decadal ventilation timescales, changes in ventilation, and ocean biological cycling rates.

Recently, our group has pioneered efficient methods for measuring sulfur hexafluoride (SF₆) in the ocean interior (Bullister and Wisegarver 2008), and the use of simultaneous determinations of independent transient tracers in the ocean to estimate mixing in the ocean interior and its impacts on transient tracer ages (Sonnerup 2001, Bullister et al., 2006, Sonnerup et al. 2007, 2008). The simultaneous use of two transient tracers to account for the effects of mixing provides improved accuracy in estimating ocean CO₂ uptake and ocean acidification from CFCs. In addition, the availability of concurrent CFC and SF₆ measurements now make it possible to estimate circulation rate changes from transient tracers and provide carbon remineralization rates in the ocean interior that can be used as benchmarks to evaluate carbon export rates from overlying surface waters. A further refinement to our measurement techniques also allows for precise measurements of dissolved nitrous oxide (N₂O) in seawater. Because N₂O plays an important role in the marine nitrogen cycle, this affords an opportunity to use the tracer and N₂O measurements in combination to estimate key rates of denitrification in the ocean.

Objectives

1. Document the transient invasion of CFCs and other tracers (including sulfur hexafluoride - SF₆) into the thermocline and deep waters of the world ocean by means of repeat long-line hydrographic sections and at time-series stations, and to improve methods for using CFC observations to estimate the ventilation rate of water masses in the ocean.

2. Use information on the rates and pathways of the invasion of these compounds in the ocean to improve estimates of the rate of uptake of other gases including anthropogenic carbon dioxide in the ocean and the rates of a variety of important biogeochemical processes.

3. Incorporate CFCs and other tracers in large-scale ocean circulation models, and evaluate the ability of these models to simulate observed tracer distributions in the ocean. Such tests are essential for detecting problems with and improving the models.

4. Recently we have developed a method for measuring full sections of N₂O in the oceans and we plan to use these observations, together with the CFCs/SF₆, to quantify removal rates of fixed nitrogen from the oceans.

5. Monitoring of oceanographic processes through collection, display and analysis of CFC, SF₆ and hydrographic data.

6. Using CFC and SF₆ observations to improve estimates of the uptake of anthropogenic carbon dioxide in the ocean.

7. Using combined CFC and SF₆ observations as a means of testing and evaluating large-scale numerical models of the ocean, simulating the evolution of tracer ages and correcting for tracer age drift due to mixing processes, and to estimate transit time distributions.

8. Participate on oceanographic expeditions as part of the CLIVAR Repeat Hydrography Program.

9. Quantify regional oceanic denitrification rates via dissolved nutrients, N₂O and CFC/SF₆ observations.
Accomplishments

1. Continued development of improved techniques for analyzing CFCs, SF₆, and other compounds in atmosphere and ocean from the same samples. We developed a method for including the measurement of dissolved nitrous oxide (N₂O). N₂O plays an important role in the nitrogen cycle in the ocean.

2. Participated in the Hawaii Ocean Time-Series (HOT) program, using the repeated cruise schedule for perfecting analytical techniques, and extending a useful time series for evaluating changes in ventilation of the North Pacific Ocean.

3. Processed oceanographic data and submitted these data to national and international data archives.

4. Examined in detail the constraints on transit time distributions in the North Pacific Ocean provided by CFC and SF₆ data (Figure 1). The transit time distributions were used to improve estimates of thermocline ventilation and oxygen utilization rates in the North Pacific Ocean (published in Deep-Sea Research).

5. Used carbon isotopic data to constrain deep water formation rates and air-sea exchange in ocean carbon cycle models (published in Global Biogeochemical cycles).

6. Used CFC and CO₂ observations from repeat sections to estimate changes in deep water CO₂ content on decadal time scales (published in Deep-Sea Research).

Figure 1. The meridional trend in biological organic carbon export from the sea surface indicated by the depth-integrated oxygen demand in the underlying thermocline. The oxygen utilization rates were estimated using oxygen deficits relative to the sea surface and water mass ventilation timescales derived from concurrent CFC and SF₆ measurements (Sonnerup et al, 2013).
Environmental Chemistry

Tropical Atmosphere-Ocean Interaction

PI
Dongxiao Zhang — UW Joint Institute for the Study of Atmosphere & Ocean

Other UW Personnel

NOAA Personnel
Paul Freitag, Steve Kunze, Douglas MacIntyre, Andy Shepherd, Mike Strick — Pacific Marine Environmental Laboratory

Task II

NOAA Primary Contact
Michael J. McPhaden — Pacific Marine Environmental Laboratory

NOAA Goal
Climate Adaptation & 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.

Our goals for this project are to: (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; and (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. Evaluate dust contamination of PIRATA radiation measurement in the northeast tropical Atlantic.
4. Improve understanding of the ENSO cycle in the Pacific.
5. Advance understanding of the dynamics of ocean circulation in the Indian Ocean.
6. Improve understanding of Atlantic Niños.
7. Understand changes in the Atlantic Ocean’s circulation and its relation to 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 multivariate time series through the TAO web page [http://www.pmel.noaa.gov/tao/]. Between April 1, 2012, and February 28, 2013, TAO web pages received more than 13 million hits and delivered more than 300,000 mooring data files to the international community.

2. Since last year’s report, we deployed one new ATLAS Flux mooring in the Indian Ocean: at 25°S, 100°E from the Australian research vessel Southern Surveyor in August 2012. This mooring represents progress in developing RAMA, which is now 67% 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. Four prototype systems have been deployed – two in 2011 and two in 2012. Preliminary comparisons between ATLAS and T-Flex systems indicate that they report comparable data.

3. Long-term and direct measurements of surface short-wave radiation (SWR) have been recorded by the Prediction and Research moored Array in the Tropical Atlantic (PIRATA) since 1997. Previous studies have shown that African dust, transported westward from the Sahara and Sahel regions, can accumulate on mooring SWR sensors in the high-dust region of the North Atlantic (8°N–25°N, 20°W–50°W), potentially leading to significant negative SWR biases. Here dust-accumulation biases are quantified for each PIRATA mooring using direct measurements from the moorings, combined with satellite and reanalysis data sets and statistical models. The SWR records from five locations in the high-dust region (8°N, 12°N, and 15°N along 38°W; 12°N and 21°N along 23°W) are found to contain monthly mean accumulation biases as large as -200 W m⁻² and record-length mean biases on the order of -10 W m⁻². The other 12 moorings, located mainly between 10°S–4°N, are in regions of lower atmospheric dust concentration and do not show statistically significant biases. Seasonal to interannual variability of the accumulation bias are found at all locations in the high-dust region. The moorings along 38°W also show decreasing trends in the bias magnitude since 1998 that are possibly related to a corresponding negative trend in atmospheric dust concentration. The dust-accumulation biases described here will be useful for interpreting SWR data from PIRATA moorings in the high-dust region. The biases are also potentially useful for quantifying dust deposition rates in the tropical North Atlantic, which at present are poorly constrained by satellite data and numerical models. Results are in press in the *Journal of Atmospheric and Oceanic Technology* (Foltz, Evan, Freitag, Brown, McPhaden).

4. We documented changes in the relationship between warm water volume (WWV), which is an index for upper ocean heat content, and El Niño/Southern Oscillation (ENSO) SST anomalies during the period 1980-2010. Upper ocean heat content represents a major source of predictability for ENSO, with WWV integrated along the equator leading ENSO SST anomalies by 2-3 seasons during the 1980s and 1990s. For the first decade of the 21st century however, WWV variations decreased and lead time was reduced to only one season, mainly due to the diminished persistence of WWV anomalies early in the calendar year. These changes are linked to a shift towards more central Pacific (CP) vs. eastern Pacific (EP) El Niños in the past decade. The results are consistent with a reduced impact of thermocline feedbacks on ENSO SST development and potentially imply reduced seasonal time scale predictability during periods dominated by CP El Niños. Results were published in McPhaden (2012).

5. We used sea surface height (SSH) derived from satellite altimetry and an analytical linear equatorial wave model to interpret the evolution of the Indian Ocean Dipole (IOD) in the framework of recharge oscillator theory. The specific question we address is whether heat content in the equatorial band, for which SSH is a proxy, is a predictor of IOD development as it is for El Niño and the Southern Oscillation (ENSO) in the Pacific. We find that, as in the Pacific, there are zonally coherent changes in heat content along the equator prior to the onset of IOD events. These changes in heat content are modulated by wind-forced westward propagating Rossby waves in the latitude band 5°-10°S, which at the western boundary reflect into Kelvin waves trapped to the equator. The biennial character of the IOD is affected by this cycling of wave energy between the equator and 5°-10°S. Heat content changes are a weaker leading indicator of IOD sea surface temperature anomaly development than is the case for ENSO in the Pacific, because other factors are at work in generating IOD variability, one of which is ENSO forcing itself through changes in the Walker Circulation. Results have been accepted for publication in *Climate Dynamics* (McPhaden and Nagura).
6. El Niño/Southern Oscillation (ENSO) in the Pacific and the analogous Atlantic Niño mode are generated by processes involving coupled ocean-atmosphere interactions known as the Bjerknes feedback. It has been argued however, that the Atlantic Niño mode is more strongly damped than ENSO, which is presumed to be closer to neutrally stable. We compared the stability of ENSO and the Atlantic Niño mode via an analysis of the Bjerknes stability index. This index is based on recharge oscillator theory, and can be interpreted as the growth rate for coupled modes of ocean-atmosphere variability. Using observational data, an ocean reanalysis product, and output from an ocean general circulation model, the individual terms of the Bjerknes index are calculated for the first time for the Atlantic, and then compared to results for the Pacific. Positive thermocline feedbacks in response to wind stress forcing favor anomaly growth in both basins, but they are twice as large in the Pacific as in the Atlantic. Negative feedbacks are dominated by thermal damping of SST anomalies in both basins. Overall, we find that both ENSO and the Atlantic Niño mode are damped oscillators, but the Atlantic is significantly more strongly damped than the Pacific. Results are in press in the *Journal of Climate* (Luebbecke and McPhaden).

7. In the tropical Atlantic, the Atlantic Meridional Mode (AMM) is the dominant source of coupled atmosphere–ocean variability, characterized by a hemispheric sea surface temperature gradient and cross equatorial surface winds that reinforce ocean temperature anomalies in both hemispheres. One major result of our 2011 *Nature Geoscience* paper was to demonstrate that much of the observed multidecadal variability of the meridional SST gradient in the tropical Atlantic was externally forced by variations in African dust outbreaks. Although there is accumulating evidence that the radiative forcing by dust will change the temperature of the ocean surface, no study has examined the dynamical response of the ocean to long-term variability in dust cover. To address this lack of knowledge we conducted forced ocean model experiments using the Massachusetts Institute of Technology Ocean General Circulation Model to single out effects of dust-related radiative forcing. We found that surface temperature anomalies are forced primarily by local radiation-induced changes to the surface heat budget, while the subsurface temperature anomalies are additionally influenced by upper ocean circulation anomalies, which are the response to dust-forced steric changes in dynamic height. Our results suggested that on decadal time scales dust-forced variability of ocean surface and subsurface temperatures are of a magnitude comparable to observed variability, implying that tropical North Atlantic multidecadal variability is related to changes in dust emissions from West Africa. These new findings were published in the *Journal of Climate* in 2012 (Evan, Foltz and Zhang).

8. As part of the community effort to evaluate the new generation climate models used for the next IPCC report, we examined the Atlantic Meridional Overturning Circulation (AMOC) simulated by ten CMIP5 models for the historical (1850-2005) and future climate. The historical simulations of the AMOC mean state are more closely matched to observations than those of the CMIP3. Similarly to CMIP3, all models predict a weakening of the AMOC in the 21st century, though the degree of weakening varies considerably between the models. Under the RCP4.5 scenario, the weakening by year 2100 is 5% – 40% of the individual model's historical mean state; under RCP8.5, the weakening increases to 15% – 60% over the same period. RCP4.5 leads to stabilization of the AMOC in the second half of the 21st century, and a slower (than weakening rate) but steady recovery thereafter, while RCP8.5 gives rise to a continuous weakening of AMOC throughout the 21st century. In the CMIP5 historical simulations, all but one model exhibit a weak downward trend (ranging from –0.1 to –1.8 Sv/century) over the 20th century. Interestingly, the multi-model ensemble mean SST anomalies in the North Atlantic bear temporal resemblance to the observed Atlantic Multidecadal Oscillation (AMO) index, but the amplitude is substantially smaller. The mechanisms behind AMO are still under active debate regarding whether it is internal variability or externally forced. The inter-relationships between the multi-model mean AMOC, North Atlantic SST, and surface shortwave radiation flux anomalies explored in this study suggest that the phasing of late 19th century to 20th century North Atlantic SST variability is generally consistent with external climate forcing variations (as represented by the North Atlantic basin averaged shortwave radiation flux anomalies), but the amplitude would be much weaker if driven by external forcing alone (submitted to *Journal of Climate*, Cheng, Chiang and Zhang).
Marine Ecosystems
Development of a Prediction System for the California Current Integrated Ecosystem Assessment

PI
Nicholas Bond — UW Joint Institute for the Study of Atmosphere & Ocean

Other UW Personnel
Albert Hermann, Samantha Siedlecki — UW Joint Institute for the Study of Atmosphere & Ocean
Jan Newton — UW Applied Physics Laboratory

NOAA Personnel
Isaac Kaplan, Philip Levin, William Peterson — Northwest Fisheries Science Center

Task II

NOAA Primary Contact
Dr. Michael Ford — NOAA Fisheries & the Environment

NOAA Goal
Resilient Coastal Communities & Economies

Description
JISAO’s Seasonal Coastal Ocean Prediction Experiment (J-SCOPE) represents a collaborative project involving scientists at JISAO and NOAA’s Northwest Fisheries Science Center (NWFSC). Quantitative forecasts have begun to be produced of physical, chemical and biological (through lower-trophic levels) ocean properties on time horizons of ~9 months. These forecasts are tailored towards NOAA and other operational stakeholders. They are based on numerical ocean model simulations using a high-resolution (grid spacing ~3 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 being provided by a global coupled atmosphere-ocean model, the Coupled Forecast System (CFS) that is currently being run operationally by NOAA/NCEP/CPC for seasonal weather prediction. The focus is on specific properties crucial to the ecosystem, including 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. Skillful predictions on time horizons of six to nine months 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. A working version of the modeling system was developed over the past year. Much of this effort involved setting up the procedures for linking the CFS to the ROMS model, and since that task has been completed, it is now possible to carry out both hindcast simulations of past seasons for use in model validation and improvement, as well as forecasts. The first forecast was initiated in January 2013 and is complete through September 2013.
2. Climate predictions from the CFS global climate model with respect to the regional ocean forcing have been evaluated; analysis of past forecasts of the CFS indicate that it has positive skill in projecting wind and sub-surface temperature anomalies out at least 6 months into the future. Present efforts include testing of the chemical and biological properties simulated by ROMS through comparisons with observations. Work has just commenced on how the model output will be hosted on the Northwest Association of Networked Ocean Observing Systems (NANOOS) website.
3. JISAO scientist Nicholas Bond presented a review of the forecast system at the Pacific Northwest Weather Workshop in Seattle on March 1, 2013.
Ecosystems and Fisheries-Oceanography Coordinated Investigations (EcoFOCI)

**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 and Chukchi seas, 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, author and co-author numerous publications each year, and present their findings at 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.

**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. EcoFOCI’s mission is to understand the dynamic relationships among climate, fisheries, and the marine environment to ensure sustainability of Alaskan living marine resources and healthy ecosystems.

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.

**PI**

Nicholas Bond — UW Joint Institute for the Study of Atmosphere & Ocean

**Other UW Personnel**


**Other NOAA Personnel**

Jeff Napp — Alaska Fisheries Science Center; Carol Ladd, James Overland — Pacific Marine Environmental Laboratory

**Task II**

NOAA Primary Contact

Phyllis Stabeno — Pacific Marine Environmental Laboratory

**NOAA Goals**

Healthy Oceans
Climate Adaptation & Mitigation
Accomplishments

1. EcoFOCI’s Arctic Ocean observing system – The third and final CHAOZ (Chukchi Acoustics, Oceanography, and Zooplankton) cruise took place on board the F/V Aquila. 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. EcoFOCI contributes to the evaluation of how annual variability in environmental conditions such as sea ice, oceanic currents, water temperature and salinity, and prey abundance influence whale distribution and relative abundance. The 2012 CHAOZ cruise took place from August 8, 2012 through September 7, 2012. We successfully recovered all oceanographic moorings, which were deployed in August 2011. A total of 70 CTD and plankton tow stations were completed, 39 long-term oceanographic and acoustic moorings were deployed, and 8 ARGOS drifters were deployed. In addition, 4 ARGOS drifters were deployed from the USCG Icebreaker Healy for the project. Animation of the drifter tracks can be viewed at http://www.pmel.noaa.gov/foci/visualizations/driver/chuk2012.html. All drifters were caught in the advancing ice in November and December. 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 deepest keels in 2012 occurred on April 16 (28.7m) and May 2 (26.5m). Deepest keels in 2011 occurred on April 19 (20.14m) and June 8 (19.48m). 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 (Wang).

2. The Arctic Whale Ecology Study (ARCWEST) began planning for the first field year in 2013. This program continues much of the work performed by the CHAOZ project, and is also BOEM-supported. EcoFOCI will conduct physical and biological oceanographic sampling to support the project’s objective to further understand the transport and advection of krill and nutrients from the northern Bering Sea through the Bering Strait and to the Barrow Arch area. Mooring sites from the CHAOZ program will also be used for ARCWEST.

3. Bering Sea Project – EcoFOCI scientists contributed 10 authored or co-authored papers from the Bering Sea Project to a special volume of Deep-Sea Research II. ROMS modeling is on-going (Nicholas Bond, Albert Hermann).

4. 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 Kachel, Hermann, and Bond are also contributors. The BEST (Bering Ecosystem Study) Synthesis continues to 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 are being 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 synthesis workshop was held from February 7-9, 2012. A meeting of synthesis participants occurred on January 20, 2013, and the second synthesis workshop was held February 26-28, 2013 in Friday Harbor, WA.

5. Gulf of Alaska Integrated Ecosystem Research Program – 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 (valleye pollock, Pacific cod, arrowtooth flounder, sabletfish, and Pacific Ocean perch). JISAO scientists are playing a major role in this effort. The specific objectives are to determine: (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. The field years for this project are 2011 and 2013. Planning is underway for the next research cruise in April 2013.
6. 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 Mordy are also contributors. The SOAR Workshop with more than 50 participants was held in Anchorage in March 2012. At this Workshop, science themes were defined and project teams were formed. This year, 16 papers have been proposed for synthesis and are in progress. More details of the SOAR project, including products and participants, can be found on the website at [http://www.arctic.noaa.gov/soar/](http://www.arctic.noaa.gov/soar/).

7. EcoFOCI continues work with Bering Sea Ecosystem Synthesis Team – EcoFOCI (including JISAO scientists Bond and 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](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.

8. Arctic – The Arctic Climate change program has co-existed within the EcoFOCI group for the past decade, and will continue to maintain close ties with the EcoFOCI program. The main focus of research activities is in the Arctic region, including sub-Arctic seas such as the Chukchi Sea, the Beaufort Sea and the Bering Sea. The research includes an important Arctic climate component, as well as the ocean monitoring component mentioned above. JISAO Scientist Muyin Wang is responsible for updating the Bering Climate Website, which is a collection of physical and biological variables for the Bering Sea. This website has been a popular source for ecosystem study communities. Wang, in collaboration with James 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/](http://www.arctic.noaa.gov/reportcard/).
Defining Eco-Regions and Spatial Analyses of Species Abundance, Community Dynamics and Stock Substructure to Incorporate Habitat in SSMs and MSMs

**PI**
Trevor A. Branch — UW School of Aquatic & Fishery Sciences

**Other UW Personnel**
Matt Baker, Kirstin Holsman — UW School of Aquatic & Fishery Sciences

**NOAA Personnel**
Anne Hollowed — Alaska Fisheries Science Center

**Task I**

**NOAA Primary Contact**
Anne Hollowed — National Marine Fisheries Service, Alaska Fisheries Science Center

**NOAA Goal**
Healthy Oceans

**Description**
This research will provide an analytical method to define boundaries of fish habitats in space and time and integrate knowledge of habitat associations as a means to measure multispecies interactions in multi-species assessments (SSMs) of Gulf of Alaska (GOA) and Bering Sea (BS) stocks. This research integrates habitat considerations into existing MSM and single species models (SSM) to improve estimation of fishing mortality targets, given multispecies interactions and stock substructure. Habitat is a continuum defined by multiple variables and defining discrete habitat types is a challenge. Understanding how habitat volume influences species interactions is critical to simulate effects of fishing and climate on species abundance and ecosystem structure, and to better evaluate species and system resilience to exploitation.

**Objectives**

1. Develop a protocol to incorporate habitat-specific data into stock assessments.
   a. Apply random forest methods to determine threshold responses and assess the importance of physical variables on species distributions.
   b. Quantify multi-species turnover along environmental gradients and partition systems into coherent spatial units as per biological community response to physical habitat.
   c. Evaluate dynamic physical forcing on the stability of eco-region boundaries.

2. Enhance MSMs for BS by distinguishing predation dynamics in distinct habitats.
   a. Incorporate temporal trends in habitat volume into MSMs to evaluate influence on predator-prey interactions. Specifically, MSM predation mortality is a function of temperature, predator biomass, and vulnerable prey biomass (V); analyses weight V as a function of changes in habitat to evaluate effects on predation dynamics.

3. Delineate stock sub-structure via spatial autocorrelation in abundance.
   a. Apply cluster analyses to times series of annual abundance to define spatially explicit sub-stocks and determine how stock substructure alters stock-recruitment models.
   b. Add an index of positive recruitment (biomass-weighted error) based on spatial stock structure to account for distinct temperature regimes for distinct sub-stocks.

4. Multivariate Autoregressive State Space Models (MARSS) models to distinguish density dependence and inter-species compensation.
   a. Apply MARSS to analyze population dynamics as an integrated response to multiple concurrent drivers and feedbacks and partition the effects of density dependence, compensatory, and environmental mechanisms.
Accomplishments

1. Compiled and analyzed data sources from NOAA trawl survey databases, fisheries observer data, stock assessments, and environmental indices.

2. Applied random forest methods to quantify threshold responses in individual species to environmental variables (e.g. temperature, depth, substrate, stratification) and determined variable importance as a means to classify species by response to environmental forcing.

3. Integrated random forest output from multiple species, synthesizing goodness-of-fit and predictor importance metrics to estimate turnover in community composition along environmental gradients as a means to identify distinct ecological regions.

4. Analyzed the effects of climate on extent and stability of ocean habitats, fish distributions, and outputs related to the delineation of distinct ecological regions.

5. Applied centroid-based clustering methods to distinguish correlated abundance trends as a means to identify sub-populations within aggregate stock complexes.

6. Applied dynamic factor analysis to identify underlying trends in abundance for species in functional guilds, determine factor loadings, and correlate to environmental indices.

7. Developed lag-one multispecies autoregressive models to facilitate analyses of the relative influence of species-specific density dependence, inter-species compensation, climate indices, and fishery extraction in productivity trends.


11. Submitted manuscript to special edition of Deep Sea Research II.

Awards Received

Matt Baker selected as ICES Early Career Scientist, and invited to present research at conference of peers.
Enhanced NOAA-UW Training and Collaboration through the Bevan Series on Sustainable Fisheries

PI
Trevor A. Branch — UW School of Aquatic & Fishery Sciences

Other UW Personnel
Iris Kemp — UW School of Aquatic & Fishery Sciences

NOAA Personnel
John Stein — Northwest Fisheries Science Center
Steven Ignell — Alaska Fisheries Science Center

Task I

NOAA Primary Contacts
John Stein — Northwest Fisheries Science Center
Steven Ignell — Alaska Fisheries Science Center

NOAA Goal
Healthy Oceans

Description
The purpose of this project is to support the Bevan Series on Sustainable Fisheries for winter 2013. Project costs include speaker travel, per diem, accommodations, advertising, and the two associated University of Washington courses (one graduate and one undergraduate).

The 13th 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, which for the 2013 series was on the general issue of “Should we eat fish?” This issue was examined throughout the 2013 series with various focuses including policy, economics, medicine, zooarchaeology, energy use, the impacts of fishing on the environment, and food provision. In addition, an undergraduate class (30 students) and a graduate class (7 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 at least two days, allowing ample time for meetings with NOAA researchers and UW academics.

General expenses were covered in 2012-13 by donations received from the Donald E. Bevan Fund in Fisheries (which covered the cost of the teaching assistant Iris Kemp during winter 2013, and lunch and dinner costs), the School of Aquatic and Fishery Sciences (part of Kemp’s position in fall 2012, administration, receptions after the seminars), and Washington Sea Grant (website design and outreach).

Objectives
1. Bring in outstanding researchers from outside Seattle who are at the forefront of marine and freshwater management and fisheries.
2. Increase collaboration between SAFS, other UW departments NOAA centers, NGOs, and industry.
3. Promote scientific research to the public.

Accomplishments
1. Ten speakers were invited. There has been broad audience support from UW and NOAA personnel.
2. Organized events allowed collaborative discussions in a more informal setting, especially over dinners following the seminar. These events have included SAFS Director André Punt, SAFS Associate Director Tim Essington, SAFS former director Dave Armstrong, Associate Dean of the College of the Environment Julia Parrish, as well as AFSC members Steven Ignell, Rebecca Reuter, and Alan Haynie, and NWFSC members John Stein, Ruth Howell, Walt Dickhoff, Dan Holland, Todd Lee, Jeff Jorgensen, Jim Thorson, Michelle McClure, and Karma Norman. Dinners also included members from other departments at the University of Washington, NGOs, fishermen, and a wide cross-section of people from diverse backgrounds. In addition, speaker and Harvard Medical School Associate Professor Emily Oken was given a tour of NWFSC by Division Director Walt Dickhoff.
3. Public participation in the series has been excellent. The venue seats 150, and for at least one seminar, the audience was too large, and people had to be turned away. Attendance has varied between about 120 and 190.
NOAA Support for DO-IT Scholars Program

PI
Sheryl Burgstahler — UW DO-IT, Information Technology

Other UW Personnel
Tami Tidwell, Doug Hayman — UW Technology Services

NOAA Personnel
Alicia Matter — Northwest Fisheries Science Center

Task III

NOAA Primary 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).

Objectives
1. 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. 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
1. Online and on-site interaction with peers, near-peers, mentors, and staff.

2. Participation in 6-day Phase II Summer Study.

3. Staff attended school meeting with, and at the request of, the funded scholar.

4. Funded scholar completed 10-week summer research internship in STEM in 2012.

5. Funded scholar applied to a STEM-related internship and 9-week summer academy for the summer of 2013, and has been accepted to both.

6. Funded scholar applied and completed her first quarters as a freshman at the University of Washington.

7. Pre and 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.

Specific activities for year two of the project, April 1, 2012 – March 31, 2013, included:

- **April 2012 – June 2012** Funded scholar continued to participate in the online community of mentors, peers, and near-peers, engaged staff in a meeting at her school, participated in quarterly networking get-togethers at the University of Washington, and completed her year-long project to present during Phase II of Summer Study.

- **July 2012** As a Phase II Scholar, funded scholar engaged in 6-day residential Phase I Summer Study at the University of Washington, gaining internet, college preparation, career planning, self-determination, and leadership skills. Funded scholar delivered her year-long project presentation to the group. Once Summer Study was complete, funded scholar became an ambassador, serving as a mentor and leader in the group.

- **August 2012 – March 2013** As an ambassador, funded scholar participated in DO-IT’s online e-mentoring community; received and provided mentoring, near-peer and peer support; weekly electronic lessons; and access to useful college preparation, academic, and career information online.

After this time period the scholar supported through this funding will continue to engage in DO-IT. She will attend a 2-week Summer Study session on the UW campus, during which she will be a program intern. After that, funded scholars can continue engaging in the e-mentoring community, gaining and offering resources and support.
Investigations of Links between the Early Life History Dynamics of Fish Species and Climate/Ocean Conditions in the Gulf of Alaska

PI
Miriam Doyle, UW Joint Institute for the Study of Atmosphere & Ocean

Other UW Personnel
Nicholas Bond, UW Joint Institute for the Study of Atmosphere & Ocean
Albert Hermann, UW Joint Institute for the Study of Atmosphere & Ocean

NOAA Personnel
Jeff Napp, Kathryn Mier — Alaska Fisheries Science Center

Task II
NOAA Primary Contact
Jeff Napp, Alaska Fisheries Science Center

NOAA Goals
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 (GOA) 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
   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. Match the new extension of the ichthyoplankton time-series with further development of time-series of environmental forcing variables; basin-scale climate and ocean indices, and local-scale physical measurements.
   Synthesize multispecies patterns in the historical ichthyoplankton data, and species life history and ecological traits, to identify coherent patterns that may help us to identify species’ early life history responses to environmental forcing.
   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. Represent the Alaska Fisheries Science Center’s Recruitment Processes program in a review of field logistics, sample collections, and data analyses and dissemination for the 2011 field season. Contribute to the analysis of ichthyoplankton data collected during 2010-2011, and participate in cruise planning and sample design for the 2013 ichthyoplankton surveys.

Accomplishments
1. Project 1 – Late spring larval fish abundance data have been accumulated annually in the Gulf of Alaska through 2011, and from 2013 will be collected on an alternate year schedule. Species abundance indices have been calculated from the designated study area for all available recent years, extending the time-series from 1981 through 2011. The ichthyoplankton species abundance time-series through 2009 is described and interpreted in the 2013 Ecosystem Considerations report to the North Pacific Fisheries Management Council (Doyle and Mier, 2012a), and has been included in a publication from Project 2 (Doyle and Mier, 2012b). Time-series data pertaining to the GOAIERP focal species are incorporated into the retrospective analysis of ichthyoplankton data for this research (Project 3). Time-series of physical variables comprising monthly mean values for January through May, 1981-2011, are being updated and developed in conjunction with scientists from the EcoFOCI research program at NOAA’s Pacific Marine Environmental Laboratory. The primary focus...
this year was the evaluation of model-generated (e.g., ROMS 10 km scale) water circulation metrics along three transects in the western Gulf of Alaska, as proxies for transport of larvae of deep water spawning species on to the continental shelf and into the Shelikof Strait region. Results suggest that finer-scale measurements of water transport within troughs and gulleys that transect the western GOA continental shelf are necessary in order to more accurately represent the onshore transport of fish early life history stages.

2. Project 2 – Multivariate analysis of historical GOA ichthyoplankton data (1977-2009) has revealed synchronicities and similarities among species early life history patterns and their links to the environment. This research has yielded an effective conceptual framework (Fig. 1) for evaluating the exposure and response of fish species to the pelagic environment during early life (Doyle and Mier, 2012b). 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. Evaluation of the effectiveness of this conceptual framework will continue as the GOA ichthyoplankton abundance time-series is extended and investigated in relation to interannual variation in the oceanographic environment. Interest in the pan-regional application of this multispecies early life history synthesis and exposure-response framework continues, and a pilot project is being undertaken for the Northern California Current region at the NOAA Northwest Fisheries Science Center in Newport, Oregon.

3. Project 3 – Synthesis of historical GOA ichthyoplankton data for the Retrospective component of the NPRB-sponsored GOAIERP program has been completed. Spatial, seasonal, and interannual patterns of variation in abundance and lengths of the early ontogenetic stages of the five key species have been integrated into the construction of individual pelagic exposure profiles for these species, and have been incorporated into the development of Individual Based Models for each species by the Modeling component of GOAIERP. 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 comprise a single large manuscript that is being prepared for submission to the NOAA professional paper NMFS series (Doyle, in prep). This historical synthesis provides a comparative framework for interpreting the results of the 2010-2013 GOAIERP surveys from the eastern and western GOA with respect to identification of early life history habitat, connectivity between spawning and nursery grounds, and early ontogeny response to the pelagic environment. Results will be presented at the March 2013 GOAIERP Principal Investigator’s meeting in Seattle.

Figure 1. Conceptual framework of early life history exposure to the pelagic environment, and associated resilience and vulnerability factors, for Gulf of Alaska fish species (from Doyle and Mier, 2012b). Primary end-point strategies are identified as synchronous, abundant, and ubiquitous with reference to the three primary gradients of production (abundance of eggs/larvae), phenology (timing of production), and ubiquity (temporal and spatial spread of larvae in the pelagic environment).
Improving Ecosystem-Based Stock Assessment and Forecasting by Using a Hierarchical Approach to Link Fish Productivity to Environmental Drivers

PI
Timothy Essington — UW School of Aquatic & Fishery Sciences

Other UW Personnel
Nathan Mantua, Trevor Branch, Megan Stachura, Christine Stawitz — UW School of Aquatic & Fishery Sciences

NOAA Personnel
Anne Hollowed, Paul Spencer — Alaska Fisheries Science Center
Melissa Haltuch — Northwest Fisheries Science Center

Task III

NOAA Primary Contact
Mike Ford — Office of Science & Technology

NOAA Goals
Healthy Oceans
Climate Adaptation & 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 (Amar et al. 2009). 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 Amar 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. Identify ecologically relevant forcing functions and develop databases that contain time series for each.

2. Collect recruitment and growth data from target and non-target (likely growth only) fisheries data as time series and develop a database structure to house these data.

3. Identify candidate grouping structures for species (i.e., what attributes of species might predispose them to respond to environmental forcing in similar ways?).

4. Run Bayesian hierarchical models under alternative grouping structures to estimate the effects of environmental variables on productivity, and test which group structure is best supported by the data.

**Accomplishments**

1. Our work on recruitment dynamics is nearly completed. We held an expert-panel workshop in September of 2012 to identify the best way to group species based on shared susceptibility to environmental parameters. We then used these groupings to test for synchrony in recruitment dynamics within and among groups, and where synchrony was present we evaluated the extent to which they were well predicted by ecologically relevant environmental drivers. We found evidence of group synchrony in the Gulf of Alaska, marginal evidence in the California Current, and no evidence in the Bering Sea. We found evidence linking Gulf of Alaska recruitment dynamics to physical processes that affect larval transport and retention. We have a draft manuscript in preparation, which is part of Megan Stachura’s MS thesis.

2. We have also accumulated all aging data for California Current and Alaska ecosystems, and we are presently testing statistical models for changes in growth rates. This is part of the Christine Stawitz MS thesis. Stawitz joined the project in June 2012, and she is making very good progress towards her degree, and towards meeting the project objectives.

3. We are slightly behind our initial timetable because of difficulties in recruiting a graduate student to the position. However, we benefited from adding Stachura to the project in an unofficial capacity, and Stawitz as a funded graduate student.
Using HPCC Techniques to Power User Tools for Ecosystem Models: The Bering Sea Example

**PI**

Albert J. Hermann — UW Joint Institute for the Study of Atmosphere & Ocean

**Other UW Personnel**

Ivonne Ortiz — UW School of Aquatic & Fishery Sciences

**NOAA Personnel**

Kerim Aydin — Alaska Fisheries Science Center

**Task III**

**NOAA Primary Contact**

Kerim Aydin — Alaska Fisheries Science Center

**NOAA Goals**

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**

1. Enhance networking, collaboration, visualization, and analysis capabilities of NOAA/JISAO and other scientists, through effective application of new or improved information technology.
2. Provide greater access to NOAA’s holdings of real-time and historical data and information to customers in a more complete, usable form, and in a timelier manner.
3. 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**

1. Both 40-year hindcast and 30-year forecasts of the Bering Sea (circulation and lower trophic level components) were translated to regularly gridded (latitude-longitude-depth) files for hosting by AOOS. These files were used for local analysis and visualization at AFSC and PMEL using 3D visualization software (UCAR’s Integrated Data Viewer).
2. During the past year, we have initiated multiyear hindcasts of the Bering Sea which include size- and age-specific fish variables, and have interpolated these new results to the same regularly gridded format.
3. Samples of these new files (which include all circulation, lower trophic level, and fish variables) are now being transferred to our colleagues at AOOS, for testing with their parallel data server.
Annotated Checklist of Bottom-Trawled Macroinvertebrates of Alaska, with an Evaluation of Identifications in the Alaska Fisheries Science Center Bottom-Trawl Survey Database

PI
Theodore W. Pietsch — UW School of Aquatic & Fishery Sciences

Other UW Personnel
David Drumm, Katherine P. Maslenikov — UW School of Aquatic & Fishery Sciences

NOAA Personnel
James W. Orr, Robert R. Lauth, Duane E. Stevenson — Alaska Fisheries Science Center

Additional Personnel
Robert Van Syoc — California Academy of Sciences

Task II

NOAA Primary Contact
James W. Orr — Alaska Fisheries Science Center

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. Produce a comprehensive annotated checklist of Alaskan invertebrates to be submitted for publication in the NOAA Professional Papers, a series available digitally over the internet with a worldwide print distribution (Figure 1).
2. Publish the results of the AFSC survey database assessment in the local Technical Memorandum series, also freely available over the internet.
3. Incorporate synthesized results of this analysis into research publications planned for the primary literature.

Accomplishments
1. The checklist has been completed and is now in internal review. The list includes over 3,500 species, listed under the higher classification down to species name, synonyms, common names (if applicable), type locality, geographic distribution, and depth distribution. The post-doctoral appointee (David Drumm) collaborated with a Japanese graduate student and is a coauthor of a manuscript published in Plankton and Benthos Research entitled “Genetic divergence of deep-sea cran gonid shrimps, Argis lar and its sibling A. hozawai from the Sea of Japan.” Drumm and James Orr also collected five of the six species of Argis found in Alaskan waters from the Arctic to Southeast Alaska, and this material will be used in a collaborative molecular phylogenetic study led by the same student. A manuscript for publication on northern range extensions and biological notes for three decapods in the eastern North Pacific is in internal review. Drumm also visited the Los Angeles County Museum of Natural History, where he discovered a new species of tanaidacean crustacean. A manuscript describing the species is now in internal review.
2. Drumm has been working with specimens collected since the early 1990s by the AFSC 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.

3. Drumm attended and presented a poster at the 2013 Alaska Marine Science Symposium entitled “An annotated checklist of the marine macroinvertebrates of Alaska.” Outreach species identification posters with photos of all species of seastars (in three separate posters), shrimps, and chitons of Alaska have been completed and are being printed by the Government Printing Office. Collection of new photos for additional posters on select invertebrate groups has begun. All will be distributed free of charge at outreach events, and will be available on-line at the AFSC web site http://www.afsc.noaa.gov/.

Figure 1. Proposed cover page for the “Annotated Checklist of Bottom-Trawled Macroinvertebrates of Alaska” to be submitted for publication in the NOAA Professional Papers series.
Archival and Dissemination of Specimens and Data for the Northeast Pacific Ocean and Bering Sea Fish Eggs, Larvae, and Adults Collected During NMFS Surveys

PI
Theodore W. Pietsch — UW School of Aquatic & Fishery Sciences

Other UW Personnel
Katherine P. Maslenikov — UW School of Aquatic & Fishery Sciences

NOAA Personnel
Ann Matarese-Kiernan, James W. Orr — Alaska Fisheries Science Center

Task III

NOAA Primary Contact
Ann Matarese-Kiernan — Alaska Fisheries Science Center

NOAA Goal
Healthy Oceans

Description

The Alaska Fisheries Science Center Resource Assessment and Conservation Engineering (RACE) Division annually collects ichthyoplankton and adult fishes from Alaska. The National Marine Fisheries Service is mandated to transfer important fish collections to the U.S. National Museum or other designated museums for permanent archival storage. The University of Washington Fish Collection (UWFC) has been designated as one of four such institutions in the United States, and is the only one that specializes in fishes from the boreal North Pacific. The facilities and personnel of the UWFC — a fully computerized, well-documented, archival research collection of freshwater and marine fishes of Washington State, the Pacific Northwest, and the Pacific Rim — is serving to serve the research and educational needs of students and professionals by providing on-site study facilities; a comprehensive library of books, journals, and reprints; loans and gifts of ichthyological materials; identification services; and an active program of public outreach — are superbly suited to perform the tasks described here. Under the current grant, the RACE Division Groundfish Task, and Recruitment Processes Task each transfers many numbers of specimens to the UWFC to be archived.

Financial support has been provided to continue a long-standing cooperative relationship with the UWFC as the repository of ichthyoplankton. As a result of previous AFSC support, we have transferred over 95,000 lots of eggs and larvae collected between 1977 and 2012. This consolidation of material has made the UWFC the largest repository of early life history stages of fishes in North America. Database records for 95,869 cataloged lots of eggs and larvae, totaling 7,609,397 individual specimens, are now available online from the UWFC website. http://biology.burkemuseum.org/ichthyology/database/search.php

At the same time, support has been provided to the UWFC to archive vouchers of adult fishes collected during surveys of the Alaskan continental shelf and upper slope. The UWFC has served as the primary repository for thousands of adult fishes collected since the 1970s. Thousands of lots of adult fishes collected from 1995 to 2012 have already been transferred to UWFC during recent years. Database records for 49,176 cataloged lots of eggs and larvae, totaling 366,619 individual specimens, are now available online from the UWFC website. These efforts will continue as we also transfer locality data and maintain a full web-based inventory of lots presently housed at UWFC.

Objectives

To provide for the archival and maintenance of specimens of fish eggs, larvae, and adults collected by the Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center during fisheries resource surveys conducted in the northeast Pacific Ocean and Bering Sea. The following specific tasks will be performed:

1. Provide location and storage of AFSC specimens within commuting distance of the AFSC at the NOAA Western Regional Center at Sand Point, Seattle, Washington, to allow for easy and frequent access by the AFSC staff.

2. Transfer all available fish eggs and larvae collected by the RACE Division, AFSC, to the University of Washington, School of Aquatic and Fisheries Science, Fish Collection, during the performance of the base year services of the resulting grant. Additional collections from subsequent years will be made available for transfer if any option is exercised for additional years of service.
3. Transfer up to 1,000 lots per year of adult fishes collected in RACE surveys to the UWFC. UWFC will transport specimens from AFSC to UWFC. Additional collections from subsequent years will be made available for transfer if the options for additional years are exercised.

4. Continue to update the UWFC specimen archival internet database to increase access speed and search efficiency for retrieval of information of AFSC specimens archived at UWFC.

5. Add and catalog lots of fish eggs, larvae, and adult fishes in standard UWFC specimen catalog system, and maintain the archived specimens and catalog system database.

6. Provide one to three students or staff per year to participate in AFSC fisheries surveys based on three round-trip fares to Dutch Harbor, Alaska, associated per diem, and any additional labor such as overtime or hardship/weekend pay to participate on a cruise.

Accomplishments

1. During the period from March 1, 2012 through September 24, 2012, the early life history collections have been mostly inactive due to the unexpected departure in March 2012 of the graduate student assigned to the work. She had, however, nearly completed the prior year's transfer of material (with only the odd-year material left to be cataloged), and all material was left well-labeled, with clear directions for her replacement, incoming graduate student Jessica Swihart, who is starting now to take over the project. Although the new material was left in an inactive state, the collection as a whole has remained accessible to researchers. The collections manager has fulfilled several data and cataloging requests from AFSC personnel, providing timely responses. The brief lapse in student curatorial work will not delay future transfers of material from the AFSC Ichthyoplankton lab. Note also that limited access to the fish collection as a result of massive renovation of our building (Fisheries Teaching and Research), to repair a long-standing water problem, brought work on curation and accessioning nearly to a stand-still beginning in late June.

2. During this same period (March 1, 2012 through September 24, 2012), 135 lots of adult fishes, including a total of 558 specimens, all obtained from AFSC sources, were identified, curated, and archived (a complete list of species is available on request). The UWFC internet database was updated to reflect these additional cataloged lots (thus fulfilling part of deliverable number 3 listed above (see www.uwfishcollection.org). At the same time, tissues for future DNA studies were taken from 69 AFSC lots, transferred to appropriate vials, and placed for long-term storage in our -86º C freezer, thus adding to our ever-growing collection of genetic resources. The number of tissues samples has now reached 4,415, representing 758 species in 129 families (a list of species and specimens is available on request). Our internet search interface allows individual searches for records with tissue samples (in addition to skeletal, early life history stages, and adults), using Latinized scientific names as well as common names.

3. During the period from September 25, 2012 through February 26, 2013, the task of curating the early life history collections fell to incoming graduate student Jessica Swihart. Much of her time was spent conducting a much-needed inventory of the odd-year material left over from the prior year's transfer of material. She also completed the transfer of this year's material received from the AFSC Ichthyoplankton lab, which included approximately 75,505 larval individuals in 4,662 vials, along with 1,918 vials of eggs. The inventory and on-line posting of this new material is now well underway. Limited access to the fish collection as a result of building renovation was finally completed in November 2012. Since the completion of construction, work has resumed as normal, allowing Collections Manager Katherine Maslenikov to fulfill numerous outstanding data and cataloging requests from AFSC personnel, as well as from many other outside user groups.

4. During this same period (September 25, 2012 through February 26, 2013), 162 lots of adult fishes, including a total of 478 specimens, all obtained from AFSC sources, were identified, curated, and archived (a complete list of species is available on request). The UWFC internet database was updated to reflect these additional cataloged lots (thus fulfilling part of deliverable number 3 listed above (see www.uwfishcollection.org). At the same time, tissues for future DNA studies were taken from 54 AFSC lots, transferred to appropriate vials, and placed for long-term storage in our -86º C freezer, thus adding to our ever-growing collection of genetic resources. The number of lots with tissues samples has now reached 4,628, representing 758 species (a list of species and specimens is available on request).
An Evaluation of Management Strategies for Implementation of Annual Catch Limits for Alaska Groundfish

PI
André Punt — UW School of Aquatic & Fishery Sciences

Other UW Personnel
Carey McGilliard — UW School of Aquatic & Fishery Sciences

NOAA Personnel
Anne Hollowed — Alaska Fisheries Science Center

Task III

NOAA Primary Contact
Anne Hollowed — Alaska Fisheries Science Center

NOAA Goals
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 (DT) 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
1. Dr. Carey McGilliard conducted a literature review of approaches that have been used to account for scientific uncertainty when setting catch limits and developed one such approach for Alaska groundfish in the BSAI and GOA that will use management strategy evaluation (MSE). She has developed mathematical specifications for the MSE and is currently developing computer code to implement it. This computer code will link to a linear programming algorithm so that a multiple-species MSE can be conducted to evaluate the potential consequences of alternative harvest strategies that include accounting for scientific uncertainty when specifying catch limits.
2. The key conclusions of the review were as follows. The "P* approach" for accounting for scientific uncertainty specifies an acceptable probability of overfishing, and calculates a harvest rate or catch limit that will result in the specified probability of overfishing. The P* approach has been interpreted and evaluated using several methods, each of which account for scientific uncertainty differently. For example, it is possible to implement a P* approach when a distribution for the limit reference point is available as an output from an assessment, and either a point estimate or distribution of the current fishing mortality rate is available. An alternative P* approach that is easy to use, and has been adopted as valid by the Pacific Fishery Management Council, involves examining the variability about estimates of biomass from stock assessments over the course of many years and thus incorporates many sources of scientific uncertainty, including variation among assessment authors and some model mis-specification error. However, the approach is ad hoc.

3. An MSE which explicitly considered estimation error and other sources of uncertainty was used to evaluate the performance of the P* approach for Bristol Bay red king crab. That MSE assumed that uncertainty is constant over time and that reference points that are proxies for FMSY and BMSY are always exactly equal to FMSY and BMSY. McGilliard is expanding this MSE by explicitly accounting for many of the sources of uncertainty absorbed into the large category of "unquantifiable uncertainty" in the previous MSE. For example, this MSE will account for uncertainty about parameters that are fixed (assumed to be known with no uncertainty) in many assessments due to an inability of the data to adequately inform estimates of those parameters. This MSE approach will then be applied to Alaska groundfish species. In addition, the MSE being developed by McGilliard will account for uncertainty in both current and limit fishing mortality rates. The MSE will have the ability to handle multiple species and to use a linear programming algorithm developed previously (but updated to reflect current fishery constraints) to simulate how management for one species may affect the catch of other species.
Development of a Package of Functions to Facilitate the Development of Custom Stock Assessment Models, Including Size-Based Crab Models

PI
André Punt — UW School of Aquatic & Fishery Sciences

Other UW Personnel
Athol Whitten — UW School of Aquatic & Fishery Sciences

NOAA personnel
James Ianelli — Alaska Fisheries Science Center

Task III
NOAA Primary Contact
Kathleen Jewett — Northwest Fisheries Science Center

NOAA Goals
Healthy Oceans
Resilient Coastal Communities & Economies

Description
General stock assessment models have many benefits, but there are cases in which the general models do not have the required structure, and inappropriate or suboptimal assumptions have to be made (i.e. shoehorning the stock into the general model) or a custom model developed. There is also a need to develop models for research so that general models can be improved. In these cases, methods that facilitate the development of models can greatly reduce development time, increasing the productivity of researchers. One such approach is the package system used in the R statistical language. Packages consist of functions developed for previous analyses put together in a consistent format so that they can be used by others. These packages are used by other developers to create new functions. There are several packages developed for fisheries stock assessment, including the Fisheries Library in R (FLR), which is used extensively in Europe. A similar package for AD Model Builder (ADMB) would greatly facilitate the development of custom stock assessment models and methodological research. It would also encourage others to produce and make available their own ADMB packages.

Objectives
1. Develop a consistent format for packages in ADMB.
2. Create, test, and provide functions.
3. Provide examples.
4. Develop a generic assessment package for North Pacific crab stocks

Accomplishments
1. Athol Whitten began work on this project on January 7, 2013. He has created an online codeshare repository to facilitate the development of an ADMB-compatible function package for fisheries stock assessment. This repository serves as the online home of the project, and is being utilized by Whitten, André Punt, James Ianelli, and Mark Maunder (IATTC; leader of the AMDB project) to collaborate on the project.
2. The function package under development will eventually be made available as a contributed library to the ADMB software suite (following the similar concept of preinstalled packages for R), and will be called Common Stock Assessment Routines (CStar). The CStar package is being developed concurrently with a Generic Crab Model (GCM), intended for use as a modelling framework for future crab stock assessments for use by the North Pacific Fishery Management Council (NPFMC) crab plan team. The GCM will be the first model developed using the CStar package, and will thus serve as an example for others. Whitten is undertaking ongoing collaborations in liaison with NOAA crab modellers, including Jack Turnock and William Stockhausen, to ensure that the GCM is designed with end users in mind. Furthermore, Whitten will present an ‘Introduction to CStar’ presentation at the February/March NPFMC Crab Modelling Workshop in Anchorage to engage with fishers and key government and industry stakeholders.
3. Fishing gear selectivity functions are an integral part of modern fisheries stock assessment modelling. As such, and to align with the selectivity workshop being held by the Center for the Advancement of Stock Assessment Methodology (CAPAM) during March 2013, selectivity functions are being developed, tested, and documented as the first core functions of the CStar package. Whitten will present these example functions and documentation at the CAPAM selectivity workshop to seek feedback and advice from stock assessment experts while the project is still in its early stages.
Forecast Effects of Ocean Acidification on Abundance of Eastern Bering Sea Tanner Crab

PI
André Punt — UW School of Aquatic & Fishery Sciences

Task III

NOAA Primary Contact
Michael Dalton — Alaska Fisheries Science Center

NOAA Goals
Healthy Oceans
Resilient Coastal Communities & Economies

Description
The increase in atmospheric CO$_2$ concentrations, caused primarily by fossil fuel emissions, deforestation, and concrete production, has led to a corresponding increase in the CO$_2$ concentrations in the ocean. This increase is leading to changes in the carbonate chemistry of the oceans and a decrease in pH. As CO$_2$ levels continue to rise over the coming decades, the pH in the ocean will fall even further. This reduction in pH, and increase in pCO$_2$, can have substantial physiological effects on marine organisms, affecting growth, survival, reproduction, and behavior. Calcifying organisms may be particularly affected because the reduction in pH makes it more difficult to excrete and sustain a calcified shell or exoskeleton. There is already some evidence that ocean acidification is likely to impact crabs. While the focus of the impacts of ocean acidification has been mainly on the biological effects, species such as crabs support valuable fishery resources, and ocean acidification may have major consequences for these fisheries and how they are managed. To forecast potential consequences of ocean acidification on the future abundance of vulnerable and commercially important North Pacific crab stocks, a work plan is proposed to develop population dynamics models and bio-economic models for Eastern Bering Sea (EBS) Tanner crab Chionoecetes bairdi. This work plan builds on past and ongoing NOAA-supported research in this area. In particular, model input will be taken from physiological research for these species that is being conducted at the Alaska Fisheries Science Center to characterize their susceptibility to ocean acidification.

Objectives
Several linked biological and bio-economic models will be developed and used to evaluate harvest strategies for EBS Tanner crab given plausible trends in ocean pH and possible relationships between changes in ocean pH and growth and mortality rates for North Pacific crabs.

1. A model which relates pre-recruit mortality and the time to grow from one stage to another given changes in ocean pH will be developed to forecast how the proportion of EBS Tanner crab eggs which lead to recruits (at 65 mm CW) will change over time.

2. A population dynamics model for adult EBS Tanner crab will be developed. This model will have two options, one in which EBS Tanner crab constitute a single homogeneous biological stock throughout its range, and another in which the dynamics (e.g. growth, fecundity), differ east and west of 166E.

3. The male-only model developed for EBS snow crab will be updated based on the most recent data.

Accomplishments
This project has yet to commence because a number of other projects need to be completed first. These projects and their current status are:

1. Dusanka Poljak, a UW MS student needed to develop the conceptual basis for the pre-recruit model which will be used to forecast the survival and growth rates for pre-recruit Tanner and snow crab. Poljak successfully defended her thesis “Impact of Ocean Acidification on Recruitment and Yield of Bristol Bay Red King Crab” on February 11, 2013.

2. André Punt needed to finalize a project funded through the Pacific States Marine Fisheries Commission to develop a model of recruited Bristol Bay red king crab. The model has been developed, and the analyses based on the model are currently being conducted. The model and analyses will be completed by the end of March 2013.

3. Punt has already been in contact with Robert Foy, NOAA Kodiak Lab, to obtain the detailed results of the experiments evaluating the impact of changes in pH on the survival of juvenile Tanner crab. Once these data have been obtained they will form the basis for the parameterization of the pre-recruit model for Tanner crab.
Improving Assessment Methods: Developing and Evaluating Alternative Estimators of Survey

PI
André Punt — UW School of Aquatic & Fishery Sciences

Other UW Personnel
Mathieu Woillez — UW School of Aquatic & Fishery Sciences

NOAA Personnel
Jim Ianelli — Alaska Fisheries Science Center

Task III

NOAA Primary 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 through 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
1. 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 modelled 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. Multiples 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.
2. 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 (m² 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).
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**

André E. Punt — UW School of Aquatic & Fishery Sciences

**NOAA Personnel**

Steve Ignell — Alaska Fisheries Science Center
John Stein — Northwest Fisheries Science Center

**Task III**

**NOAA Primary Contacts**

Russ Nelson — Alaska Fisheries Science Center
John Stein — Northwest Fisheries Science Center

**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**

1. Faculty support – hire and support two tenure-track faculty members at the UW School of Aquatic and Fishery Sciences.
2. Graduate student support – identify, support, and train graduate students in stock assessment and resource economics for fisheries management.

**Accomplishments**

1. The School of Aquatic and Fishery Sciences hired Trevor A. Branch as an assistant professor, tenure track as of September 16, 2010. He is running the Bevan Series to increase collaboration between the SAFS and NOAA. He lectures courses in introductory and advanced R programming, in converting data to scientific graphics in R, and in fisheries population dynamics. Since being hired, Branch has published 23 scientific papers, has been awarded the Ecological Society of America’s 2011 Sustainability Science Award, and is a Leopold Leadership Fellow in 2013.
2. Branch is using money from this award to support Cole Monnahan, a graduate student who comes from the QERM (Quantitative Ecology and Resource Management) program, who has completed 2.5 years of coursework in modeling and statistics, and his research project at the graduate level. Monnahan is finalizing a model to separate catches of eastern and western North Pacific blue whales, and constructing and fitting a Bayesian population model of northeast Pacific blue whales with Brett McClintock from the National Marine Mammal Laboratory, NOAA. He has also completed a project on methods to improve convergence time in Bayesian stock assessments with scientists at the Northwest Fisheries Science Center. Monnahan is applying to continue with a PhD using a Sea Grant/NMFS population dynamics fellowship, which will supplement the NOAA money in this grant. In addition, Branch has two other students supported on other grants, Melissa Muradian and Peter Kuriyama, who will be trained in the methods of stock assessment.
3. SAFS hired Christopher M. Anderson as a tenured Associate Professor of Fisheries Economics beginning January 1, 2012. He taught a graduate level course in fishery economics for students in SAFS, the School of Marine and Environmental Affairs (SMEA), and the UW Department of Economics in Spring 2012. Going forward, he will be teaching a graduate seminar in frontier bioeconomic modeling for Economics and SAFS students, an introductory graduate course on fishery economics for SAFS and SMEA students, and an introductory level undergraduate course on natural resource economics.
4. Anderson has research programs focusing on behavioral responses to catch share management, assessing the economic performance of the harvest, post-harvest and fishing community sectors of fisheries around the world, and public willingness to pay for ecosystem services. Anderson's lab presently includes two graduate students who transferred into SAFS with him from the University of Rhode Island. He is also working closely with a few students from the UW Economics department who have become interested in fisheries issues. He is actively recruiting one to two new students for the coming fall quarter.
West Coast Groundfish Stock Assessment

PI
André Punt — UW School of Aquatic & Fishery Sciences

Other UW Personnel
Kotaro Ono, Kelli Johnson — UW School of Aquatic & Fishery Sciences

Task III

NOAA Primary Contact
Kathleen Jewett — Northwest Fisheries Science Center

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. Develop quantitative methods for the analysis of the population dynamics of groundfish species which could form the scientific basis for evaluating the consequences of alternative fisheries management actions.
2. Collaborate with National Marine Fisheries Service (NMFS) scientists who are conducting quantitative stock assessments of West Coast groundfish species on the implementation of population dynamics and stock assessment methods.
3. Build expertise among scientists conducting management-related research for West Coast groundfish in the application of state-of-the-art methods.
4. Provide support, training, and mentoring for graduate students in the field of quantitative fisheries science.

Accomplishments
1. André Punt extended the projection software developed for the Pacific Fishery Management Council (PFMC) during a previous NMFS-funded project. This extension allows multiple species to be projected forward simultaneously, which then allows the impact of constraining (i.e., rebuilding) stocks on healthy stocks to be quantified. This work is being conducted in collaboration with Jason Cope (NOAA, NWFSC). The approach was presented to a UW/NWFSC/AFSC Fisheries Think Tank, and during a joint meeting of the PFMC SSC Groundfish Subcommittee and the PFMC Groundfish Management Team. Further development of this modelling framework requires provision of a model which quantifies the interactions among catches of different West Coast groundfish stocks.
2. Punt, along with Mark Maunder (IATTC), completed the special issues of the journal Fisheries Research on Stock Synthesis and its applications. This volume includes 11 papers, including the definitive paper on stock synthesis. NMFS authors contributed to seven of the papers. Punt co-authored one of the papers with Maunder, and also wrote the preface. This special issue is due to be published during April 2013.
3. Punt has extended the work of Motoki Wu (UW MS student, previously funded by this project) on evaluating the performance of methods for estimating meta-analysis-based priors for the steepness parameter of the stock-recruitment relationship, by expanding on the set of methods considered previously, including evaluating the impact of choices for hyperpriors within Bayesian methods for analyzing assessment outputs. This work has been presented at a UW/NWFSC/AFSC Fisheries Think Tank, and will form the basis for a peer-reviewed scientific paper to be submitted during May–June 2013 with co-author Martin Dorn (NOAA, AFSC). The preliminary results of the study confirm that a variant of the meta-analysis method applied by NMFS scientists during the 2011 assessment round is the best of the available methods.
4. Punt is conducting an evaluation of the best ways to select among alternative selectivity patterns when conducting stocks assessments in collaboration with a UW Postdoc (Athol Whitten) and a UW PhD student (Felipe Hurtado). The methods being considered include residual diagnostics, model selection methods, and simulation testing. The results of the study will form the basis for a keynote address during the March 2013 CAPAM selectivity workshop being organized by scientists from the Scripps Institution of Oceanography, NOAA SWFSC, and the IATTC. A paper resulting from this work will be published in the proceedings of the workshop.

5. Kelli Johnson (UW PhD student) is working on methods to improve the estimation of trophic interactions for multi-species stock assessments. Using simulations, she is testing if functional response parameters can be estimated from abundance time-series to alleviate the dependence of multi-species stock assessments on diet data. Johnson is also working on improving the performance of a multi-species stock assessment framework developed by Doug Kinzey (NOAA, SWFSC) and Punt. The framework allows for uncertainty in the functional response using both integrated analysis and model selection. Additionally, Johnson is working on a collaborative project with other UW SAFS students to assess the performance of stock synthesis when time-varying life history patterns exist. Results from this work will be presented at the World Conference on Stock Assessment Methods for Sustainable Fisheries, in Boston, Massachusetts in July 2013.

6. Kotaro Ono (UW PhD student) is continuing to evaluate the performance of new statistical methods to improve the accuracy of a catch per unit effort (CPUE) standardization method for application to multi-species fisheries, such as the West Coast groundfish fishery. He is specifically testing the effect of spatial stratification based on a CPUE trend cluster analysis, the inclusion of targeting behaviour, and the use of year*area interactions, on the accuracy of the derived index of abundance. He is developing general rules of thumb about when and where any of these methods should or should not be used. His simulation is based on a spatially-explicit 3-species (two target and one bycatch species) operating model that includes vessel dynamics. He is analyzing the results at present. In addition to this work, Ono is helping Melissa Haltuch (NOAA, NWFSC) on the 2013 assessment of petrale sole, and is taking the lead on the standardization of CPUE for that assessment.

7. The series of regular (generally bi-weekly) UW/NWFSC/AFSC Fisheries Think Tanks continued during the reporting period, coordinated by Ono. NMFS scientists and UW faculty and students participated 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.
Sablefish Reproductive Life History and Genetics

**PI**
Steven Roberts — UW School of Aquatic & Fishery Sciences

**Other UW Personnel**
Andy Jasonowicz, Doug Immerman, Crystal Simchick, Jon Dickey — UW School of Aquatic & Fishery Sciences

**NOAA Personnel**
Frederick Goetz, Penny Swanson, Krista Nichols, Adam Luckenbach, Jose Guzman — Northwest Fisheries Science Center

**Task II**

**NOAA Primary Contact**
Penny Swanson — Northwest Fisheries Science Center

**NOAA Goal**
Healthy Oceans

**Description**

Sablefish (Anoplopoma fimbria) are an important commercial fishery in the North Pacific, and currently are the highest valued finfish per pound in the Alaska fishery. However, information on their reproductive life history is very limited. While it is generally known that sablefish reproduce in the winter and early spring, the precise timing and duration of reproduction in a given population, and the relationship of timing to latitude, are still unknown. This study aims to assess the reproduction of sablefish populations at two sites in the Pacific (California and Washington) throughout the year by measuring gonadosomatic indices, assessing gonadal stage by histology, and by measuring the levels of reproductive hormones. This is being done on samples collected from sablefish taken monthly throughout the year.

While it is believed that different stocks of sablefish exist in the Pacific, the number and arrangement of those stocks is still unclear. Further, comprehensive genetic analyses of sablefish populations across the Pacific have not been conducted. A second part of this study is directed at developing SNP (single nucleotide polymorphism) markers by RAD (restriction site associated DNA) sequencing from samples taken across the entire range of sablefish from California to Alaska and across to the Aleutian Islands and the Bering Sea. SNPs will be used to evaluate population structure using standard population genetic methods, and for the evaluation of specific genes that may be under selection.

**Objectives**

1. Analyze the tissue samples that are being collected in the field – specifically, blood will be extracted and analyzed for estradiol (females) and 11-ketotestosterone (males); gonad tissue will be fixed and processed for histology and slides containing sections will be viewed under a compound microscope and stages of oogenesis and spermatogenesis described; and fecundity will be analyzed in the ovaries of females sampled at the peak of oogenesis. Once collected, data will be analyzed by ANOVA against sampling site and time.

2. Establish conditions for the cryopreservation of sablefish sperm by acquiring and using resources (temperature controlled freezing system, liquid nitrogen storage containers, and computer aided analysis system (CASA)).

3. Use RAD-tag sequencing to generate SNPs from sablefish samples to be taken on NOAA surveys. SNPs will be analyzed to evaluate the genetic relationship of sablefish across their range, and to identify possible SNPs under selection (showing unusually high or low patterns of diversity) in these populations.

**Accomplishments**

1. The reproductive life history study was initiated in August 2012 and sampling of sablefish off the Washington and California coasts has been underway on a monthly basis since that time. Thus, we are approximately halfway through the collection of samples. Processing of gonad samples collected during the first four months is complete, and slides have been made and are being analyzed for the staging of oogenesis and spermatogenesis. Samples were taken for the analysis of fecundity and methods for assessing fecundity are being developed. Assays used to measure the levels of steroids have been validated for use on the sablefish samples.

2. A Crystalyys PTC-9500 user-programmable controlled-rate freezing system and liquid nitrogen storage dewars were acquired for sablefish sperm cryopreservation and storage. A computer-aided sperm analysis (CASA) system (microscope, video camera, and computer) has been acquired and is operational for determining sperm motility as an endpoint for the analysis of cryopreserved sperm samples. Experiments have been initiated to determine the optimal conditions for storing and activating sablefish sperm.
3. For the completion of this objective, samples were collected in the summer of 2012 by various NOAA surveys conducted in Alaska and off the West Coast of the United States. The Alaska Fisheries Science Center’s Marine Ecology and Stock Assessment (MESA) division collected 1,922 fin clips and otoliths during their annual sablefish longline survey in the Gulf of Alaska. The Resource Assessment and Conservation Engineering Division (RACE) of the Alaska Fisheries Science Center collected 140 samples during their groundfish bottom-trawl survey of the Bering Sea slope and 580 finclip and otolith samples were obtained from the Fishery Resource and Monitoring (FRAM) Division’s West Coast Groundfish survey to represent the southern sablefish stock. A test RAD sequencing run of DNA isolated from selected samples taken across the surveys was conducted.
ECOHAB – Modeling Favorable Habitat Areas for Alexandrium Catenella in Puget Sound and Evaluating the Effects of Climate Change

**PI**
Eric P. Salathé, Jr. — UW Bothell School of STEM

**Other UW Personnel**
Nathan Mantua — UW School of Aquatic & Fisheries Science
Neil Banas — UW Joint Institute for the Study of Atmosphere & Ocean
Cheryl Greengrove, Julie Masura — UW Tacoma

**NOAA Personnel**
Stephanie Moore — Northwest Fisheries Science Center

**Task III**

**NOAA Primary Contact**
Quay Dortch — ECOHAB Program

**NOAA Goal**
Climate Adaptation & Mitigation

**Description**

The dinoflagellate Alexandrium catenella produces a suite of potent neurotoxins that accumulate in shellfish and cause severe illness or death if contaminated shellfish are consumed by humans. Alexandrium catenella form dormant cysts that overwinter on the seafloor and provide the inoculum for toxic blooms the following summer when conditions become favorable again for growth of the motile cell. In order to provide advanced warning of A. catenella blooms, managers need to know how much “seed” is available to initiate blooms, where this seed is located, and when/where this seed could germinate and grow. Evaluating how favorable habitat areas for cyst germination and vegetative growth will be altered by climate change would allow for risk assessments of A. catenella blooms through the late 21st century.

**Objectives**

The six objectives of this project are to:

1. Determine interannual variations in A. catenella cyst distribution in Puget Sound.
2. Quantify rates of cyst germination and vegetative growth for a range of temperature, salinity, and light conditions.
3. Determine the presence/absence of an endogenous clock that regulates cyst germination.
4. Model favorable habitat areas for cyst germination and vegetative growth.
5. Evaluate climate change impacts on favorable habitat areas.
6. Establish a time series with sufficient depth to provide seasonal forecasts of toxic blooms.

**Accomplishments**

1. This is the second year of the planned three year cyst mapping initiative. As mentioned last year, we shifted all three years of our cruises from the fall to January and February after reviewing the Washington State Department of Health (WADOH) shellfish data which indicated Alexandrium blooms could occur as late as November in Puget Sound. Cyst mapping needs to occur when vegetative Alexandrium cells are not in the water column in order to meet objective 1.

2. As cyst mapping efforts continue in Year 3 of this project, we will be able to meet objective 6 above, and evaluate relationships between cyst abundances and bloom severity the following year. This will allow us to determine the feasibility of using winter cyst mapping to provide seasonal bloom risk forecasts.

3. Three regional atmospheric climate simulations have been completed for this project using the Weather and Research Forecasting (WRF) model at 12 km grid spacing and forced by large-scale boundary conditions. One is a retrospective simulation (1948-2011) using NCEP-NCAR reanalysis as boundary conditions for WRF to support hind-cast studies where the historic observed timing of daily weather and interannual variability is required. Two are free-running climate simulations (1970-2070) forced by output from the ECHAM5 (Max Planck Institute, Hamburg) and CCSM3 (i.e., Community Climate System Model Version 3) global climate models. These results
provide forcing fields to the Regional Ocean Modeling System (ROMS) to simulate the circulation and biophysics of the coastal ocean and Puget Sound.

4. We have conducted a climate analysis of the WRF simulations and historical data to understand the linkages among regional climate, coastal upwelling, and physical conditions in Puget Sound. Results from an analysis of historic sea surface temperatures in the Northeast Pacific (NE Pac SST) and air temperatures at Puget Sound stations show strong correlation between the NE Pacific and the Sound. Results (Figure 1) suggest that the window of opportunity for Alexandrium may broaden by ~1 month in much of the region, particularly in the spring. The preliminary model also indicates that much of Puget Sound may, in future climate, exceed the optimal Norris and Chew (1975) temperature range in mid-summer.

**Figure 1**

**Media coverage**

Glenn Farley from King 5 news and Ashley Ahearn from KUOW joined the PS-AHAB science crew aboard the R/V Barnes during the 2012 Alexandrium cyst survey (Figure 2). The stories can be accessed using the following links:


**Figure 2**: Still shot from the King 5 news story and the online slide show for the KUOW story.

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

PI
Kathleen M. Stafford — UW Applied Physics Laboratory

Task III

NOAA Primary Contact
Catherine Berchok — National Marine Mammal Laboratory

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 of 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. Attend project meetings. Milestone: Use these meetings as an open forum in which to present proposals for acoustic research.

2. Coordinate analysis of the detection results with other members of the Bowhead Whale Feeding project, particularly Catherine Berchok of NMML, Mark Baumgartner of WHOI, and physical oceanographer Steve Okkonen of the University of Alaska, Fairbanks. Milestone: Documentation of temporal occurrence of bowhead whales in the study area and preparation for further analysis in successive years of this project. Milestone: Integrate oceanographic data when available with passive acoustic detections; determine temporal differences in call type usage.

3. Outreach/communication with other scientists, managers, and members of the North Slope Borough community to keep them up-dated on project progress and results. Milestone: Presenting material in scheduled meetings and through routine reports as requested.

4. Submission of manuscripts to peer-reviewed journals.

Accomplishments

1. Attended project meetings in Seattle (March 2012) and Anchorage (April 2013) to discuss results and synthesis of data from 5 years of BowFEST

2. Provided detections to Catherine Berchok and generated ambient noise level data for comparisons among years and locations. Bowhead whale detection data have been provided to Steve Okkonen to be compared with data from Acoustic Doppler Current Profiler data to determine if the diel vertical migration of zooplankton seen in the ADCP data corresponds with bowhead whale detections.

3. Visited Barrow in April 2012 and presented a talk at the local Saturday Academy, and interacted with hunters out on the ice. This entailed bringing a dipping hydrophone out on the ice so local hunters could listen to the ocean.

4. A manuscript co-authored with Kalyn MacIntyre and Catherine Berchok on bearded seal data has been accepted by *Polar Biology* pending revisions. A manuscript incorporating the bowhead whale detection data is in prep for a special issue of *Progress in Oceanography*. 
Ambient Noise Data
Ambient noise data from different hydrophones and different years are shown in the plots below (Figure 1). In all instances ambient noise levels are higher in the late summer and fall than at other times of the year. This is the open water season, and wind, wave, shipping, and seismic exploration all increase noise levels. For all locations, the highest ambient noise levels are at the lower frequencies which correspond to ice, shipping, waves, seismic and bowhead whale signals with some contribution from bearded seals. The interannual and geographic differences are presently being examined in light of the sources of sound at each location during each month.

Figure 1. Locations of passive acoustic recorders during the 2010-12 BOWFEST field season.
interannual and geographic differences are presently being examined in light of the sources of sound at each location during each month.

Ambient noise levels from four hydrophones deployed from August 2007–March 2008 for sites M2, M3, M4 and M5 as shown on the map in Figure 1.

**Figure 2:** Ambient noise levels from four hydrophones deployed from August 2007–March 2008 for sites M2, M3, M4 and M5 as shown on the map in Figure 1.

**Figure 3:** Ambient noise levels from four hydrophones deployed from August 2007–March 2008 for sites M2, M3, M4 and M5 as shown on the map in Figure 1.
Ambient noise levels from a single hydrophone deployed from August 2009 – August 2010 for site M3, as shown on the map in Figure 1.

Figure 4: Ambient noise levels from a single hydrophone deployed from September 2010 – July 2011 for site M2, as shown on the map in Figure 1.

Figure 5: Ambient noise levels from a single hydrophone deployed from September 2011 – July 2012 for site M3, as shown on the map in Figure 1.
Ocean and Coastal Observations
Observing System Research Studies

PI
Nick Bond — UW Joint Institute for the Study of Atmosphere & Ocean

Other UW Personnel
Andrew Chiodi, Kevin O’Brien, Karl Smith, Heather Koyuk — UW Joint Institute for the Study of Atmosphere & Ocean

NOAA Personnel
D.E. Harrison, Pacific Marine Environmental Laboratory

Task II

NOAA Primary Contact
D.E. Harrison, Pacific Marine Environmental Laboratory

Task II

NOAA Goal
Healthy Oceans

Description
The Observing System Research Studies group performs data and modeling studies to identify climatically significant ocean-atmosphere interaction patterns and their linkages to US and global weather anomalies, with the goals of improving our awareness and understanding of present climate conditions and the effectiveness of the global observing system for climate. The Observing System Research Studies group also develops and makes use of information technology capabilities to manage and analyze large observational and computer generated data sets.

Objectives
1. To undertake observing system research studies with an emphasis on evaluating and better understanding the activities needed to properly sample climate-relevant variability at the marine surface, in the upper ocean, and more generally for air-sea interaction.

2. The overarching objective is to identify useful climate indices/indicators of the state of the climate system, together with estimates of their uncertainty, that help society understand, forecast, and project seasonal and longer term weather and climate anomalies.

3. The project will also undertake other observing system research studies deemed important by the Office of Climate Observations, and work to develop and maintain information technology solutions that make global oceanographic and climate datasets more accessible to the wider scientific community.

Accomplishments
1. Group work has led to publication of a manuscript that describes how outgoing longwave radiation (OLR) information over the tropical Pacific can be used to sort through the El Nino events identified by the commonly used definitions to separate those that are most likely to have a strong influence on U.S. weather from those that are not. Since the tell-tale OLR behavior typically occurs before winter, considering this OLR behavior may allow more skillful seasonal forecasts to be issued than previously thought possible (see Chiodi and Harrison 2013 and the NOAA press release archive http://www.noaanews.noaa.gov/stories2013/20130207_pmel_elnin.html for more information).

2. Further work has identified a comparably useful OLR-based index for La Nina and shown that not just in the U.S., but globally as well, most of the useful seasonal weather associations are due to the El Nino and La Nina years distinguished by OLR behavior.

3. We have shown that El Nino and La Nina events have substantially asymmetrical effects on the global carbon cycle. It has long been known that there is a connection between ENSO behavior and the atmospheric CO2 variability. Our results reveal that the El Nino effects are about twice as large and persist longer into the calendar year than the La Nina effects. We expect these results will provide useful benchmarks for the ongoing development and evaluation of Earth System Models (see Figure 1 below).

4. Recent results have confirmed, with a near doubling of period, that Westerly Wind Events in the western equatorial Pacific (various tropical weather phenomena that produce average westerly winds of ~7m/s for ~7 days) remain a primary forcing for the cold-tongue warming seen in the developing stages of El Nino events. Our analysis shows, on the other hand, that the Madden-Julian Oscillation (MJO), an atmospheric phenomenon characterized by lower amplitude easterly-westerly oscillations in tropical near-surface winds that occur over timescales of 40-80 days, is not closely connected with such warming unless a WWE occurs during an MJO. Further results show that the presence of an MJO does not significantly affect the likelihood of seeing a WWE. Thus, studying WWEs remains important for better understanding the predictability of warm-ENSO events. Up to now, the published literature is unclear about these relationships.
5. We have revisited the question of whether or not ENSO has a very-long term trend, and whether such a trend can be reliably determined from multi-decadal subsegments of a geophysical historical record. We use the Darwin sea level pressure record, the longest (135yr) high-quality ENSO-proxy available to do this, and find that the full-record trend in this case is not found to be statistically significant, even by the most lenient statistical test considered, while, on the other hand, even the strictest test finds many more statistically significant trends at shorter multi-decadal timescales (both positive and negative) than should be expected under the null hypothesis of there being no long term trend. These results offer a cautionary reminder about the risks of imputing meaning to the trends seen in geophysical time series based on statistical methods alone.

An illustration of some of the CO2-ENSO results from group work:

![Figure 1: El Niño-Southern Oscillation effects on atmospheric CO2.](image1)

The illustration at left summarizes some of the main results of our composite study of the effects of El Nino and La Nina on the concentration of CO2 in the atmosphere. Based on analysis of annually-averaged CO2-change measures, El Nino effects are more than 50% larger than La Nina effects. At seasonally-averaged timescales, it is clear that ENSO effects are seen in winter-to-spring CO2 levels in each phase, but there are also some asymmetries in timing; significant El Nino effects begin later and last about a season longer than the La Nina effects. The composite CO2-change amplitudes revealed here are on the same order of magnitude as the trend due to fossil fuel emissions. We believe these results provide useful benchmarks to test for the successful inclusion of biogeochemical processes in coupled land-ocean-atmosphere models.

6. Information Technology-side accomplishments. The Observing Systems Research Studies group has been actively involved in promoting and encouraging data integration and interoperability through the embracing of community data and metadata standards. We have also been involved in providing improved community access to data and data products.

Data Integration Efforts.
Through projects that we lead, including the Observing System Monitoring Center (OSMC), and the Unified Access Framework (UAF), we have been working to promote the use of data standards to improve data interoperability. In the past year, we have implemented, through the UAF project, a tool that allows us to crawl remote data catalogs, analyze the information collected, and then create a new, publicly available, catalog that serves data through a wide variety of data access services.

This process makes the data directly available through many popular desktop and web applications for analyzing and visualizing data, and allows scientists to use those tools with which they are most comfortable. We have successfully been able to serve data from a wide variety of NOAA and non-NOAA sources to the community and, in fact, have made available approximately 11,000 datasets in this manner. Up to this point, the primary data focus has largely been numerical model data. However, we have recently embarked on work to provide interoperable access to the entire collection of real-time ocean observation data. This work, done through the OSMC project, aims to allow access to the near-real time stream of ocean data through a wide variety of services and formats. We aim to wrap up this work in FY2013. In the coming year, we will also be working on similar data integration issues with science groups at NOAA’s Pacific Marine Environmental Laboratory (PMEL), including the Ocean Acidification group.
7. Community access to data and data products. In addition to leading the community in attempts to improve data integration and interoperability, the Observing System Research Studies group continues to help scientists visualize and analyze data. The group has also been involved in assisting scientists in creating very high quality data products.

PyFerret, the python version of the popular application Ferret, has been officially released for public use. In fact, it is currently being widely used at NOAA’s Geophysical Fluid Dynamics Laboratory (GFDL) in the post-processing workflow that is integrated with all of their model runs, including those as part of the Coupled Model Intercomparison Project (CMIP). PyFerret has greatly improved graphics creation and integration of numerical and scientific libraries. In addition, we have added two additional dimensions to the computational facilities of Ferret/PyFerret. These two additional dimensions will allow scientists to extend their analysis to a total of six dimensions. Typically, the additional dimensions will be used for ensemble and forecast analysis, both of which are becoming increasingly important to large-scale modeling projects.

The group continues to play a central role in the data management of the Surface Ocean Carbon Atlas (SOCAT) project. This project, which establishes a high quality, global surface CO2 data set, has laid the foundation for years to come in terms of defining formats for metadata and data, as well as methods for doing first level quality control. The SOCAT v2 update, which extends the data through Dec, 2011 and contains 10.1 million observations, will be released in June, 2013 at the 9th International Carbon Dioxide Conference (ICDC9) in Beijing, China. In addition, we are already hard at work making vast improvements for the next version of SOCAT. Version 3 of SOCAT will include an automated system for scientists to submit their data and metadata and will be designed to provide some first level quality control. The automated system will allow updates to the global SOCAT data product to be released on a more frequent basis.

Information Technology-side Presentations

- O’Brien, Kevin M., “SOCAT v2 status and SOCAT v3 automation plans' SOCAT data managers meeting, July 3-5 2013, Tsukuba, Japan
Ocean Climate Stations

PI
Nicholas Bond — UW Joint Institute for the Study of Atmosphere & Ocean

Other UW Personnel
Keith Ronnholm, Jennifer Keene, Adrienne Sutton — UW Joint Institute for the Study of Atmosphere & Ocean

NOAA Personnel
Meghan F. Cronin, Christian Meinig — Pacific Marine Environmental Laboratory

Task II

NOAA Primary contact
Dr. Diane Stanitski — NOAA Climate Program Office

NOAA Goal
Climate Adaptation & Mitigation

Project 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 partnerships. 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.

All OCS moorings carry a suite of sensors to monitor air-sea heat, moisture, and momentum, as well as the upper ocean temperature, salinity, and currents. The surface buoy also contains systems for measuring the carbon fluxes (CO₂) into or out of the ocean, and the associated effects on ocean acidification (pH measurements of surface water). Surface

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.
and subsurface data are telemetered to shore in near-real time. OCS data are made available through the project website http://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. Subsets 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.

PMEL OCS stations contribute to the global network of OceanSITES reference stations. These stations provide high quality data that can be used to assess biases and uncertainties in forecasting model and observational product analyses, to detect rapid changes and episodic events, as well as long-term changes in the climate system, and to identify mechanisms and relationships within the climate system.

Objectives

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

1. JISAO and NOAA scientists participated in two cruises during 2012 in support of the Papa and KEO stations. In June 2011, JISAO employee Jennifer Keene, along with NOAA mooring specialist Michael Craig 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 2013 deployment. Currently, all systems are functioning properly and real-time data are being telemetered from the buoy by the ATLAS, CO2 and FLEX systems.

2. In July 2012, JISAO employees Keith Ronnholm and David Zimmerman successfully recovered the KEO mooring and deployed a replacement mooring. Work was performed from the JAMSTEC research ship MIRAI. The prior KEO mooring and all subsurface sensors were recovered, and the newly deployed system remains fully functional.

3. Keene led the effort to find and implement a solution to the early termination of data collection from subsurface Seabird instruments due to issues with the Lithium AA batteries. The redesigned battery packs were deployed in the summer of 2012, and to-date, no instruments have failed due to battery depletion. Keene has also conducted all of the field-testing of the internal software in the newly developed FLEX data logger.

4. OCS website pages were viewed over 17,800 times during the federal fiscal year 2012 (Oct 2011-Sept 2012) and over 79 GB of text and data were downloaded by visitors. In addition, the OCS Data Display and Delivery page had 180 download requests, yielding 385 ASCII files and 281 cdf files. Over the last two years, data was requested by users in government agencies (NOAA, CPC, NCEP, NASA, DFO Canada, JAMSTEC, UK Met Office) and Universities (UW, UW/APL, JHU/APL, Scripps, MBARI, University of Cape Town, University of Tokyo, Tohoku University, Korea Institute of Ocean Science and Technology, Imperial College London, University of Redding UK) and by many 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. It should be noted that we still also make KEO and Papa data available through project pages that do not require user registration, and therefore the above data download statistics are an underestimate. During 2013, Ronnholm expects to complete a major redesign of the OCS website that should make it easier to obtain information about sensors and data collection parameters.

5. An ongoing project begun in June 2012 is the development of data processing procedures for the release of data from primary and redundant sensors from the moorings, an enhancement beyond the previous release of “best available” data. Data released will be in the standardized OceanSITES. Ronnholm has been coordinating this activity and JISAO personnel Curran Fey, Daniel Dougherty, and Dai McClurg have been preparing the data and processing procedures.

6. An effort to improve the accuracy of relative humidity measurements, led by Keene, resulted in an OCS technical note documenting the wide range of tests and data analysis conducted, and has resulted in an improved calibration procedure.
7. The JISAO team has published three peer-reviewed articles and has one peer-reviewed article in press, while three others are under review. Several more articles are currently in preparation, and three non-peer review articles were published or are in press in professional newsletters and conference proceedings. Of note, Cronin et al. (2013) used more than 5 years of KEO data to evaluate the processes responsible for the formation and erosion of the seasonal thermocline in the Kuroshio Extension Recirculation Gyre.

8. Meghan Cronin organized a one-day Station P science workshop at PMEL on April 2, 2012. The workshop brought together more than a 15 researchers from UW, PMEL, and IOS to discuss collaborative projects that have resulted from the OCS mooring deployment at Station P, including three UW PhD dissertation projects. Another similar one-day meeting focused on “Station Papa ‘Holistic’ Ocean Balances” is planned for April 4, 2013.

9. While the NSF RAPID grant to Nicholas Bond for the deployment of a surface flux mooring in the Agulhas Return Current was completed in 2011, research activities have continued. Most notably, Cronin was a co-organizer for the Chapman Conference on “The Agulhas System and its Role in Changing Ocean Circulation, Climate, and Marine Ecosystems”, held in South Africa October 8-12, 2012. At the conference, Cronin presented an invited talk and two poster presentations. She also spoke at a high school science class in a black township and continues to work with these students through the South African Environmental Observation Network and the NOAA Adopt a Drifter program.

10. Cronin and JISAO team member Ronnholm participated in the Line-P workshop held in Sydney, B.C. in March 2013. The purpose of this workshop was to help coordinate work on the upcoming Line-P cruise (JISAO will participate in the June 2013 cruise), and to foster collaboration with Line-P and Station P data. Discussions included the integration of the Papa mooring into the array of subsurface flanking mooring being deployed as part of the NSF Ocean Observing Initiative (OOI).

Figure 2. The KEO-2012 mooring is shown just after deployment from the Japanese R/V Mirai in July 2012. Sensors for wind speed and direction, air temperature, relative humidity, barometric pressure, rainfall, solar and infrared radiation are visible on the tower. The buoy hull contains batteries, data telemetry systems, and a MAPCO2 system to measure the flux of CO2 between the atmosphere and ocean. The buoy, anchored in 18,000 feet of water, has 28 subsurface instruments attached to the anchor wire to measure ocean temperatures, salinity, pH, and currents.
The Effect of Wind-Driven Mixing on Observations of Plastic Marine Debris: Modeling, Verification and Reanalysis

**PI**
Giora Proskurowski — UW School of Oceanography

**Non-UW/NOAA CO-PIs**
Kara Lavender Law — Sea Education Association; Tobias Kukulka — University of Delaware

**Task III**

**NOAA Primary Contact**
Nancy Wallace, Courtney Arthur — Office of Response and Restoration- Marine Debris Program

**NOAA Goal**
Healthy Oceans

**Description**

Since the introduction and popularization of “engineered thermoplastics” in the 1950s, plastic has become one of the world’s most important and widespread commodities. The same engineered properties that contribute to the enormous utility of plastic, namely durability and resistance to degradation, also result in long residence times (decades to millennia) when plastic is introduced into the natural environment. The bulk of scientific measurements of plastics in the open-ocean come from surface net tows. However, because the surface ocean is a dynamic environment and plastic fragments act as passive particles, this plastic debris is subject to the physics of mixing within the ocean surface boundary layer. Thus, surface measurements underestimate the total amount of plastic in the upper water column. Previous results by our project team suggest that the surface ocean actually contains between 2 and 27 times the amount of plastic measured using surface net tows. This project is designed to improve our modeling ability, as well as provide the scientific and citizen scientist communities with easy-to-use numerical tools to report total plastic content given surface plastic and wind observations.

**Objectives**

We have three major work objectives:

1. To validate the numerical model with additional laboratory data, resulting in an improved model that can be easily adopted by the marine debris community.

2. To apply this improved model to ultimately reanalyze a multi-decadal data set of surface plastic observations.

3. To publish and present the model in an accessible manner so that interested scientists and citizen scientists can apply measurements of surface plastic and wind speed to get total plastic content. In order for model results to be accepted as a useful modification to pure observations by the scientific community, it must be both trusted and viewed as an important contribution. It is our intent to use the reanalysis of a broader subset of the Sea Education Association (SEA) Atlantic dataset to illustrate the importance of including wind speed into plastic content estimates, and to build confidence in the methodology.

**Accomplishments**

The award was granted in late August 2012, and money arrived at JISAO in September 2012. Subcontracts were sent out to the University of Delaware and the SEA in late September, but not finalized until late October for the University of Delaware, and January 2013 for the SEA. Despite the slow progress in moving funding, the project proceeded through the following activities:

1. A graduate student at the University of Delaware was chosen, briefed on the project, and familiarized with the current model mathematics and code. The student proceeded to incorporate more complexity into the initial 1-dimensional model, bringing increasing realism to the modeling effort. One preliminary result is that when components of Langmuir circulation were incorporated into the model, the vertical distribution profiles bear an increasing resemblance to the observed plastic profiles.

2. The reanalysis of the Atlantic data set using the new, more complex, model commenced (see Figure 1). Data sets for external wind measurements (e.g. satellite) were identified, and the data is being matched to samples.
3. Samples were identified and acquired for physical property measurements, polymer composition, and rise velocity. These samples are from depth-tow Tucker trawl net tows during a 2010 cruise in the North Atlantic subtropical gyre. Sample ownership is with the SEA, and a Memorandum of Understanding was put into place for the study and use of these samples.

4. A draft text of a publication of accessible model explanation is in revision. The target journal is *Marine Pollution Bulletin*.

5. We are still on track to meet all objectives, and have received verbal approval for an extension beyond the August 31, 2013 project end date to accommodate the academic schedules of the PIs and graduate students involved.

---

**Figure 1.** Spatially-averaged plastic concentration as determined from (a) 343 surface net tow measurements, (b) depth-integrated plastic content from model calculations using surface net tow measurements and concurrently measured wind speed, and (c) preliminary results from new more complex model incorporating elements of Langmuir circulation. Figure parts (a) and (b) from Kukulka et al. (2012).
The Argo Project: Global Observations for Understanding and Prediction of Climate Variability

PI
Stephen C. Riser — UW School of Oceanography

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

Task III

NOAA Contact
Steve Piotrowicz — NOAA Climate Program Office

NOAA Goals
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 30 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, Stephen Riser serves as a member of the US and International Argo Steering Teams.

Objectives
1. 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.

2. 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 (Scripps Institution of Oceanography (SIO), Woods Hole Oceanographic Institution (WHOI), Pacific Marine Environmental Laboratory (PMEL), and UW).

3. In the past year funds were received to build and deploy 90 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.

4. 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
1. During the past year, the team deployed 107 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 five winter seasons.

2. 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.

3. In addition, floats were deployed in the western N. Pacific, in the Kuroshio Extension region, in a jointly NOAA-NSF sponsored program to examine the oceanic uptake in CO2, in the western Pacific along the subtropical/subpolar boundary. In this case, US Argo floats were equipped with O2 sensors (funded by NSF) in order to help to interpret a large amount of CO2 and carbon-species data collected via ship-based resources (funded by NSF). Eleven NOAA-sponsored Argo floats were deployed during the cruise. Note that in the past several years, the US Argo consortium has strongly suggested that western boundary current regions were places where enhanced Argo sampling (beyond the standard 3° × 3° resolution) is desirable.
Protection and Restoration of Marine Resources
Northwest Fisheries Science Center and University of Washington Undergraduate Intern Program

PI
Janice DeCosmo — UW Undergraduate Academic Affairs

Other UW Personnel
Tracy Nyerges — UW Center for Experiential Learning and Diversity

Task III

NOAA Primary Contact
Kathleen Jewett — Northwest Fisheries Science Center

NOAA Goal
Resilient Coastal Communities & Economies

Description
This project is an educational collaboration between Undergraduate Academic Affairs at the University of Washington (UW) and the 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. Between 5 and 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.

2. One of the internships will also include fieldwork and travel during the summer.

3. Selected interns will commit between 10 and 19.5 hours per week during the academic year and up to 40 hours per week during summer and interim periods to their research projects. The number of interns engaged in the program will depend upon the time commitment each intern is able to make to the experience, the type of research in the host lab – for instance, some research requires longer blocks of time and occasional field work – determines the total number of students involved each year.

4. 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, and presenting their projects in poster format at NWFSC and/or at the UW undergraduate research symposium.

5. Anticipated outcomes 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, six students participated in the internship program, and three new interns came on board in January, 2013. All of the interns participated in networking activities and poster sessions at NWFSC.

2012 Interns/Majors
• David Berman, Aquatic & Fishery Sciences
• Stanley Biryukov, Public Health
• Brian Harmon, Aquatic & Fishery Sciences
• Kelsi Penewit, Biology
• Oleksandr Stefankiv, Environmental Science & Resource Management
• Megan Stephens, Biology

2013 Interns/Majors
• Zach Oyafuso, Aquatic & Fishery Sciences
• Susie Dobkins, Aquatic & Fishery Sciences
• Yu-Hsuan Peng, Biology
Fish Productivity and Fishing Impacts Compared Across a Range of Marine Ecosystems

**Objectives**

1. Compare shifts in mean trophic level across ecosystems in surveys, stock assessments and catch.

2. Evaluate the correlation between species, trophic levels and functional groups and productivity over time. Analyses will investigate:
   a. Temporal trends and variability in productivity of individual stocks, as well as production for the ecosystem as a whole.
   b. The correlation structure of surplus production, either by species, trophic levels, or functional group (pelagic/demersals).
   c. 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:
   a. Environmental impacts on productivity.
   b. The extent to which productivity has been driven by abundance, environmental regime changes, or random fluctuations.
   c. 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).
   d. The correlation in breakpoints across species or groups for significant regime shifts.
   e. 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).
   f. 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. Compiled and analyzed data sources from NOAA trawl survey databases, fisheries observer data, stock assessments, and environmental indices.

2. Characterized trends in biomass for individual species and aggregate functional guilds in the eastern Bering Sea (EBS), Gulf of Alaska (GOA), Aleutian Islands (AI) systems.

3. Developed correlation matrices of species abundance trends within functional guilds.

4. Mapped comparisons abundance and coefficient of variation in abundance of species to distinguish core habitats and use of marginal habitat in response to species density.

5. Applied random forest methods to quantify threshold responses in individual species to a range of environmental variables (e.g. temperature, depth, substrate, stratification) and determined variable importance measures as a means to classify species by common response to environmental forcing.

6. Integrated random forest outputs from multiple species, synthesizing goodness-of-fit and predictor importance metrics to estimate turnover in species composition along environmental gradients.

7. Clustered output of community threshold shifts in a spatial context, representing inferred biological assemblages associated with features in the physical environment, as a means to delineate distinct ecological regions within marine ecosystems.

8. Analyzed the effects of climate effects on extent and stability of ocean habitats, fish distributions, and outputs related to the delineation of distinct ecological regions.

9. Computed variance ratio tests at a system level (between functional guilds) and within functional guilds (between species within guilds) to determine evidence for compensation related to inter-species competition in the EBS, AI, and GOA ecosystems.

10. Developed and applied 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.

11. Applied dynamic factor analysis (linear combinations of hidden random walks) to identify common underlying time series trends in abundance for species within functional guilds and determine factor loadings and correlation to environmental indices.

12. Developed lag-one multispecies autoregressive models to facilitate analyses of the relative influence of species-specific density dependence, inter-species compensation, climate indices, and fishery extraction in productivity trends.

13. Presented poster at the Western Groundfish Conference, February 2012.


15. Presented and participated in FATE workshops on improving ecosystem-based assessment and forecasting through a hierarchical approach to link fish productivity to environmental drivers, September 2012.


17. Presented analyses at the Alaska Fisheries Science Center (RACE) Seminar series, February 2013.


Awards received

Matt Baker was selected as ICES Early Career Scientist, and invited to present research at conference of peers.
Fisheries Acoustic Research

**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, 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 (AFSC) and postdoctoral associates working with RACE scientists. Service activities include fostering collaboration between the SAFS and the AFSC, co-organizing and administering the SAFS-AFSC 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 adapt and apply spatiotemporal distribution metrics developed using acoustic survey and ocean observatory data to additional data analyses.
3. To automate classification of acoustic backscatter using multifrequency data.

**Accomplishments**

1. A total of eight graduate students (4 Masters, 4 PhDs) were active during the reporting period. Kresimir Williams defended his PhD dissertation entitled, “Estimation of midwater trawl selectivity and its influence on acoustic-based fish population surveys,” which examines the influence of midwater-trawl catch bias on acoustic abundance estimates and subsequent stock assessment population models. The first chapter, “Length-selective retention of walleye pollock, Theragra chalcogramma, by midwater trawls” was published in the *ICES Journal of Marine Research* in 2011. The second chapter, “Walleye pollock (Theragra chalcogramma) behavior in midwater trawls” is scheduled for publication in *Fisheries Research*. The first chapter of Steve Barbeaux’s PhD dissertation, “Characterizing walleye pollock (Theragra chalcogramma) winter distribution from opportunistic acoustic data” has been accepted by the *ICES Journal of Marine Science*. Stan Kotwicki, a PhD student who has transferred to the laboratory has published the first chapter of his dissertation, “Combining bottom trawl and acoustic data to model acoustic dead zone correction and bottom trawl efficiency parameters for semi-pelagic species” in the *Canadian Journal of Fisheries and Aquatic Sciences*.

2. When monitoring aquatic life with remote sensing tools, a large challenge is parsimoniously characterizing spatial and/or temporal distributions of aquatic organisms. Previous efforts have developed suites of metrics that were used to quantify spatial distributions of walleye pollock in the Bering Sea (Burgos and Horne 2008), and temporal fluxes of acoustic backscatter at an observatory in Monterey Bay (Urmy et al. 2012). This approach is being adapted to two additional applications: marine renewable energy, and bathypelagic layers. Monitoring the effects of marine renewable devices on biological community composition and distribution is just recently being addressed by federal regulators, device developers, and biological researchers. The suite of metrics used to characterize changes in vertical distributions of acoustic backscatter at an observatory is being tested and applied to spatially and temporally indexed data collected at a proposed tidal marine renewable energy site in Puget Sound, WA. Use of the metric suite will enable standardized monitoring of aquatic organisms in the water column at offshore wind, surface wave, or tidal turbines at any marine renewable site.
Design and Conduct Research to Reduce Seabird Bycatch in West Coast Longline Fisheries

PI
Edward F. Melvin — UW Washington Sea Grant/School of Aquatic & Fisheries Sciences

Other UW Personnel
Troy Guy, Sarah Jennings — UW Washington Sea Grant

NOAA Personnel
Tom Good, Northwest Fisheries Science Center

Non-UW/non-NOAA Personnel
Rob Suryan, Amanda Gladics — Oregon State University

NOAA Primary Contact
Tom Good, Northwest Fisheries Science Center

NOAA Goals
Healthy Oceans

Description
The incidental take of a rare, ESA-listed short-tailed albatross in the West Coast sablefish longline fishery in April 2011 has focused attention on seabird-fisheries interactions and bycatch mitigation efforts in the West Coast groundfish fisheries. The overlap of wide-ranging seabirds with commercial fisheries virtually guarantees seabird interactions with fisheries prosecuted within the U.S. Exclusive Economic Zone. Interactions with longline vessels include seabirds attacking baited hooks after their deployment, where they can get hooked or snagged on the gear, and can be pulled underwater where they drown. In addition to the high-profile short-tailed albatross take, black-footed albatross bycatch in the last decade has been documented in three sectors (fixed gear limited-entry sablefish primary – tier endorsed), fixed gear open access daily trip limit, and at-sea Pacific hake). The take of black-footed albatross, a species of concern that co-occurs with the short-tailed albatross, primarily occurs in the longline fisheries for sablefish. While no take limit is currently in place for short-tailed albatross in West Coast groundfish fisheries, in Alaska, biological opinions issued by the U.S. Fish and Wildlife Service currently limit incidental take of short-tailed albatross in the Pacific halibut longline fishery (two birds in two years), the groundfish longline fishery (four birds in two years), and the trawl fishery (two birds over the time period in which the current biological opinion remains in effect). An incidental take statement for short-tailed albatross is likely to result from an ESA consultation initiated between NMFS and the USFWS.

All of this highlights the need for pro-active, cooperative research with the fishing industry on ways to minimize seabird bycatch in West Coast groundfish fisheries. Fortunately, there is model for such an endeavor. In collaboration with the fishing industry, National Marine Fisheries Service, and the U.S. Fish and Wildlife Service, Washington Sea Grant has been a pioneer in the field, conducting research to test a host of seabird bycatch mitigation measures in Alaska demersal longline fisheries among others. Their research spawned innovation that won the 2011 World Wildlife Fund Smart Gear grand prize and tuna prize awards, and their research has led to new International Commission for the Conservation of Atlantic Tunas conservation measures, as well as revised regulations in the South Africa tuna joint venture fishery, the Commission for the Conservation of Antarctic Marine Living Resources longline fisheries, and Alaska and British Columbia groundfish and Pacific Halibut longline fisheries. In Alaska, streamer lines, also known as tori lines or bird scaring lines, were shown to be the most effective mitigation measure, reducing mortalities of albatrosses and other surface foraging seabirds by 96 percent when used singly and by 100 percent when used in pairs bracketing the sinking longline. This body of research has led to the adoption of streamer line performance and material standards by the Alaska industry, and their continued use has significantly reduced seabird bycatch in Alaska demersal longline fisheries. Washington Sea Grant-led research has also clarified appropriate streamer line configuration for smaller vessels and vessels using snap-on gear, and demonstrated that mitigation was unnecessary in inside waters of Southeast Alaska, Prince William Sound, and Cook Inlet.

Seabird mitigation is not currently required in West Coast groundfish fisheries, although Washington Sea Grant has recently initiated a program to promote voluntary use of streamer lines. A recently completed (November, 2012) Biological Opinion for West Coast groundfish fisheries by the UW Fish and Wildlife Service establishes an incidental take of two short-tailed albatross over two years and calls for the use of streamer lines on West Coast longline vessels 55 feet and over. The regulatory change will go through the rulemaking process of the Pacific Fishery Management Council in 2013. The bulk of the fleet under 55 feet will not be required to use mitigation under the Biological Opinion. Nonetheless, the need for research to determine the most effective seabird mitigation for the specific conditions experienced by the West Coast demersal longline fleets is clear, as is the need to develop mitigation options for smaller vessels and to encourage vessels under 55 feet to voluntary adopt albatross mitigation technologies.
Objectives
The key part of the project is the estimation of seabird interactions with longline fisheries under alternative configurations of seabird avoidance streamer lines, as well as the floats and weights used on longlines in these particular fisheries. These data would make possible recommendations for seabird bycatch mitigation throughout the West Coast longline fleet. Specifically, Washington Sea Grant will carry out a number of tasks to assist in creating recommendations for seabird bycatch mitigation in the West Coast sablefish longline fisheries. These include:
1. Recruiting and training fishing industry liaisons.
2. Identifying host longline fishing vessel for research through liaisons and other cooperators and providing incentives for their participation in the research activity (in lieu of vessel charters).
3. Designing and conducting research to estimate and minimize seabird bycatch rates and seabird attack rates on baited hooks as they are deployed. The research activity would seek to develop gear configurations that maximize longline sink rates and streamer line efficiency. Configurations could include modifying streamer line design and deployment strategies as well as the sequence and arrangement of weights and floats on the longlines.
4. Deliverables is a final report at the end of the project.

Accomplishments
1. Collected preliminary data at-sea for eight days on a longline vessel out of Astoria, OR. This opportunity allowed us to cross-train staff, while implementing and testing protocols.
2. Developed protocols to measure the sink rates of longlines and to quantify the rates of seabird attacks by species on sinking baited hooks.
3. Criteria were developed for selection of port-liaisons, as were tasks and timelines for the work they would do under the project.
4. We are in the process of developing an ad-hoc advisory committee to recruit liaisons with the priority of establishing project liaisons in Newport, OR, Neah Bay, WA, and Seattle, WA.
5. In the reporting period, Washington Sea Grant secured new funding in the amount of $115,000 from the Packard Foundation to further support the research and port liaisons under this grant, and to expand outreach efforts to the sablefish longline fleets with port-to-port workshops. We were also able to leverage funding from this project and from related funding from NMFS Northwest Region as match, allowing an award to Oregon State University from the National Fish and Wildlife Foundation to expand the personnel and resources for the work under this grant, as well as a grant from the Northwest Region, and the Packard Foundation.
6. Difficulties in routing NMFS funding to Washington Sea Grant delayed progress on this project in this reporting period. Although Northwest Science Center learned that this project would be funded in early February 2012, the mechanism by which funding could be made available to the University took time to determine. Uncertainty regarding the likelihood and timing that funding would be made available for this project suspended most plans to recruit port liaisons until winter of 2013. The sablefish longline fishing effort peaks in April and May; therefore, funding was highly uncertain for this time period. The five weeks following formal notification of funding was insufficient to fully ramp up programs for fall 2012.
3. A second application of metric suites is the characterization of aquatic life in the deep sea across latitudinal gradients. Two depth strata (1,000-1,500 m; 1,500 m to bottom) are being characterized using 18 kHz acoustic data from a survey extending from south of Iceland to the Azores Islands. Three regions are being examined inside, and south of the Charlie Gibbs Fracture Zone (Fig. 1). Use of the metric suite will enable comparison of vertical distributions through the water column and along the mid-Atlantic Ridge.

4. Automated classification of remotely-sensed acoustic data remains a long term goal in the fisheries acoustics community. This project extends the work of Woillez et al. (2012) through the development and implementation of a semi-supervised, Bayesian Dirichlet Process Mixture Model clustering algorithm to classify multifrequency acoustic data. The extension also includes a mechanism for the selection of the number of groups in the classification model, the ability to include knowledge from training data, and adjust the resolution of clustering when new data are added. Objective, probabilistic classification of constituent fish and macroinvertebrate species is expected to increase reproducibility of analyses, reduce bias from supplementary direct samples, increase data processing efficiency, and provide estimates of classification uncertainty. At this time, the algorithm has been coded and initial testing with known species composition data has been completed. Application of this approach can be expanded beyond fisheries science to any field with a need to categorize multithreaded, remotely-sensed data that has supplemental samples.

Figure 1. Metric suite characterizing 18 kHz acoustic backscatter measured along the mid-Atlantic Ridge in two depth strata: 1000-1500 (left panel) and 1500 to bottom (right panel). Metrics include (from left to right in each panel): aggregation index (m²), proportion occupied (%), area backscattering strength (Sa), center of mass (m), and inertia (m²). See Urmy et al. (2012; ICES J. Mar. Sci. 69: 184-196) for metric calculations.
Marine Biological Interactions in the North Pacific – Fish Interactions

PI
Bruce Miller — UW School of Aquatic & Fishery Sciences

Other UW Personnel
Richard Hibpshman, Kirstin Holsman, Sean Rohan, Caroline Robinson, Kimberly Sawyer — UW School of Aquatic & Fishery Sciences
George A. Whitehouse — UW Joint Institute for the Study of Atmosphere & Ocean

NOAA Personnel
Kerim Aydin, Stephani Zador — Alaska Fisheries Science Center

Task II

NOAA Primary Contact
Kerim Aydin — Alaska Fisheries Science Center, Resource Ecology & 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. To perform investigations of the Feeding Ecology of North Pacific Fishes.
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. Multispecies Statistical Model modifications – as part of NOAA’s Integrated Ecosystem Assessment (IEA) program, a multispecies statistical model (MSM) was developed for the Bering Sea, connecting the stock assessment models of three groundfish species. Considerable statistical work was performed for the improved, bioenergetic estimation of fish rations based on 30 years of available diet data.
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. This year, the Ecosystem Considerations chapter includes both new and updated sections.
5. The section describing ecosystem and management indicators includes updates to 44 individual contributions, and presents seven new contributions. In November 2012, the Eastern Bering Sea and Aleutian Islands Ecosystem Assessments were updated. In August 2012, an initial draft of the Arctic Ecosystem Assessment and Report Card was produced.
6. The EBS and AI report cards and Ecosystem Assessments were presented to the NPFMC Groundfish Plan Teams in November 2012, and to the NPFMC in December 2012, as part of the annual catch specification process. The final report, including the Report Card and the Ecosystem Assessment, is available at http://access.afsc.noaa.gov/reem/ecoweb/Eco2012.pdf
7. Develop ecosystem models of Arctic regions – a 2-year research project was completed to build an ecosystem model for the Chukchi Sea marine ecosystem. The model will be used to 1) characterize the trophic structure of the eastern Chukchi Sea; 2) investigate the potential impacts of introducing commercial fisheries for snow crab (Chionoecetes opilio) and/or arctic cod (Boreogadus saida); and 3) identify key uncertainties about food web dynamics.

Accomplishments
1. Investigations of the Feeding Ecology of North Pacific Fishes – a total of more than 19,000 groundfish stomachs were analyzed in the laboratory or at sea.
Coastal Observation and Seabird Survey Team (COASST)

PI
Dr. Julia K. Parrish — UW School of Aquatic & Fishery Sciences

Other UW Personnel
Jane Dolliver, Elizabeth Mack, Charles Wright — UW School of Aquatic & Fishery Sciences

Task III
NOAA Primary Contact
Kim Rivera, National Marine Fisheries Service, Alaska Region

NOAA Goals
Healthy Oceans
Resilient Coastal Communities & Economies

Description
COASST is citizen-science program in which trained volunteers collect data monthly, or more frequently, 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 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 14 training and refresher sessions to train new volunteers and refresh skills of current volunteers (Alaska: Cordova, Homer; Washington: Stanwood, Aberdeen, Coupeville, Moclips, Kalaloch; Oregon: Florence, Newport, Bandon, Cannon Beach, Lincoln City, Brookings, Port Orford).
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 requester directly (5 requests: Oregon State University, Washington Dept. of Natural Resources, Kenai Fjords National Park, The Learning Enrichment Center, Olympic Coast National Marine Sanctuary).
4. Analyzed existing data for fishery mortality trends, and trends in beaching rates of species known to be bycatch in North Pacific fisheries.

Figure 1: COASST participants tag a Sooty Shearwater as part of their beached bird survey on the south coast of Washington State.
Floodplain Diversity and Spawning Area Productivity in the Yakima River, Part V: Linking Variation in Spawner Phenotype with Habitat Characteristics

PI
Christian Torgersen — UW School of Environmental & Forest Sciences

Other UW Personnel
Darran May — UW School of Aquatic & Fishery Sciences
Jeremy Cram, Ryan Klett — UW School of Environmental & Forest Sciences

NOAA Personnel
Andrew Dittman, George Pess — Northwest Fisheries Science Center

Non-NOAA/non-UW Personnel
Todd Pearsons — Grant County PUD

NOAA Primary Contact
Kathleen Jewett — National Marine Fisheries Service

NOAA Goal
Healthy Oceans

Description
This study is Phase V of on-going work on floodplain diversity and spawning area productivity in the Yakima River. The initial phases of the proposed work (funded by NOAA) involved collecting and georeferencing spatially continuous data on aquatic habitat and fish assemblages throughout the entire upper Yakima basin (160 km). The goals of the current project are to (1) use these data to develop spatially explicit models that predict habitat selection by hatchery versus wild salmon and (2) analyze the relationship between individual spawner phenotype (e.g. size) and habitat selection.

Objectives
1. Analyze the relationship between individual phenotype of adult spawners and spawning habitat selection.
2. Conduct multivariate analysis using demographic data from over 15,000 georeferenced spawning salmon in relation to gradients in physical habitat quality.
3. Use these data to refine models for quantifying and predicting differences in habitat selection by hatchery and wild salmon at multiple scales.

Accomplishments
1. Data entry and analysis for redd surveys were completed and analyzed, and the relationship between individual spawner phenotype and spawning habitat selection was quantified by Darran May. A final report and manuscript for publication have been drafted and are being prepared for submission.
2. Jeremy Cram analyzed data and made significant progress on writing Chapters 2 and 3 of his dissertation (Chapter 1 is published in a peer-reviewed journal; see publications), which identify aquatic habitat predictors of redd and carcass distribution at multiple spatial scales (See Figure 1). Cram recently accepted a job with Washington Department of Fish and Wildlife and is completing his dissertation as part of this job; he is no longer funded by this grant.
3. Ryan Klett completed his Master’s thesis (see publications) and is revising a journal article from his thesis; he is employed by Pacific Northwest National Laboratories and is no longer funded by this grant.

Figure 1. Pearson’s correlations for interannual comparisons of redd distributions in 2004-2008 as a function of spatial scale. Correlations were calculated among years at the following scales: 35 m, 175 m, 500 m, 800 m, 1 km, 1.5 km, 2 km, 3 km, 6 km, and 10 km. The fitted line shows the logistic relationship between interannual redd distribution consistency and the spatial scale of observation. The inset shows the variance for redd distribution correlations at each spatial scale. The inset fitted line depicts the exponential decay of variance in interannual spawning distribution at increasing spatial scales of observation.
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

PI

Alberto Aliseda — UW Department of Mechanical Engineering

Other UW Personnel

James Riley, Ryan Keedy, Chin Hei Ng, Colin Bateson — UW Department of Mechanical Engineering

Task III

NOAA Primary Contact

William Lehr — Emergency Response Division, National Ocean Service

Description

The goal of this project is to provide NOAA’s Emergency Response Division with a 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.

Air and liquids of different physical properties (density, viscosity and surface tension) have been injected coaxially with a high Reynolds number jet inside a large water tank. Bubble and droplet breakup has been studied and correlated with the velocity field in the jet measured \textit{a priori} with Particle Image Velocimetry. The statistics of the turbulent flow, mean velocity, turbulent fluctuations (rms) and shear values across the jet and a function of distance downstream have been measured (Figure 1.)

The break up frequency and resulting droplet/bubble size have been measured from High Speed Visualization. A typical image of the droplet breakup in the jet is shown in Figure 2. Automatic image analysis finds the droplet outlines and determines their size, shape and velocity (from tracking across multiple images taken a short time apart). The statistical characteristics of the droplet size and breakup frequency at any point in the field imaged, have been correlated with the turbulent statistics of the background turbulent jet flow. A first principles relationship of the breakup and the stresses on the droplet surface is been developed to extend these results to breakup of viscous oils in environmental flows at Reynolds number that are not accessible for laboratory experiments.

Figure 1: Photograph of turbulent jet dyed with rhodamine (a fluorescent molecule). The turbulent structures can be seen from light patterns on the surface of the jet, at the interface between the injected and the ambient fluids. Velocity analysis of these images provide statistics of the velocity in the jet that are used to understand and model the droplet/bubble breakup process.
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

1. We have collected high speed visualization data of breakup of gas and liquid threads, at different location in the jet and with different properties of the disperse phase fluid. The results are been expressed in terms of the relevant non-dimensional parameters: Weber number, Ohnesorge number, Reynolds number, and shear number.

2. We have not yet published this in peer review journals or presented it at conferences. Two manuscripts are been prepared and will be submitted soon.

Figure 2: Photograph of Droplet Breakup in a high Reynolds turbulent jet submerged in a water tank. A low viscosity fluid is injected at the center of the jet through a hypodermic needle (right of the image). The end of the needle is a few diameters downstream from the jet nozzle. The turbulent fluctuations that develop in the jet as it destabilizes break the fluid thread injected at the nozzle into individual droplets. These break further as they move to the edge of the jet where fluctuations are highest. The flow is back-illuminated so the droplets appear as shadows due to light scattering off of their surface.
Vents Hydrothermal Research Group

PI
David A. Butterfield, Joseph A. Resing — UW Joint Institute for the Study of Atmosphere & Ocean

Other UW Personnel
Ben Larson, Kevin K. Roe, Nathaniel J. Buck, Hoang-My Christensen — UW Joint Institute for the Study of Atmosphere & Ocean;
Marvin D. Lilley, John Baross, Eric Olson, James Murray, Lia Slemons, Pamela Barret — UW School of Oceanography

NOAA Personnel

Task II

NOAA Contact
Mark Koehn — Pacific Marine Environmental Laboratory

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 scientific 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. Vents offer important lessons in the link between chemistry and microbial ecology with broad applicability to the oceans. Natural products with anti-pathogen activity have recently been extracted from biological material collected during Vents cruises. Finally, it is critical to understand the ecosystem structure and function of deep-ocean vents in advance of any mineral exploitation of economically significant hydrothermal ore deposits by international mining companies. The research conducted by JISAO Vents researchers Butterfield and Resing is critical to NOAAs 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 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 in the NE Lau basin, the first observed eruption of the rare lava-type boninite, 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 CO₂ and low pH on marine life.

Axial Seamount, a mid-ocean ridge volcano in the NE Pacific, is the site of PMELs long-term NeMO observatory and the NSF-funded OOI cabled observatory now under construction. In 2012, Vents researchers conducted submersible dives at Axial to monitor post-eruptive processes following the large eruption in April, 2011. Time-series data collected from 1998 to 2012 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
1. Exploration

Direct observations of submarine volcanic eruptions and sampling of eruption products are required to understand the volcanic-hydrothermal cycle and its effect on the ocean. JISAO researchers are on the cutting edge of this research area and are making significant progress in understanding the evolution of hydrothermal venting and biological succession. Their work in the Western Pacific (e.g., NW Rota and W Mata), suggests that there must be a transition in hydrothermal systems from those dominated by magmatic fluids rich in SO₂ and CO₂ to systems dominated by the interaction between hot rock and seawater. The ability of microbes and macrofauna 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. Although economic and political events have stalled the planned submarine mining of sulfide mineral deposits in the western Pacific, it is still important to evaluate the environmental impacts of this economic activity. It is possible that the impact of eruptive activity on benthic communities and the injection of volcanic plumes into the water column from active submarine volcanoes may provide some advance indication of the potential impacts of mining submarine deposits.

a. 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 nine 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://oceanexplorer.noaa.gov/explorations/explorations.html) and [http://laueruptions.blogspot.com/](http://laueruptions.blogspot.com/).

b. 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 (Figure 1), which in turn produces sulfuric acid and elemental sulfur, and rapidly dissolves volcanic rock, resulting in a significant impact on the global hydrothermal fluxes of sulfur and aluminum. Magmatic gases are severely fractionated during this process (Figure 1). Huber et al. (2010) 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.

c. Lau Basin – The Lau Basin has been examined by NOAA and JISAO scientists on six different cruises between 2004 and 2012. Resing was the chief scientist and led the effort on three of these cruises, including the most recent expedition with the German ROV QUEST on board the R/V Revelle. Like the Marianas, the Lau Basin contains many novel hydrothermal systems and geological settings. The NE sector of the Lau Basin sits in an extremely dynamic tectonic environment, with extremely high volcanism. Of particular interest is the “Mata” series of volcanoes whose morphology (Mata is Tongan for ‘eye’, reflecting the oval shape) is similar to that of the erupting W. Mata Volcano. Plume measurements indicate that six of the seven Matas are hydrothermally active, making the density of hydrothermal activity amongst the highest anywhere in the world. We conducted ROV dives on four of the Mata volcanoes in 2012. Many of the initial results are highlighted on the NOAA Ocean
Figure 1. Erupting arc volcano releases magnetic sulfur dioxide.

Figure 2. Map of NE Lau Basin expedition with ROV Quest on R/V Revelle, September 2012. ROV dives were conducted at Vai Lili, Fonualei, Volcano O. (Niuatapu), W. Mata, Mata Ua, Mata Tolu, Mata Fitu, Niua North and Niua South.
2. **Ecosystem Studies**

a. The scientists are in the 15th year of continuous monitoring at Axial Seamount with the NeMO observatory, and have now captured a complete volcanic cycle spanning the 1998 and 2011 eruptions at Axial. Papers reporting the forecasting of the 2011 eruption and its duration from volcanic inflation monitoring (Chadwick et al., 2012), and on precursor seismicity, magma movement, and temperature on/near the lava (Dziak et al., 2012) were published in *Nature Geoscience*. Butterfield was chief scientist on the 2012 research cruise on board the *Maurice Ewing* with Jason 2 ROV operating at Axial Seamount, Juan de Fuca Ridge. 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 2009-2012 have resulted in the exciting discovery of new bioactive chemical compounds with significant anti-bacterial 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.

b. 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 recovered an interactive water sampler after a 2-year deployment on the Main Endeavour node of the NEPTUNE Canada network [www.neptunecanada.org](http://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. The Canadian Foundation for Innovation announced in January, 2013 that it will fund a major expansion of NEPTUNE Canada, including adding chemistry/DNA samplers built at PMEL. The installation of the US OOI and growth of NEPTUNE Canada are creating a regional network of instruments to study interlinked geological, oceanographic, and ecosystem processes in the NE Pacific.

c. 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, 2012) 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 3-year, multi-institution proposal to help this effort was funded in 2012 by the Moore Foundation. Butterfield is leading the UW team, and has hired a new JISAO Research Scientist, Ben Larson, to work on modeling microbial reactions, integrating thermodynamic reaction modeling with fluid and heat transport models, and linking these to ecosystem models in collaboration with scientists at the Marine Biological Lab in Woods Hole.

d. Resing conducted 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 paper by Slemons et al (2012) 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 paper by Barrett et al on the distribution of particulate matter in the Atlantic Ocean was published in Marine Chemistry. The research, based on a north to south transect of the North Atlantic Ocean, demonstrates that the major sources of particulate and dissolved metals in the Atlantic Ocean are Saharan dust and European pollutant aerosols.
e. In an effort to understand the impact of hydrothermal activity on the global ocean, Resing attended a workshop hosted by the US 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 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 is funded by NSF to participate in the Geotraces’ Pacific section cruise scheduled for Fall 2013.

f. The long-term increase in atmospheric carbon dioxide and the consequent increased CO\textsubscript{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\textsubscript{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\textsubscript{2}, low-pH waters that would normally dissolve their shells (Tunnicliffe et al., 2009). 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\textsubscript{2} environments, and to relate such adaptations to other marine environments.
Seafloor Processes

Figure 6. Top: ROV Quest taking a scoop sample of volcanic sediment and microbial mat on Niuatahi (Volcano O) summit slope. Bottom: Smoke-like plumes of white sulfur particles emanating from the edge of a pit crater covered with solidified molten sulfur flows from recent eruptive activity. JISAO scientists are studying the effects of volcanic emissions on deep-sea animals and ocean chemistry. Images courtesy of MARUM, University of Bremen and NOAA-Pacific Marine Environmental Laboratory.

Figure 7. High-temperature smoker chimneys coated with white microbial mat Niua South. Chimneys at this site were over 10 m in height. Image courtesy of MARUM, University of Bremen and NOAA-Pacific Marine Environmental Laboratory.

Figure 8. Two species of large (6-8cm across) hydrothermal snails (Ifremeria and Alvinocochna) at Niua South volcano. Image courtesy of MARUM, University of Bremen and NOAA-Pacific Marine Environmental Laboratory.

Figure 9. From Huber et al., 2010. Taxonomic breakdown and relative abundance at the genus level for the epsilonbacteria in each vent fluid sample from 5 different Mariana arc submarine volcanoes. Only those genera that occurred more than 1000 times across all datasets are labeled. All others are lumped into "Other." From left to right, 431 and 432 are from Forecast volcano, 445-449 are from NW Rota, 467 and 468 from NW Eifuku, 473 and 475 from Daikoku and 479-481 from Nikko. There is high diversity and little overlap in the microbial community structure of individual volcanoes.
**Figure 10.** Metal sulfide mineral chimneys at the Fonualei Rift vent site named Kakai Loloa (“Tall People”). These massive chimneys near Tonga stand 35-40 meters above the seafloor, with >250°C mineral-laden water blasting out of the tops. A crab is scaling the chimney at left, and two snails are attached lower right. *Image courtesy of MARUM, University of Bremen, and NOAA Pacific Marine Environmental Lab.*
Tsunami Observations and Modeling
DART Data Inversion: Source Selection and Improved Alpha and Inundation Forecast Uncertainty Assessment

PI
Donald B. Percival — UW Applied Physics Laboratory

Task III

NOAA Primary Contact
Vasily Titov — Pacific Marine Environmental Laboratory

NOAA Goal
Weather-Ready Nation

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

1. To estimate tsunami source amplitudes.
2. To produce CIs for the true unknown amplitudes.
3. The estimation of the amplitudes must not only be reliable, but also use methods that allow them to be computed as rapidly as possible.
4. 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

1. The scientists completed a study on how well the so-called lasso method can automatically select unit sources for use 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 handpick 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 unit sources are needed to describe the data. For large events such as the March 11, 2011 Honshu tsunami, approximate collinearity amongst the unit sources led to undesired gaps in the spatial structure, which can be handled using a sweeping window version of the elastic net (a generalization of the lasso that can handle collinearity). The scientists use the Akaike information criterion to settle the most window from the sweeping process and to set the tuning parameter associated with the lasso. Using the 2011 Honshu and the 2006 Kuril Islands tsunamis as test cases, the scientists found that the lasso-based automatic procedure yields model fits and verification equal
to or better than those from a time-consuming hand-selected solution. A paper summarizing the proposed methodology has been submitted to the *Journal of the American Statistical Association*. Efforts are under way to incorporate this new methodology into the operation SIFT system used by the Tsunami Warning Centers.

2. 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 and local harmonic methods for detiding with and without joint estimation of the tsunami source amplitudes. The local harmonic 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). The scientists evaluated the efficacy of the different detiding methods by adding artificial tsunamis to data collected by four DART buoys under ambient conditions. To increase the value of the study, the scientists are in the process of processing data from four or five additional buoys that represent ocean conditions different from the original four buoys. A paper summarizing the conclusions of this study is under preparation.
Tsunami Research

PI
Vasily Titov — UW Joint Institute for the Study of Atmosphere & Ocean

Other UW Personnel
Diego Arcas, Donald Denbo, Edison Gica, Linus Kamb, Christopher Moore, Jean Newman, Clinton Pells, Dylan Righi, Michael Spillane, Liujuan Tang, Burak Uslu, Lindsey Wright, Yong Wei — UW Joint Institute for the Study of Atmosphere & Ocean

NOAA Personnel
Eugene Burger, Marie Eble, Christopher Moore — Center for Tsunami Research;
Nancy Soreide — Pacific Marine Environmental Laboratory

Task II

NOAA Primary Contact
Pacific Marine Environmental Laboratory

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 scientists affiliated with JISAO 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 provide scientific and operational support for the 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. The final version 3.1.0 of the tsunami forecasting software SIFT, developed by the tsunami research group, has been undergoing testing and evaluation by the Alaska and Hawaii Tsunami Warning Centers since its installation in April 2012. Some minor fixes and improvements were introduced at the request of the Warning Centers during this period. The Operational Testing and Evaluation period has concluded successfully in February 2013. 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. Collaboration with Washington State Emergency Management Division has continued during 2012-2013, and has materialized in the conclusion of two tsunami hazard assessment studies of the areas of Grays Harbor and W Ilapu Bay from a large field near the Cascadia Subduction Zone. An additional hazard assessment study for the San Juan Islands from the same tsunamigenic event is scheduled to be completed in 2013. Hazard assessment work in conjunction with the National Ocean Service (NOS) continues with the final development of inundation maps for the Commonwealth of the Northern Marianas (CNMI). The tsunami group has already continued its close collaboration with the US Nuclear Regulatory Commission to produce a NUREG report documenting best tsunami modelling practices for nuclear power plant sites, and to develop software (TsunamiCast) that will notify NRC officials and provide access to site specific forecasts.

3. Substantial progress has been made in the development of Tweb. Tweb is a web-based interface to the MOST Tsunami models that will allow for full tsunami event modeling capability from any internet connected web-browser. The application architecture entails multiple server tiers and a web client written in GWT/GXT. Server tier development is mostly complete with functionality still being added to the Tweb application server to support client functionality. The SIFT-Translator tier and development on a new Google Maps tile renderer is completed. Client development is nearing completion with only the inversion functionality to be implemented. Tweb will be undergoing user testing and trials later this year before it's released for full-time research use.

4. NCTR has completed the development of 75 high-resolution tsunami inundation models called Forecast Models (FMs) (formerly known as Stand-by Inundation Models, SIMs) as part of the Tsunami Forecast System. The models are intended to provide real-time community specific tsunami forecasts for coastal communities in the US. An update of early-development models will be conducted during 2013.

5. Collaboration with the University of Málaga, Spain has continued with the development of new landslide generated tsunami capabilities and the implementation of the propagation version of the tsunami code MOST in CUDA, which will allow the use of Graphics Processing Units for calculation, and is expected to accelerate computations by at least one order of magnitude.

6. A series of sizable tsunami events have occurred during the current reporting period with Sumatra (April 2012, Mw=8.6) being the largest. NCTR has responded to all of these events in real time, and has made experimental forecasts for each event available to the public only hours after the event. In addition, these smaller events have been central in the operation testing and evaluation of the SIFT software at the Warning Centers.

7. One additional training workshop, using the Community Modeling Interface for Tsunami (ComMIT) was conducted during the current reporting period in Portland, Oregon at the American Society of Civil Engineers (ASCE) to facilitate the study of tsunami forces on buildings and coastal structures. Two additional workshops are scheduled to take place in April and August 2013, in Tonga and the Cook Islands respectively.

**Figure 1.** Photo taken by a member of the JISAO tsunami research group during a field survey of the tsunami generated by an Mw=7.3 earthquake off the coast of El Salvador on August 27, 2012. The photo shows an aerial view of the affected area with dead vegetation from tsunami inundation.
Figure 2. Snapshot of the tsunami forecasting software T-web which has been in development at NCTR for the last few years. This forecasting tool is intended to be available to a number of different organizations via the internet. The picture shows a deep water forecast of the tsunami generated by the Mw=8.0 forecast off the Santa Cruz Islands.

Figure 3. Distribution of the maximum wave elevation and inundation of a tsunami originating along the Cascadia Subduction Zone from two Mw=9.3 seismic event (right panel). Updated values of wave elevation and inundation area using an updated tsunami source.
Appendices
Appendix 1

JISAO Senior Fellows and Council Members*

University of Washington

*Ackerman, Thomas, Professor, Atmospheric Sciences, Executive Director, JISAO
Armstrong, David, Professor, Aquatic and Fishery Sciences
Battisti, David S., Professor, Atmospheric Sciences
Bretherton, Christopher, Professor, Atmospheric Sciences/Applied Mathematics
Charlson, 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 Emeritus, 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 and Atmospheric Sciences
Lettenmaier, Dennis P., Professor, Civil and Environmental Engineering
McDuff, Russell, Professor, Oceanography
*Miles, Edward L., Professor Emeritus, Marine and Environmental Affairs, Climate Impacts Group
Murray, James W., Professor, Oceanography
*Punt, Andre E., Professor and Director, Aquatic and Fishery Sciences
Quay, Paul D., Professor, Oceanography
Rhines, Peter B., Professor, Oceanography and Atmospheric Sciences
Ruesink, Jennifer, Professor, Biology
Thompson, LuAnne, Professor, Oceanography, Director, Program on Climate Change
Wallace, John M., Professor Emeritus, 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 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

*2012-2013 Council Members
Appendix 2

JISAO Professional Awards, Funded Events and Visitors

Professional Awards
- Matt Baker, School of Aquatic and Fishery Sciences, selected as ICES Early Career Scientist and invited to present research at conference of peers. (Trevor Branch, PI and Hilborn, PI)
- Trevor A. Branch, School of Aquatic and Fishery Sciences, selected as a 2013 Leopold Leadership Fellow, based in part on the public outreach efforts associated with the Bevan Series.
- Mark Raleigh, Civil and Environmental Engineering, was awarded a CH2MHill Engineers without Borders-USA Scholarship February, 2012.

Events and Visitors

June 15 – August 15, 2012
- Kajsa Parding, PhC, Geophysical Institute, University of Bergen, Bergen, Norway, as part of UW VISIT Program, prepared manuscript, “Influence of meteorological patterns on global dimming and brightening in Europe,” for Atmos Chem Phys., with Beate G. Liepert, Thomas P. Ackerman, Knut-Frode Dagestad, Laura M. Hinkelman, and Jan Asle Osleth

August 3 – 6, 2012
- Dr. Anna Astrakova, Novosibirsk State University, Novosibirsk, Russia – met with Tsunami Research group

August 12 – 16, 2012
- Keith Parker, summer intern – to attend STAR Conference at UW

Sep 30 – Oct 2, 2012
- Deborah Finch (Keynote Speaker), USDA Forest Service Rocky Mountain Research Station
- Graduate students: Michael Case, Joseph Hamman, Se-Yeun Le, Maureen Ryan, Julie Vano
Speakers/participants, 3rd Annual Pacific Northwest Climate Science Conference, Boise, Idaho

October 20 – 22, 2012
- Siyu Chen, Key Laboratory for Semi-Arid Climate Change of the Ministry of Education, Lanzhou University, Lanzhou, Gansu, China
- Yun Qian, Atmospheric Science and Global Change Division, Pacific Northwest National Laboratory, Richland, WA
Collaborators with PI Sarah Doherty (JISAO) on “Black Carbon in North China Snow”

October 22, 2012
- Dr. Henry Huntington, Pew Charitable Trusts, Science Director for the Arctic Program, BEST-BSIERP Ecosystem Partnership
Speaker for IGERT Program on Ocean Change, “Beyond the Ice: People and a changing Arctic Ocean”

Oct 26 – 28, 2012
Graduate students funded to attend Graduate Climate Change Conference at UW Pack Forest:
- Leif Anderson, University of Colorado-Boulder, Boulder, CO
- Adriana Raudzens Bailey, University of Colorado-Boulder, Boulder, CO
- Jennifer Carroll, University of Notre Dame, Notre Dame, IN
- Rabi Gyawali, Michigan Technological University, Houghton, MI
- Kuniaki Inoue, University of Wisconsin-Madison, Madison, WI
- Mohamed Abdel Kader, The Cyprus Institute, Nicosia, Cyprus
- Coretha Komba, University of Cape Town, Cape Town, South Africa
- Iara Lacher, University of California-San Diego, San Diego, CA
- Matt Ruppel, University of California-San Diego, San Diego, CA
- Martin Singh, Massachusetts Institute of Technology, Cambridge, MA

January 14, 2013
- Dr. Ken Caldeira, Stanford University Carnegie Institution for Science, Department of Global Ecology, Stanford, CA
Speaker for IGERT Program on Ocean Change, “Ocean acidification: long-term perspectives and near-term action”

February 8, 2013
- Dr. Nicole Riemer, University of Illinois Urbana-Champaign, Department of Atmospheric Sciences, Urbana, IL
UW Department of Atmospheric Sciences Colloquium Speaker, “Stochastic Particle-Resolved Models for Simulating Atmospheric Aerosol”

February 12, 2013
- Dr. Kathleen Moore, Oregon State University School of History, Philosophy, and Religion, Corvallis, OR
Speaker for IGERT Program on Ocean Change, “Red Sky at Morning: Ethics and the Oceanic Crisis”
March 1-30, 2013

Visiting scientists from Langzou University, Lanzhou, Gansu, China:
- Jinming Ge
- Dongmei Lin
- Beidou Zhang
- Wu Zhang

Drs. David Covert of JISAO and Qiang Fu of UW Atmospheric Sciences mentored this faculty team through the initial phase of developing and implementing cloud radar research at Langzou University in China. JISAO served as their physical and scientific home base during four weeks in the US, during which time they also visited other locations for the purposes of learning about and establishing their own program.
## Appendix 3

### New Cooperative Agreement Awards Funded in 2012-2013

<table>
<thead>
<tr>
<th>Task #</th>
<th>Principal Investigator</th>
<th>Department</th>
<th>Title of Project</th>
<th>Award Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Ackerman, Thomas</td>
<td>JISAO</td>
<td>JISAO Task I</td>
<td>$300,100</td>
</tr>
<tr>
<td>I</td>
<td>Branch, Trevor</td>
<td>SAFS</td>
<td>Bevan Lecture Series</td>
<td>$15,000</td>
</tr>
<tr>
<td>II</td>
<td>Ackerman, Thomas</td>
<td>JISAO</td>
<td>JISAO Task II PMEL Projects</td>
<td>$7,980,045</td>
</tr>
<tr>
<td>II</td>
<td>Doyle, Miriam</td>
<td>JISAO</td>
<td>Links between the early life history dynamics of fish, climate and ocean conditions in the large marine ecosystems of Alaska</td>
<td>$63,561</td>
</tr>
<tr>
<td>II</td>
<td>Roberts, Steven</td>
<td>SAFS</td>
<td>Sablefish Reproductive Life History and Genetics</td>
<td>$184,869</td>
</tr>
<tr>
<td>II</td>
<td>DeCosmo, Janice</td>
<td>URP</td>
<td>Northwest Fisheries Science Center and University of Washington Undergraduate Intern Program</td>
<td>$52,060</td>
</tr>
<tr>
<td>III</td>
<td>Bond, Nicholas</td>
<td>JISAO/APL</td>
<td>Development of a Prediction System for the California Current Integrated Ecosystem Assessment</td>
<td>$152,994</td>
</tr>
<tr>
<td>III</td>
<td>Branch, Trevor</td>
<td>SAFS</td>
<td>Defining eco-regions and applying spatial analyses of species abundance, community dynamics and stock substructure to incorporate habitat in SSMs and MSMs</td>
<td>$106,259</td>
</tr>
<tr>
<td>III</td>
<td>Burgstahler, Sheryl</td>
<td>DO-IT</td>
<td>NOAA Support for DO-IT Scholars Program 2012</td>
<td>$9,990</td>
</tr>
<tr>
<td>III</td>
<td>Holzworth, Robert</td>
<td>ESS</td>
<td>Lightning Studies</td>
<td>$125,000</td>
</tr>
<tr>
<td>III</td>
<td>Horne, John</td>
<td>SAFS</td>
<td>Fisheries Acoustics Research</td>
<td>$62,565</td>
</tr>
<tr>
<td>III</td>
<td>Melvin, Edward</td>
<td>Sea Grant</td>
<td>Design and conduct research to reduce seabird bycatch in West Coast longline fisheries</td>
<td>$160,000</td>
</tr>
<tr>
<td>III</td>
<td>Miller, Bruce</td>
<td>SAFS</td>
<td>Marine Biological Interactions in the North Pacific – Fish Interactions Task</td>
<td>$361,806</td>
</tr>
<tr>
<td>III</td>
<td>Percival, Don</td>
<td>APL</td>
<td>Automatic Unit Source Selection and Joint Detiding and Inversion for the SIFT Application</td>
<td>$100,000</td>
</tr>
<tr>
<td>III</td>
<td>Pietsch, Theodore</td>
<td>SAFS</td>
<td>Annotated checklist of bottom-trawled macroinvertebrates of Alaska, with an evaluation of identifications in the Alaska Fisheries Science Center bottom-trawl survey database</td>
<td>$4,000</td>
</tr>
<tr>
<td>III</td>
<td>Proskurowski, Giora</td>
<td>Oceanography</td>
<td>The Effect of Wind-Driven Mixing on Observations of Plastic Marine Debris: Modeling, Verification and Reanalysis</td>
<td>$61,521</td>
</tr>
<tr>
<td>III</td>
<td>Punt, Andre</td>
<td>SAFS</td>
<td>Forecast Effects of Ocean Acidification on Abundance of Eastern Bering Sea Tanner Crab</td>
<td>$46,200</td>
</tr>
<tr>
<td>III</td>
<td>Punt, Andre</td>
<td>SAFS</td>
<td>West Coast Groundfish Stock Assessment</td>
<td>$140,000</td>
</tr>
<tr>
<td>III</td>
<td>Punt, Andre</td>
<td>SAFS</td>
<td>Partnership with the Northwest Fisheries Science Center and Alaska Fisheries Science Centerto Develop Increased Capacity in the School of Aquatic and Fishery Sciences to Enhance Teaching and Research</td>
<td>$200,000</td>
</tr>
<tr>
<td>III</td>
<td>Rigor, Ignatius</td>
<td>APL</td>
<td>International Arctic Buoy Programme (IABP) — Monitoring the Eurasian Basin of the Arctic Ocean.</td>
<td>$50,000</td>
</tr>
<tr>
<td>III</td>
<td>Riser, Steven</td>
<td>Oceanography</td>
<td>Global Observations for Understanding and Prediction of Climate Variability</td>
<td>$3,006,768</td>
</tr>
<tr>
<td>III</td>
<td>Stafford, Kate</td>
<td>APL</td>
<td>Bowhead Whale Feeding in the Western Beaufort Sea: Passive Acoustic Survey Component</td>
<td>$50,000</td>
</tr>
<tr>
<td>III</td>
<td>Woodgate, Rebecca</td>
<td>APL</td>
<td>Synthesis of Arctic Research (SOAR) and Applied Physics Laboratory collaborative projects</td>
<td>$73,067</td>
</tr>
</tbody>
</table>
## Appendix 4

### JISAO Awards Funded Outside the Cooperative Agreement

<table>
<thead>
<tr>
<th>Project Title</th>
<th>Principal Investigator</th>
<th>Award Amount</th>
<th>Awarding Agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAS/PPS (RASFL, PPSDN) Data Products, Instrument Driver and Automated Quality Control/Quality Assurance for Ocean Observatories Initiative Regional Scale Nodes (OOI-RSN)</td>
<td>Butterfield, David</td>
<td>$29,915</td>
<td>NSF</td>
</tr>
<tr>
<td>Collaborative Research: Dynamics of eruptive plumes above a submarine arc volcano</td>
<td>Resing, Joseph</td>
<td>$31,419</td>
<td>NSF</td>
</tr>
<tr>
<td>Retrieval of Cumulus Cloud Properties using 3D Radiative Transfer and Polarized Reflectance</td>
<td>Marchand, Roger</td>
<td>$41,270</td>
<td>NASA</td>
</tr>
<tr>
<td>Relating Solar Resource Variability to Cloud Type</td>
<td>Hinkelman, Laura</td>
<td>$45,785</td>
<td>NREL</td>
</tr>
<tr>
<td>Analysis of the NASA/GEWEX Surface Radiation Budget Products</td>
<td>Hinkelman, Laura</td>
<td>$58,384</td>
<td>NASA</td>
</tr>
<tr>
<td>A Multi-Scale Observational and Modeling Study of Cirrus and Boundary Layer Clouds Using A-Train Data</td>
<td>Muhlbauer, Andreas</td>
<td>$60,000</td>
<td>PNNL</td>
</tr>
<tr>
<td>CloudSat Global Summary and Geometric Profile (GeoProf) Datasets</td>
<td>Marchand, Roger</td>
<td>$60,288</td>
<td>JPL</td>
</tr>
<tr>
<td>Coastal and Marine Spatial Planning</td>
<td>Banas, Neil</td>
<td>$63,388</td>
<td>DNR</td>
</tr>
<tr>
<td>Sea Ice Reanalysis</td>
<td>Wang, Muyin</td>
<td>$70,279</td>
<td>NSF</td>
</tr>
<tr>
<td>Stressor Maps in PSND</td>
<td>Banas, Neil</td>
<td>$74,880</td>
<td>NOAA</td>
</tr>
<tr>
<td>In-Situ Biological Carbon Fluxes in the Pacific Ocean</td>
<td>Sonnerup, Rolf</td>
<td>$91,937</td>
<td>NOAA</td>
</tr>
<tr>
<td>Development of an Adaptive Vertical Grid Scheme for Large Scale Models</td>
<td>Marchand, Roger</td>
<td>$105,195</td>
<td>NOAA</td>
</tr>
<tr>
<td>Bering Sea Synthesis</td>
<td>Banas, Neil</td>
<td>$105,505</td>
<td>NSF</td>
</tr>
<tr>
<td>Validation and Application of MISR Cloud Retrievals</td>
<td>Ackerman, Thomas</td>
<td>$120,000</td>
<td>JPL</td>
</tr>
<tr>
<td>Tsunami Hazard Modeling for U.S. Coastlines</td>
<td>Arcas, Diego</td>
<td>$154,000</td>
<td>NRC</td>
</tr>
<tr>
<td>ECOHAB – Modeling favorable habitat areas for Alexandrium catenella in Puget Sound and evaluating the effects of climate changes</td>
<td>Salathe, Eric</td>
<td>$283,707</td>
<td>NOAA</td>
</tr>
<tr>
<td>The interaction among mesoscale dynamics, microphysical properties and radiative effects of mid-latitude cirrus clouds</td>
<td>Ackerman, Thomas</td>
<td>$181,067</td>
<td>NSF</td>
</tr>
<tr>
<td>Using CERES and MODIS Data to Improve Energy Balance Snowmelt Modeling</td>
<td>Hinkelman, Laura</td>
<td>$205,000</td>
<td>NASA</td>
</tr>
<tr>
<td>Functional Dynamics, Interactions and Biogeochemical Impact of Chemolithoautotrophic Subseafloor Microbial Ecosystems at Axial Seamount, a Mid-Ocean Ridge Cabled Observatory</td>
<td>Butterfield, David</td>
<td>$256,375</td>
<td>MBL</td>
</tr>
<tr>
<td>Ventilation and timescales for oxygen and nutrient cycling in the oxygen deficient waters of the Eastern Tropical South Pacific</td>
<td>Sonnerup, Rolf</td>
<td>$267,800</td>
<td>NSF</td>
</tr>
<tr>
<td>The role of cross-shelf and along-shelf transports as controlling mechanisms for nutrients, plankton and larval fish in the coastal Gulf of Alaska</td>
<td>Mordy, Calvin</td>
<td>$269,092</td>
<td>NPRB</td>
</tr>
<tr>
<td>Collaborative Research: US GEOTRACES Pacific Section: Shipboard Al, Mn, and Fe in support of the Eastern Pacific Zonal Transect</td>
<td>Resing, Joseph</td>
<td>$300,140</td>
<td>NSF</td>
</tr>
</tbody>
</table>
# Appendix 5

## Graduate Students

<table>
<thead>
<tr>
<th>Student Name</th>
<th>Academic Unit</th>
<th>Degree</th>
<th>Degree Advisor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barrett, Pamela M.</td>
<td>School of Oceanography</td>
<td>Ph.D.</td>
<td>Joseph Resing</td>
</tr>
<tr>
<td>Bateson, Colin Padriac</td>
<td>School of Oceanography</td>
<td>Ph.D.</td>
<td>Alberto Aliseda</td>
</tr>
<tr>
<td>Bobej, Alaric J.</td>
<td>Mechanical Engineering</td>
<td>Ph.D.</td>
<td>Joyce Cooper</td>
</tr>
<tr>
<td>Degnin-Warner, Michelle</td>
<td>Mechanical Engineering</td>
<td>M.S.</td>
<td>Theodore Pietsch</td>
</tr>
<tr>
<td>Dilmen, Derya Itir</td>
<td>School of Aquatic and Fishery Sciences</td>
<td>M.S.</td>
<td>Vasily Titov, Joanne Bourgeois</td>
</tr>
<tr>
<td>Dixson, Kenneth</td>
<td>Earth and Space Sciences</td>
<td>Ph.D.</td>
<td>Cliff Mass</td>
</tr>
<tr>
<td>Fassbender, Andrea J.</td>
<td>Atmospheric Sciences</td>
<td>M.S.</td>
<td>Chris Sabine</td>
</tr>
<tr>
<td>Gray, Alison R.</td>
<td>School of Oceanography</td>
<td>Ph.D.</td>
<td>Cliff Mass</td>
</tr>
<tr>
<td>Harbitz, Caroline R.</td>
<td>School of Oceanography</td>
<td>Ph.D.</td>
<td>Stephen Riser, Peter Rhines</td>
</tr>
<tr>
<td>Hennon, Tyler D.</td>
<td>School of Oceanography</td>
<td>Ph.D.</td>
<td>Stephen Riser, Matthew Alford</td>
</tr>
<tr>
<td>Hurtado Ferro, Felipe</td>
<td>School of Oceanography</td>
<td>Ph.D.</td>
<td>Andre Punt</td>
</tr>
<tr>
<td>Lin, Chi-Yu</td>
<td>School of Aquatic and Fishery Sciences</td>
<td>Ph.D.</td>
<td>Dennis Lettenmaier</td>
</tr>
<tr>
<td>Madaus, Luke E.</td>
<td>Civil and Environmental Engineering</td>
<td>Ph.D.</td>
<td>Cliff Mass, Greg Hakim</td>
</tr>
<tr>
<td>McGilliard, Carey</td>
<td>Department of Atmospheric Sciences</td>
<td>M.S.</td>
<td>Ray Hilborn</td>
</tr>
<tr>
<td>Monnahan, Cole C.</td>
<td>School of Aquatic and Fishery Sciences</td>
<td>Ph.D.</td>
<td>Trevor Branch</td>
</tr>
<tr>
<td>Muradian, Melissa L.</td>
<td>Quantitative Ecology &amp; Resource Mgmt</td>
<td>M.S.</td>
<td>Trevor Branch</td>
</tr>
<tr>
<td>Ono, Kotaro</td>
<td>School of Aquatic and Fishery Sciences</td>
<td>M.S.</td>
<td>Ray Hilborn</td>
</tr>
<tr>
<td>Purkey, Sarah M.</td>
<td>School of Aquatic and Fishery Sciences</td>
<td>Ph.D.</td>
<td>Gregory Johnson</td>
</tr>
<tr>
<td>Shi, Xiaogang</td>
<td>School of Oceanography</td>
<td>Ph.D.</td>
<td>Dennis Lettenmaier</td>
</tr>
<tr>
<td>Shukla, Shraddhanand</td>
<td>Civil and Environmental Engineering</td>
<td>Ph.D.</td>
<td>Dennis Lettenmaier</td>
</tr>
<tr>
<td>Stawitz, Christine C.</td>
<td>Civil and Environmental Engineering</td>
<td>Ph.D.</td>
<td>Timothy Essington</td>
</tr>
<tr>
<td>Stingle, Kelli F.</td>
<td>Quantitative Ecology and Resource Management</td>
<td>M.S.</td>
<td>Andre Punt</td>
</tr>
<tr>
<td>Swihart, Jessica A.</td>
<td>School of Aquatic and Fishery Sciences</td>
<td>Ph.D.</td>
<td>Theodore Pietsch</td>
</tr>
<tr>
<td>Wagner, Cherie A.</td>
<td>School of Aquatic and Fishery Sciences</td>
<td>M.S.</td>
<td>Patrick Christie</td>
</tr>
<tr>
<td>Wayand, Nicholas E.</td>
<td>School of Marine &amp; Environmental Affairs</td>
<td>M.S.</td>
<td>Jessica Lundquist</td>
</tr>
<tr>
<td>Wenegrat, Jacob O.</td>
<td>Civil and Environmental Engineering</td>
<td>M.S.</td>
<td>Michael McPhaden</td>
</tr>
<tr>
<td>Williams, Nancy L.</td>
<td>School of Oceanography</td>
<td>M.S.</td>
<td>Richard Feely, Chris Sabine</td>
</tr>
<tr>
<td>Wu, Motoki</td>
<td>School of Oceanography</td>
<td>M.S.</td>
<td>Andre Punt</td>
</tr>
</tbody>
</table>
Appendix 6

Personnel Count

<table>
<thead>
<tr>
<th>Category</th>
<th>Number</th>
<th>B.S.</th>
<th>M.S.</th>
<th>Ph.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Personnel Paid &gt;50%</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Faculty</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Research Scientist</td>
<td>60</td>
<td>10</td>
<td>24</td>
<td>26</td>
</tr>
<tr>
<td>Visiting Scientist</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postdoctoral Fellow**</td>
<td>6</td>
<td></td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Research Support Staff</td>
<td>7</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total (&gt; or = 50%)</strong></td>
<td>73</td>
<td>17</td>
<td>24</td>
<td>32</td>
</tr>
</tbody>
</table>

| **Total Personnel Paid <50%** |        |      |      |       |
| Undergraduate Students        | 8      |      |      |       |
| Graduate Students             | 28     |      |      |       |
| Employees receiving less than 50% NOAA support | 63 |      |      |       |
| Located at Lab                | 69 (PMEL), 1 (AFSC), 1 (NWFSC) | | | |
| Obtained NOAA employment      | 2      |      |      |       |
| within the last year          | 2      |      |      |       |

**an additional 6 PostDocs received less than 50% support**
# Appendix 7

## Postdoctoral Research Associates

<table>
<thead>
<tr>
<th>Name</th>
<th>Support Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baker, Matthew</td>
<td></td>
</tr>
<tr>
<td>Drumm, David</td>
<td></td>
</tr>
<tr>
<td>Hristova, Hristina**</td>
<td></td>
</tr>
<tr>
<td>Johnstone, James**</td>
<td></td>
</tr>
<tr>
<td>Lique, Camille Emilie</td>
<td></td>
</tr>
<tr>
<td>McGilliard, Carey</td>
<td></td>
</tr>
<tr>
<td>Shukla, Shraddhanand**</td>
<td></td>
</tr>
<tr>
<td>Siedlecki, Samantha**</td>
<td></td>
</tr>
<tr>
<td>Uslu, Burak</td>
<td></td>
</tr>
<tr>
<td>Whitten, Athol**</td>
<td></td>
</tr>
<tr>
<td>Woillez, Mathieu**</td>
<td></td>
</tr>
<tr>
<td>Zhou, Hongqiang</td>
<td></td>
</tr>
</tbody>
</table>

**Received less than 50% support from JISAO**
## Appendix 8

### Publications Count

2010 – 11 and 2012 – 2013

<table>
<thead>
<tr>
<th></th>
<th>11-12</th>
<th>12-13</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>JISAO Lead Author</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peer-reviewed</td>
<td>89</td>
<td>85</td>
</tr>
<tr>
<td>Non-peer-reviewed</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>95</td>
<td>88</td>
</tr>
<tr>
<td><strong>NOAA Lead Author</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peer-reviewed</td>
<td>20</td>
<td>34</td>
</tr>
<tr>
<td>Non-peer-reviewed</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>22</td>
<td>37</td>
</tr>
<tr>
<td><strong>Other Lead Author</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peer-reviewed</td>
<td>75</td>
<td>109</td>
</tr>
<tr>
<td>Non-peer-reviewed</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>79</td>
<td>115</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peer-reviewed</td>
<td>184</td>
<td>228</td>
</tr>
<tr>
<td>Non-peer-reviewed</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Total</td>
<td>196</td>
<td>240</td>
</tr>
</tbody>
</table>
Appendix 9

Publications April 1, 2012 – March 31, 2013

Not Previously Reported


Published


37. Buckley, M., Y. Wei, B. Jaffe, and S. Watt (2012), Inverse modeling of velocities and inferred cause of overwash that emplaced inland fields of boulders at Anegada, British Virgin Islands, Nat Hazards, 63(1), 133-149.


Appendices


121. Lang, S. Q., G. L. Früh-Green, S. M. Bernasconi, and D. A. Butterfield (2013), Sources of organic nitrogen at the serpentinite-hosted Lost City hydrothermal field, Geobiology, 11(2), 154-169.


123. Lawrence, D. J., J. D. Olden, and C. E. Torgersen (2012), Spatiotemporal patterns and habitat associations of smallmouth bass (Micropterus dolomieu) invading salmon-rearing habitat, Freshwater Biol, 57(9), 1929-1946.


129. Lique, C., and M. Steele (2012), Where can we find a seasonal cycle of the Atlantic water temperature within the Arctic Basin?, Journal of Geophysical Research C: Oceans, 117(3).


139. Marchand, R. (2012), Spatial correlation of hydrometeor occurrence, reflectivity, and rain rate from CloudSat, J Geophys Res-Atmos, 117.


159. Overland, J. E., and M. Wang (2013), When will the summer arctic be nearly sea ice free?, *Geophysical Research Letters*, DOI: 10.1002/grl.50316, n/a-n/a.


201. Thorson, James T., Jason M. Cope, Trevor A. Branch, and Olaf P. Jensen (2012), Spawning biomass reference points for exploited marine fishes, incorporating taxonomic and body size information, *Canadian Journal of Fisheries and Aquatic Sciences*, 69(9), 1556-1568.


**Accepted**


238. McPhaden, M. J., and M. Nagura (Accepted), Indian Ocean Dipole interpreted in terms of Recharge Oscillator theory, *Clim Dynam*.

239. Parada, C., B. Ernst, S. L. Hinckley, J. M. Orensanz, D. A. Armstrong, E. N. Curchitser, and A. J. Hermann (Accepted), Patterns of connectivity and potential settlement regions of snow crab (Chionoecetes opilio) larvae in the eastern Bering Sea, *Prog Oceanogr*.

240. Steinemann, A. (Accepted), Drought Information for Improving Preparedness: Survey of State Drought Managers in the Western U.S.
# Appendix 10

## Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC&amp;C</td>
<td>Atmospheric Chemistry &amp; Climate</td>
</tr>
<tr>
<td>AC&amp;H</td>
<td>Atmospheric Chemistry &amp; Health</td>
</tr>
<tr>
<td>ACCMIP</td>
<td>Atmospheric Chemistry &amp; Climate Model Intercomparison Project</td>
</tr>
<tr>
<td>ACPC</td>
<td>Aerosols, Clouds, Precipitation, &amp; Climate</td>
</tr>
<tr>
<td>ADMB</td>
<td>AD Model Builder</td>
</tr>
<tr>
<td>ADS</td>
<td>Automated Drifting Station</td>
</tr>
<tr>
<td>AFSC</td>
<td>Alaska Fisheries Science Center</td>
</tr>
<tr>
<td>AGU</td>
<td>American Geophysical Union</td>
</tr>
<tr>
<td>AI</td>
<td>Aleutian Islands</td>
</tr>
<tr>
<td>AIChemInteractions</td>
<td>Air-Ice Chemical Interactions</td>
</tr>
<tr>
<td>AM</td>
<td>annual mean</td>
</tr>
<tr>
<td>AMM</td>
<td>Atlantic Meridional Mode</td>
</tr>
<tr>
<td>AMMA-AC</td>
<td>African Monsoon Multidisciplinary Analysis – Atmospheric Chemistry</td>
</tr>
<tr>
<td>AMOC</td>
<td>Assessing the Atlantic Meridional Overturning Circulation</td>
</tr>
<tr>
<td>AMS</td>
<td>American Meteorological Society</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis of variance</td>
</tr>
<tr>
<td>AOMIP</td>
<td>Arctic Ocean Model Intercomparison Project</td>
</tr>
<tr>
<td>AON</td>
<td>Arctic Observing Network</td>
</tr>
<tr>
<td>AOX</td>
<td>Arctic Observing eXperiment</td>
</tr>
<tr>
<td>ARCWEST</td>
<td>Arctic Whale Ecology Study</td>
</tr>
<tr>
<td>ARM</td>
<td>Atmospheric Radiation Measurement</td>
</tr>
<tr>
<td>ASCE</td>
<td>American Society of Civil Engineers</td>
</tr>
<tr>
<td>ATLAS</td>
<td>Autonomous Temperature Line Acquisition System</td>
</tr>
<tr>
<td>AXIB</td>
<td>Airborne expendable Ice Beacon</td>
</tr>
<tr>
<td>AXIB</td>
<td>Airborne Expendable Ice Buoy</td>
</tr>
<tr>
<td>BC</td>
<td>black carbon</td>
</tr>
<tr>
<td>BEST</td>
<td>Bering Ecosystem Study</td>
</tr>
<tr>
<td>BOEM</td>
<td>Bureau of Ocean Energy Management</td>
</tr>
<tr>
<td>BowFEST</td>
<td>Bowhead Whale Feeding Ecology Study</td>
</tr>
<tr>
<td>BROMEX</td>
<td>Bromide Ozone Mercury Experiment</td>
</tr>
<tr>
<td>BRP</td>
<td>Bioacoustics Research Program</td>
</tr>
<tr>
<td>BS</td>
<td>Bering Sea</td>
</tr>
<tr>
<td>BSAI</td>
<td>Bering Sea Aleutian Islands</td>
</tr>
<tr>
<td>BSIERP</td>
<td>Bering Sea Integrated Ecosystem Research Program</td>
</tr>
<tr>
<td>CAPAM</td>
<td>Center for the Advancement of Stock Assessment Methodology</td>
</tr>
<tr>
<td>CASA</td>
<td>computer-aided sperm analysis</td>
</tr>
<tr>
<td>CCHDO</td>
<td>CLIVAR &amp; Carbon Hydrographic Data Office</td>
</tr>
<tr>
<td>CCMI</td>
<td>Chemistry-Climate Model Initiative</td>
</tr>
<tr>
<td>CCN</td>
<td>cloud condensation nuclei</td>
</tr>
<tr>
<td>CCSM3</td>
<td>Community Climate System Model Version 3</td>
</tr>
<tr>
<td>CDR</td>
<td>climate data record</td>
</tr>
<tr>
<td>CFC</td>
<td>chlorofluorocarbons</td>
</tr>
<tr>
<td>CFS</td>
<td>Climate Forecast System</td>
</tr>
<tr>
<td>CFS</td>
<td>Coupled Forecast System</td>
</tr>
<tr>
<td>CHAOZ</td>
<td>Chukchi Acoustics, Oceanography, and Zooplankton</td>
</tr>
<tr>
<td>CI</td>
<td>confidence interval</td>
</tr>
<tr>
<td>CIG</td>
<td>Climate Impacts Group</td>
</tr>
<tr>
<td>CLIVAR</td>
<td>Variability and predictability of the ocean-atmosphere system</td>
</tr>
<tr>
<td>CMIP5</td>
<td>Coupled Model Intercomparison Project Phase 5</td>
</tr>
<tr>
<td>CNMI</td>
<td>Commonwealth of the Northern Marianas</td>
</tr>
<tr>
<td>ComMIT</td>
<td>Community Modeling Interface for Tsunami</td>
</tr>
<tr>
<td>CP</td>
<td>Central Pacific</td>
</tr>
<tr>
<td>CPC</td>
<td>Climate Prediction Center</td>
</tr>
<tr>
<td>CPUE</td>
<td>catch per unit effort</td>
</tr>
<tr>
<td>CRN</td>
<td>Climate Reference Network</td>
</tr>
<tr>
<td>CStar</td>
<td>Common Stock Assessment Routines</td>
</tr>
<tr>
<td>CTD</td>
<td>Conductivity, Temperature, Depth</td>
</tr>
<tr>
<td>CUDA</td>
<td>Compute Unified Device Architecture</td>
</tr>
<tr>
<td>DAC</td>
<td>Data Assembly Center</td>
</tr>
<tr>
<td>DART</td>
<td>Deep-ocean Assessment and Reporting of Tsunamis</td>
</tr>
<tr>
<td>DEBITS</td>
<td>Deposition of Biogeochemically Important Trace Species</td>
</tr>
<tr>
<td>DFO</td>
<td>Department of Fisheries and Oceans (Canada)</td>
</tr>
<tr>
<td>DIC</td>
<td>dissolved inorganic carbon</td>
</tr>
<tr>
<td>DOE</td>
<td>Department of Energy</td>
</tr>
<tr>
<td>DO-IT</td>
<td>Disabilities, Opportunities, Internetworking, and Technology</td>
</tr>
<tr>
<td>DT</td>
<td>Decision Theoretic</td>
</tr>
<tr>
<td>EBS</td>
<td>Eastern Bering Sea</td>
</tr>
<tr>
<td>ECC</td>
<td>Ecosystems Considerations Chapter</td>
</tr>
<tr>
<td>EcoFOCI</td>
<td>Ecosystems &amp; Fisheries-Oceanography Coordinated Investigations</td>
</tr>
<tr>
<td>ENSO</td>
<td>El Niño and the Southern Oscillation</td>
</tr>
<tr>
<td>EP</td>
<td>Eastern Pacific</td>
</tr>
<tr>
<td>ESRL</td>
<td>Earth System Research Laboratory</td>
</tr>
<tr>
<td>FEMA</td>
<td>Federal Emergency Management Agency</td>
</tr>
<tr>
<td>FM</td>
<td>forecast models</td>
</tr>
<tr>
<td>FRAM</td>
<td>Fishery Resource and Monitoring</td>
</tr>
<tr>
<td>GCM</td>
<td>Generic Crab Model</td>
</tr>
</tbody>
</table>
Appendices

GDAC..........Global Data Assembly Center
GEIA..........Global Emissions Initiative
GFS..........Global Forecast System
GLM.........generalized linear models
GLM..........Global Lightning Mapper
GOA IERP.....Gulf of Alaska Integrated Ecosystem Research Program
GOES-R......Geostationary Operational Environmental Satellite – R Series
GTC..........Global Telecommunications System
GWT..........Google Web Toolkit
HilT..........Halogens in the Troposphere
HOT...........Hawaii Ocean Time-Series
IABP..........International Arctic Buoy Programme
IAMA..........International Association of Meteorology and Atmospheric Sciences
IATTTC.......Inter-American-Tropical-Tuna-Commission
iCACGP.......International Commission on Atmospheric Chemistry and Global Pollution
ICES..........International Council for the Exploration of the Sea
ICESat.......Ice, Cloud, and land Elevation Satellite
IEA..........Integrated Ecosystem Assessment
IGAC.........International Global Atmospheric Chemistry
IGBP.........International Geosphere-Biosphere Programme
IOC...........Intergovernmental Oceanographic Commission
IOD..........Indian Ocean Dipole
IOS..........Institute of Ocean Sciences (Canada)
IPCC..........Intergovernmental Panel on Climate Change
JAMSTEC......Japan Agency for Marine-Earth Science and Technology
JGOFS........Joint Global Ocean Flux Survey
JISAO........Joint Institute for the Study of the Atmosphere and Ocean
J-SCOPE......JISAO’s Seasonal Coastal Ocean Prediction Experiment
KEO..........Kuroshio Extension Observatory
KESS.........Kuroshio Extension System Study
LCA.........Life Cycle Assessments
MAIRS........Monsoon Asia Integrated Regional Study
MARSS.........multivariate autoregressive state-space models
MBARI........Monterey Bay Aquarium Research Institute
MESA..........Marine Ecology and Stock Assessment
MODIS ........Moderate Resolution Imaging Spectroradiometer
MOST.........Method of Splitting Tsunami
MSE.........management strategy evaluation
MSM..........multi-species assessments
MSM..........multi-species statistical model
NANOOS.......Northwest Association of Networked Ocean Observing Systems
NASA..........National Aeronautics and Space Administration
NCAR.........National Center for Atmospheric Research
NCEP.........National Centers for Environmental Prediction
NCTR.........NOAA Center for Tsunami Research
NDBC.........National Data Buoy Center
NF..........North Fork
NGO.........Non-governmental organization
NIDIS.........National Integrated Drought Information System
NMFS.........National Marine Fisheries Service
NMML.........National Marine Mammal Laboratory
NMQ..........National Mosaic and quantitative precipitation estimates
NOAA........National Oceanic and Atmospheric Administration
NOS..........National Ocean Service
NPFMC........North Pacific Fishery Management Council
NPRB.........North Pacific Research Board
NRC..........Nuclear Regulatory Commission
NSF..........National Science Foundation
NSIDC........National Snow and Ice Data Center
NTHMP........National Tsunami Hazard Mitigation Program
NUREG.......Nuclear Regulatory Commission Regulation
NWFSC.......Northwest Fisheries Science Center
NWP..........Numerical Weather Prediction
NWS.........National Weather Service
OCS..........Ocean Climate Station
OIB..........Operation IceBridge
PAM.........passive acoustic monitoring
PAWS.........Polar Area Weather Station
PFMC.........Pacific Fishery Management Council
PIRATA.......Prediction and Research Moored Array in the Tropical Atlantic
PMEL.......Pacific Marine Environmental Laboratory
PNW.........Pacific North West
PSC..........Polar Science Center
PSW.........Polar Science Weekend
PWS..........portable weather station
QERM.........Quantitative Ecology and Resource Management
QU/QC.......quality assurance/quality control
RACE.........Resource Assessment and Conservation Engineering
RAD.........restriction site associated DNA
RAMA.........Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction
RHC.........reactive halogen compounds
ROMS.........Regional Ocean Modeling System
RUSALCA.....Russian American Long-term Census of the Arctic
SAFE.........Stock Assessment and Fishery Evaluation
SARP..........Sectoral Applications Research Program
SAT..........surface air temperature
SIFT..........Short-term Inundation Forecast for Tsunamis
SIM..........Stand-by Inundation Models
SIO..........Scripps Institution of Oceanography
SIZRS.........Seasonal Ice Zone Reconnaissance
SLP..........sea level pressure
SMEA.........School of Marine and Environmental Affairs
SNP..........single nucleotide polymorphism
SOAR.........Synthesis of Arctic Research
SOLAS........Surface Ocean Low Atmosphere Study
SPARC........Stratospheric Processes and their Role in Climate
SSC..........Scientific Steering Committee
SSH..........sea surface height
SSM..........single species models
SST..........Sea Surface Temperature
STEM.........science, technology, engineering and mathematics
SVP..........Surface Velocity Program
SWR..........shortwave radiation

TAO..........Tropical Atmosphere Ocean
TRITON ......Triangle Trans-Ocean Buoy Network
TTL..........Tropical Tropopause Layer
ULS..........upward looking sonars
UNOLS........University-National Oceanographic Laboratory System
USGS.........United States Geological Survey
USIABP.......United States Interagency Arctic Buoy Program
UTC..........Coordinated Universal Time
UW ..........University of Washington
UW/APL.......University of Washington Applied Physics Laboratory
UWFC.........University of Washington Fish Collection
VOC ..........Volatile Organic Compounds
WACS..........Western Atlantic Climate Study
WHOI.........Woods Hole Oceanographic Institution
WMO.........World Meteorological Organization
WOCE ........World Ocean Circulation Experiment
WRF ..........Weather and Research Forecasting
WSDOH.......Washington State Department of Health
WWLLN.......World Wide Lightning Location Network
WWV ..........warm water volume