July 1, 2010 – March 31, 2011

Joint Institute for the Study of the Atmosphere and Ocean

Annual Report

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EXECUTIVE SUMMARY 2010-2011

INTRODUCTION

Through a NOAA competitive grant process, the Joint Institute for the Study of the Atmosphere and Ocean (JISAO) at the University of Washington (UW) was successfully reestablished in 2010. As part of the UW's innovative College of the Environment (CoEnv), JISAO is expanding its interdisciplinary research and education programs, building on its long tradition of cooperation and excellence in the study of the atmospheric and marine environments. Among the largest and oldest of NOAA's Cooperative Institutes, JISAO promotes collaborative, multidisciplinary research between NOAA and university scientists on a broad range of projects that span the globe from pole to pole, and focus on such critical issues as climate change, ocean acidification, tsunami forecasting, and fisheries assessment. JISAO's research falls within seven major themes: **1. Climate research and impacts; 2. Environmental chemistry; 3. Marine ecosystems; 4. Ocean and coastal observations; 5. Protection and restoration of marine resources; 6. Sea floor processes; and, 7. Tsunami observations and modeling.**

UW is one of the preeminent institutions of higher education in the United States providing world-class resources, facilities and the established infrastructure required to manage a large cooperative institute. JISAO's incorporation into the CoEnv enhances and strengthens its position on campus, as the college brings together a group of departments, schools, programs, and scientists whose interests are focused on environmental issues. Among these, the Department of Atmospheric Sciences, the School of Oceanography, and the School of Aquatic and Fishery Sciences (SAFS) are the three academic units that are most closely aligned with NOAA's goals. CoEnv also includes the Program on the Environment, an undergraduate degree-granting program in environmental science and policy; the Program on Climate Change, a graduate student certificate program in climate studies; the Department of Earth and Space Sciences, which includes paleoclimate research; the Schools of Marine and Environmental Affairs and Forest Resources; Friday Harbor Laboratories, and NOAA Washington Sea Grant. In addition, JISAO works with departments outside CoEnv, including the Evans School of Public Affairs and the Department of Civil and Environmental Engineering. UW provides access to an unprecedented academic and research environmental organization covering the entire domain of NOAA interests.

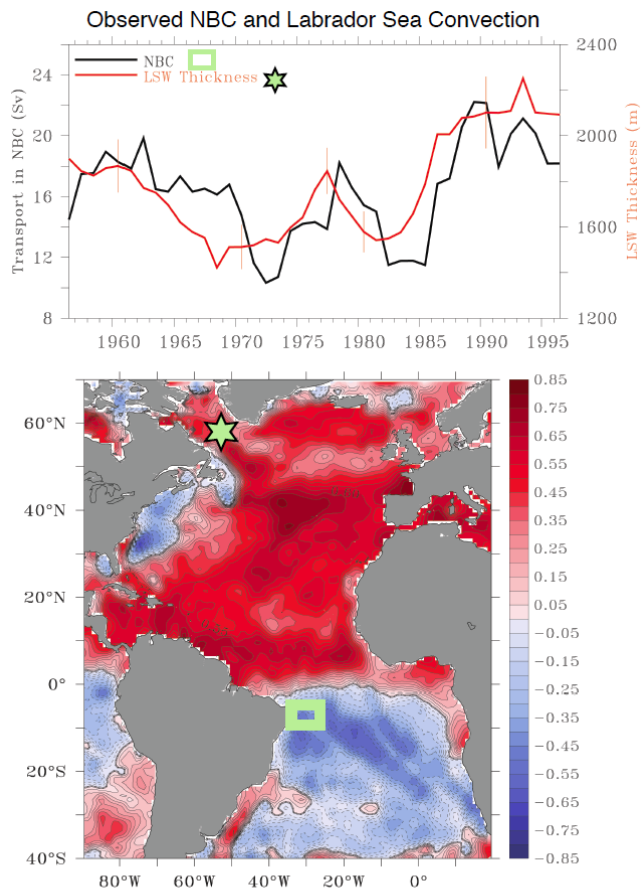
The JISAO Education and Outreach (E&O) Program is continuously involved in a variety of events and programs involving K-12 and college-age students as well as the general public. Supporting the NOAA education goal of promoting environmental literacy, JISAO researchers are attending training sessions at Seattle's Pacific Science Center to learn how to communicate science effectively to non-scientists. To further the goal of developing a future workforce that reflects the diversity of our nation, JISAO's summer internship program, now in its fourth year, recruits students from across the US, including minority-serving institutions, to spend 9 weeks with a mentor, either at UW or NOAA, to work on a specific project related to JISAO research. The first intern from 2008, Angel Adames Corraliza, from the University of Puerto Rico-Mayaguez, began graduate school in the Department of Atmospheric Sciences at UW this fall. More details of JISAO's E&O activities, as well as a financial and administrative management report for the past year, follow the Science Highlights section.

SCIENCE HIGHLIGHTS

The work of JISAO scientists is well recognized in the scientific community and literature, and is featured widely in the media. Specific projects are highlighted in news and spotlight sections of the JISAO website. Below is a summary of the major highlights for the past 9 months.

Climate Research and Impacts

The Atlantic Meridional Overturning Circulation (AMOC) is a key feature of the ocean environment because of its effects on global climate. Nevertheless, only a few papers have been published on the long-term AMOC variability from the instrumental record. JISAO scientist Dongxiao Zhang led a study (2011, JGR in press) featuring analysis of a 50-year time series of flow in the upper ocean off the coast of northern Brazil that proved to represent an index of the AMOC changes. This research also highlighted the link between deep convection in the high latitudes of the North Atlantic, northward flow in tropical Atlantic, and the Atlantic Multidecadal Oscillation through both observations and a thousand-year climate model simulation.



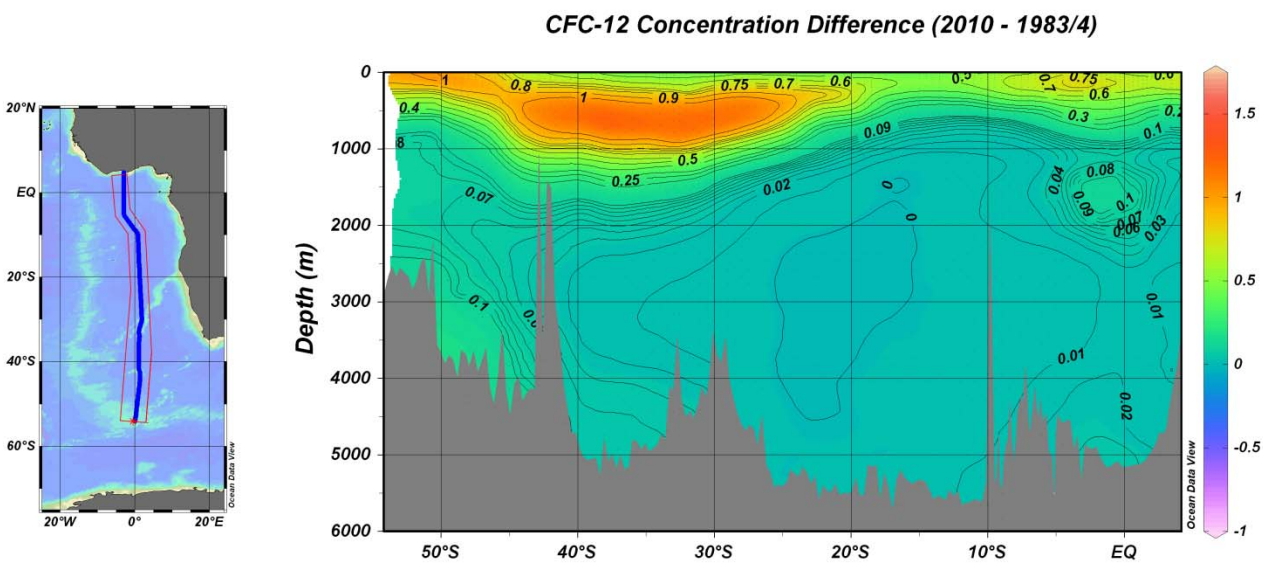
Observed correlation of NBC and SST resembles the spatial pattern of Atlantic Multidecadal Oscillation

The Northern Hemisphere instrumental surface air temperature (SAT) record includes a prominent episode of warming in the early 20th century. This event has been the subject of study over the past 80 years, but has not been fully explained. This topic was pursued by JISAO scientist Kevin Wood and Jim Overland of NOAA/PMEL and collaborators. This work featured

the compilation and analysis of a SAT index for the transition region between the North Atlantic and Arctic Ocean that extends back well into the 19th century, and a comparison of this time series against time series of North Atlantic sea surface temperature over the common period of record (Wood et al. 2010). The idea here was to examine the relationships between multi-decadal fluctuations in the North Atlantic circulation and in the climate of the Northern Hemisphere. The results suggest that the early 20th century warm event could be considered more a singular event rather than a manifestation of a regular cycle in the atmosphere-ocean system. This work represents an example of JISAO's contributions towards our understanding of past climate variability, and in particular the interplay between extended, but random, perturbations in the climate with those associated with anthropogenic forcing.

Environmental Chemistry

JISAO scientist Rolf Sonnerup and collaborators have diagnosed various properties of ocean general circulation models, with a focus on the sensitivity of oceanic $\delta^{13}C$ fields to overturning and gas exchange. The deep and oceanic mean concentrations of $\delta^{13}C$ in the models are dependent on the rate that deep waters form in the North Atlantic and the Southern Ocean. At many modeling centers, the Southern Ocean deep water formation rate has been 'stepped up' to improve deep sea $\delta^{14}C$ and AOU fields. This practice degrades the fidelity of the model simulations with respect to$\delta^{13}C$. Some related work was made possible by the A13 CLIVAR Repeat Hydrography expedition in the South Atlantic Ocean in March-April 2010. This cruise included featured a hydrographic section occupied roughly 25 years earlier, and provided a clear indication of decadal changes in the invasion of anthropogenic compounds such as chlorofluorocarbons into the South Atlantic Ocean (see example below). The observed changes in these tracer fields are providing another means for evaluating global ocean model simulations and for estimating the oceanic uptake of other tracer gases, including carbon dioxide.



A significant impetus for ocean biogeochemical research over the last few decades has been to better understand the ocean's role as a sink for CO_2 released by human activity. The Marine Carbon group at NOAA/PMEL and UW/JISAO is at the forefront of this research. A new article

by Sabine and Tanhua (2010) summarizes the latest research on ocean storage of CO_2 in the second volume of Annual Reviews of Marine Science. The interactions of ocean acidification and other natural and human induced processes on pH and aragonite saturation state changes in a coastal estuary, based on measurements collected in Puget Sound, were documented by Feely et al. (2010). The combined effects of ocean acidification, upwelling, mixing and hypoxia lower the pH and aragonite saturation state in the subsurface waters to values that are substantially lower than what would be expected from atmospheric CO_2 increases alone. Ocean acidification presently accounts for 24-49% of the pH decrease in the deep waters of Puget Sound, and this contribution will almost certainly increase to rising concentrations of atmospheric CO_2. These changes may have profound impacts on the Puget Sound ecosystem over the next several decades.

Marine Ecosystems

For the first time, a synthetic, ecosystem-based assessment of the eastern Bering Sea is available to provide scientific advice to the North Pacific Fishery Management Council (NPFMC). An interdisciplinary team of 21 scientists formed the Eastern Bering Sea Ecosystem Synthesis Team (including JISAO scientists Stephani Zador of AFSC/REFM, and Nick Bond and Lisa Guy of EcoFOCI) to provide an Eastern Bering Sea Ecosystem Assessment "Report Card". In a series of three workshops held during August, September, and October of 2010 the team identified a suite of 10 (out of >200) ecosystem indicators to determine the current state and likely future trends of ecosystem productivity overall, including switches between major pathways involving the benthic versus pelagic domains of the ecosystem. The team also selected indicators thought to best guide managers on ensuring the needs of non-fishery apex predators and maintaining a sustainable species mix in the harvest. The results of this assessment are reported in the Ecosystem Considerations Chapter of the Stock Assessment and Fishery Evaluation reports delivered to the North Pacific Fishery Management Council, (*http://access.afsc.noaa.gov/reem/ecoweb/Index.cfm*). The team will reconvene each year to re-evaluate the suite of selected indicators and develop an updated assessment of the eastern Bering Sea ecosystem.

The identification and classification of marine organisms remain important endeavors. Under the leadership of Theodore Pietsch, Curator of Fishes at the Burke Museum of Natural History and Culture and a professor in the School of Aquatic and Fishery Sciences, significant portions of an annotated checklist of selected macroinvertebrates of Alaska have been completed. Most of the hydrozoans, asteroids, crustaceans, and five of the six molluscan classes have been listed with the higher-level taxonomic classification down to species name, synonyms, common names, type locality, geographic distribution, and depth distribution. Three posters illustrating the Alaskan seastars have been produced. All are available at the Alaska Fisheries Science Center home page *http://www.afsc.noaa.gov/*.

Ocean and Coastal Observations

The Kuroshio Extension Observatory (KEO) represents one of highly-instrumented moored buoys designed and maintained by the Ocean Climate Station (OCS) program of JISAO and NOAA/PMEL. This buoy took a direct hit by Typhoon Choi-Wan on 19 September 2009, with peak winds exceeding 80 knots. While the buoy sustained some damage, the data that it collected and telemetered to shore is providing an unprecedented view of the details in the

ocean's response to forcing by a tropical cyclone. The typhoon caused rapid cooling of the surface waters and a large outgassing of CO_2. The wind forcing also set off rotating currents (near-inertial internal oscillations) that caused water as deep as 500 m to be pumped up and down on a daily basis for over a week. JISAO scientist Nick Bond led a team of scientists from the US and Japan in the analysis of this event, culminating in a recent article in Journal of Geophysical Research Oceans (Bond et al. 2011). It bears emphasizing that this case study could only be undertaken through the capabilities of OCS to design and build moorings such as KEO that can operate in very harsh conditions.

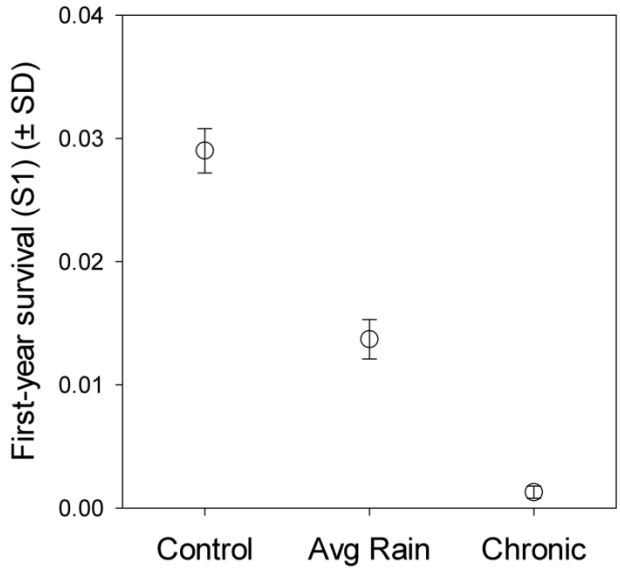
Protection and Restoration of Marine Resources

On April 22, 2010, the Deepwater Horizon wellhead had a catastrophic blowout, causing the release of millions gallons of light Louisiana crude oil into the Gulf of Mexico. Upon discharge into the environment, the composition of the crude oil began physical and chemical changes through several processes often termed weathering. Professor Russel Herwig of the School of Aquatic and Fishery Sciences (SAFS) assisted NOAA's Office of Response of Restoration by providing expertise in environmental microbiology and petroleum hydrocarbon biodegradation. There was an urgent need for this work. The existing relationship between JISAO and NOAA allowed it to be carried out expeditiously.

While it is commonly thought that salmon always return to spawn where they were incubated and emerged, the degree of fidelity to the natal site, versus straying, can vary considerably. Forest Resources professor Christian Torgerson examined the potential effects of habitat quality on homing patterns of female Chinook salmon in the Yakima River and found that salmon were less likely to spawn in reaches in which they were acclimated as juveniles if higher quality spawning habitat was available elsewhere. In another project on the Yakima River, the work focused on the effects of spatial patterns of fine sediment infiltration in salmon redds. The results indicated that although there was not a strong relationship between egg-to-fry survival and fine sediment intrusion in spawning substrates, and that fine-sediment infiltration patterns varied substantially at fine and coarse spatial scales. This example illustrates the multi-disciplinary nature of the research being conducted under this theme.

Joel Baker of the Interdisciplinary Arts and Sciences Program at the University of Washington, Tacoma led the development of field and laboratory methods to sample and quantify marine microplastics and continued to characterize the spatial and temporal variability in microplastics concentrations in the Puget Sound. The Second International Workshop on Marine Microplastic Debris was held at the UW Center for Urban Waters in Tacoma in November 2010. A special effort has been devoted to engaging the public through establishment of cooperative sampling programs with several Puget Sound environmental education groups.

A group led by Professor David Beauchamp of SAFS developed a model to project population-level consequences of sublethal copper exposure in juvenile coho salmon. At the concentrations and exposure durations modeled, the primary expected effect on juvenile coho salmon was reduced sensory detection of the risk of predation. As shown below, its impact on survival rate is substantial.



Model projection of average first year survival from emergence for juvenile coho salmon in a typical Puget Sound lowland stream: Model scenarios contrast a 'Chronic', 'Avg. Rain', and 'Control' scenarios. In the 'Chronic' scenario, juvenile coho were exposed daily to the Washington State chronic copper criterion for a typical Puget Sound basin stream (4.3 ppb). For the 'Avg. Rain' scenario, exposure was 4.3 ppb dissolved copper only during rain events with > 0.5" precipitation/day. In the control condition it was assumed that no copper entered the stream. Modeled effects arose from the reduced ability of juvenile coho to detect predators and avoid predation during copper exposure. The results from this research suggest that low levels of bioavailable copper may contribute to reduced resiliency of coho salmon in urbanizing basins of Puget Sound.

Sea Floor Processes

Exploration of the oceans is a NOAA priority, and has led the NOAA/PMEL and UW/JISAO Hydrothermal Research Group to discover unique volcanic features and ecosystems on the ocean floor that have importance for global ocean processes. Of recent interest is the first ever discovery of submarine volcanoes with persistent ongoing eruptions, affording a spectacular first look at deep ocean volcanic processes. Erupting volcanoes and the hydrothermally active volcanoes around them emit large quantities of acid and carbon dioxide, creating conditions of local acidification. The study of biological communities in these acidified environments has provided an understanding of the physiological effects of high CO_2 and low pH on marine life. JISAO scientists Joseph Resing and David Butterfield re-visited these volcanoes during two research cruises in the past year to gain a better perspective on their oceanic impacts. This work was carried out in the context of existing data and samples, and includes an ongoing effort to inform the public of the findings. Additionally, detailed studies of volcanic and hydrothermal processes at Axial Seamount and Endeavour long-term seafloor observatory sites in the NE Pacific continue to provide a deeper understanding of the complex links between volcanic activity, hydrothermal chemistry, and microbial ecology.

Tsunami Observations and Modeling

Just over a year ago the Nazca tectonic plate in the South Pacific slipped under the South American plate along the central coast of Chile, generating the fifth largest earthquake by magnitude in recorded history. This enormous seismic event generated a similarly large tsunami, with devastating impacts near the epicenter. Immediately after the event, UNESCO organized and coordinated several international teams of scientists and researchers from different countries to survey the affected coastlines. Diego Arcas, a member of the JISAO tsunami research group and NOAA Center for Tsunami Research (NCTR) participated in one of the survey teams. The lessons he learnt from his work in the aftermath of the tsunami are many, at both the scientific and personal level. From a scientific standpoint this event underlined the need to expedite the

forecast process for the near-field region. Despite the size of the tsunami in the vicinity of the rupture area, a very small proportion of the damage, and only about 1% of the casualties occurred in the intermediate or far fields. This result has motivated tsunami scientists to consider the ways in which accurate and timely forecasts can be generated for the near-field region. It was a profound experience for Diego to witness the humanitarian disaster and to hear about so many personal tragedies brought about by the tsunami. It represented a powerful reminder that tsunami science is ultimately about reducing the societal consequences of these events.

EDUCATION AND OUTREACH

"I am very grateful to have had this opportunity to be an intern at JISAO, particularly because it was key to my decision to become a graduate student in the Department of Atmospheric Sciences at UW, one of the most respected in the nation."

~Angel Adames Corraliza, JISAO Intern

JISAO's Education and Outreach (E&O) Program has continued to make important contributions to UW College of the Environment (CoEnv) and to NOAA's goals of advancing environmental literacy at all levels of society while mentoring the next generation of scientists who reflect the diversity of our nation and are skilled in science and technology. Of the many projects supported by the E&O Program, perhaps most noteworthy is the success of the JISAO Summer Internship Program. Now in its fourth year, the internship program began in 2008 with one student, expanded to four students in summer 2009, and in 2010, JISAO hosted seven interns from universities across the US. This was made possible in part by the additional support of NOAA's Office of Oceanic and Atmospheric Research (OAR). In past years, the NOAA Center for Atmospheric Research (NCAS) at Howard University collaborated with JISAO and provided intern support.

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

- **JISAO and NOAA Center for Atmospheric Sciences (NCAS) and Howard University Partnership**
    - JISAO contributed to the NCAS Color of Weather event at the annual American Meteorological Society meeting in Seattle, January 2011.
    - NCAS and JISAO are currently exploring ways to reestablish summer internship collaboration
    - NCAS and JISAO are planning a more formalized faculty exchange program between the two institutions
    - JISAO scientist, Dr. Kevin Wood, recently visited NCAS to discuss a possible collaboration which would involve Howard students in working with weather data from logbooks collected on historical cruises in Alaskan and Arctic waters. These log books are in the National Archives in Washington, DC. The data will be used to better diagnose high-latitude historical climate.

- **Morehouse College Collaboration**
    - JISAO director, Tom Ackerman, plans continued discussions on ways the institute can collaborate with Morehouse to offer more opportunities for student internships in the future.

- **JISAO Summer Research Internship**
    - JISAO welcomed seven undergraduate students in summer 2010. Students were matched with mentors at NOAA's Pacific Marine Environmental Laboratory, UW Friday Harbor Laboratories on San Juan Island, and UW Atmospheric Sciences, Oceanography, and Fisheries. Student web pages and videos are displayed in the Outreach section on JISAO's website at: These interns and their universities are listed below:

        - Angel Adames-Corraliza, University of Puerto Rico, Mayaguez
        - Korita Humphries,Claflin University
        - Alex Kowaleski: Davidson College
        - Nikki Marschke: Drake University
        - Cole Perkinson: Reed College
        - Kelsey Powers: University of Washington
        - Kyle Thomas: Texas Southern University

    - Angel Adames-Corraliza, JISAO undergraduate intern in 2008, began graduate school last fall in the UW Department of Atmospheric Sciences.

- **Pacific Science Center (PSC) Partnership**
    - Science Communication Fellows
        - JISAO scientists continue to undergo training as official Science Communication Fellows as part of PSC's Portal to the Public initiative. Science Communication Fellows are professionals who have been certified by PSC as current science ambassadors and excellent communicators.
        - Each scientist participated in a series of professional development workshops and created a hands-on educational activity related to their work.
        - In September, Jed Thompson participated in a two-day discussion about the Portal to the Public (PoP) program and new ways to improve public audiences' engagement with science. An important part of the discussion was to determine next-step innovations for the future of the PoP program.
    - 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. Five JISAO scientists were featured with activities showing their work on climate change, tsunamis, and underwater volcanoes.

- **K-12 Events**
  - JISAO co-sponsored the 2011 Orca Bowl event presented by Washington Sea Grant. Teams of high school students from around Washington State came to the UW campus to challenge their knowledge of the world's oceans. Top prizes included UW Oceanography scholarships and shipboard science experiences. JISAO's sponsorship of the event made travel and lodging possible for students coming to Seattle for the competition.
  - JISAO sponsors workshops and other events in collaboration with the UW GEAR UP, a program that fosters college awareness and readiness for low-income middle and high school students by providing a variety of programs targeted to students, administrators, and teachers. In 2010 JISAO hosted two GEAR UP Summer Institute workshops focusing on NOAA's climate and ocean literacy principles.
  - NOAA Science Camp: JISAO scientists led sessions and participated in NOAA Science Camp. 2010 was the fifth year that JISAO funded NOAA Science Camp scholarships for low income and underrepresented students. JISAO was able to increase the amount of scholarships this year. 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 go. Cara MariAnna and JISAO were awarded a NOAA Bronze Award for their work with NOAA Science Camp.
  - Nick Bond visited Anchorage, Alaska to help develop educational resources based on his research with the Bering Sea Integrated Ecosystem Research Program (BSIERP). The workshop gathered K-12 teachers from the BSIERP research cruises, teachers form Bering Sea communities, and other members of the scientific community to develop curriculum based on results from the BSIERP research program.
  - Sound Waters: Nick Bond co-taught a class with Dr. Richard Feely of NOAA/PMEL called Ocean Acidification, Ecosystems, and Climate. The second-annual class was part of the public education efforts by the Island County Beach Watchers. The issues that were addressed involved how climate change effects the Northwest and how citizens can limit their carbon footprint.

- **Conferences and Career Fairs**
  - AISES (American Indian Science and Engineering Society) National Conference, Albuquerque, NM: JISAO scientist Jessica Kleiss attended the 2010 meeting and talked with students about JISAO internships and other opportunities. AISES is an organization supporting Native American students working in various fields of science. JISAO is making an effort to recruit Native American students, so the conference was a valuable opportunity to make connections and learn about issues facing these students and their communities.
  - SACNAS (Advancing Hispanics, Chicanos and Native Americans in Science) National Conference in Anaheim, CA: Scott Schaffer from UW Aquatic and Fishery Sciences represented the College of the Environment and distributed applications for JISAO's internship program.

- Celebration of Oceans and Community - *Connecting Scientists, Educators, and Citizens to Address Environmental Challenges*: In February, 2011, Nick Bond and Jed Thompson represented JISAO at the Seattle Aquarium during a gathering of scientists and community members who shared an interest in marine environmental issues. The keynote speaker of the evening was Dr. Lisa Graumlich, the dean of the UW's College of the Environment (CoEnv). Following her presentation Dr. Graumlich announced the CoEnv's outreach award to honor public engagement in sciences.

- **Outreach Communication**
  - JISAO debuted its new online video program called Science in 180. Each three-minute video highlights the work of one of JISAO's scientists and is aimed at students in middle or high school. The website debuted with three videos on: ocean acidification, undersea volcanic eruptions, and JISAOs sun photometer contribution to the Around the Americas voyage. The response on this project has been good.
  - 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.
  - A new JISAO website is in design stages and will debut in a month or so. It will provide a more effective means to communicate institute activities to constituents and will have an improved, user-friendly format and organization.

FINANCIAL MANAGEMENT AND ADMINISTRATION

JISAO's management and organizational structure changed over the past year to reflect the business plan in the recompetition proposal. Dr. Nicholas Bond assumed the new Deputy Director role and Mary Smith is now Assistant Director for Finance and Administration. The staff continually work to improve services to JISAO constituents and to streamline operations, cutting costs wherever possible. A financial summary for past 9 months is below. JISAO's Cooperative Agreement research is funded through three tasks:

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

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

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

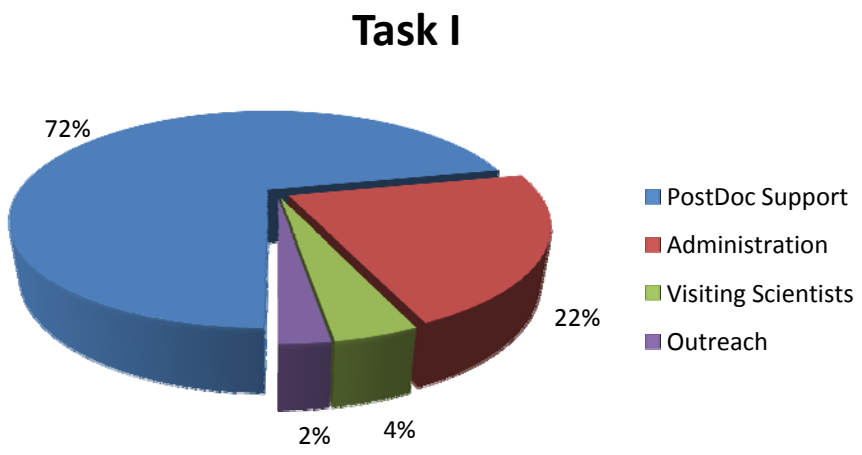
Steven J. Davis, JD, PhD, visited this year and worked in the JISAO Climate Impacts Group. He is from the Department of Global Ecology, Carnegie Institution of Washington in Stanford, CA. His ongoing research into the social, economic and technological drivers of greenhouse gas emissions dovetails very well with the research carried out in JISAO, especially within the Climate Impacts Group and UW's Program on Climate Change, which coordinates climate science teaching and outreach on campus. JISAO provided Dr. Davis with office space and access to UW facilities; his home institution provided his salary. He plans to continue work here for another year.

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

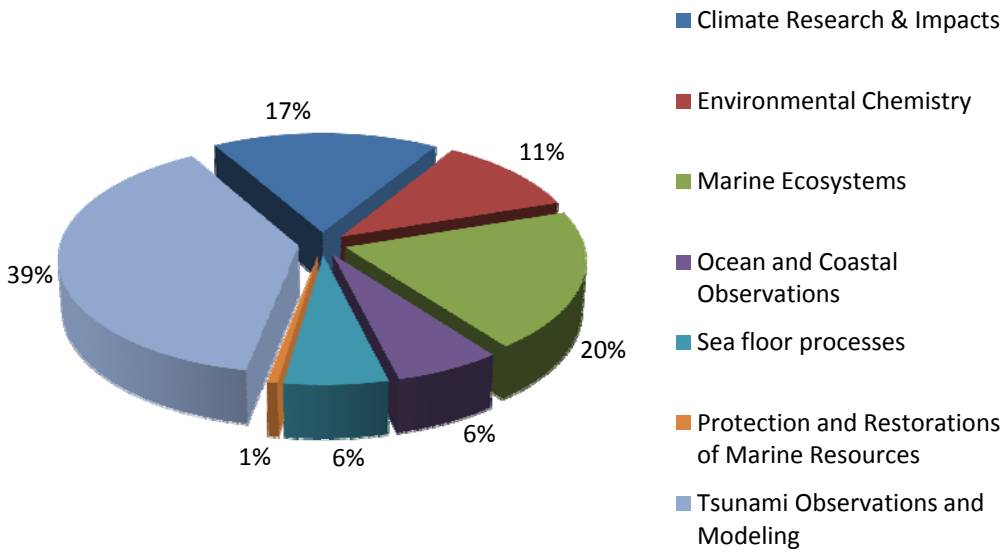
Task II serves as a vehicle for funding research scientists (UW professional staff), postdoctoral research associates, graduate students and technical staff through the JISAO Cooperative Agreement. The Task II program supports directed, collaborative research efforts between NOAA and university scientists.

Task III supports University of Washington research in areas compatible with the institute's major research themes. Along with Task II, Task III programs serve as vehicles for funding research scientists (UW faculty and professional staff,) postdoctoral research associates and graduate students through the JISAO Cooperative Agreement. Task III also supported postdoctoral research associates housed at NOAA. University of Washington grants and principal investigators on NOAA grants funded through Task III are listed in Appendix 2.

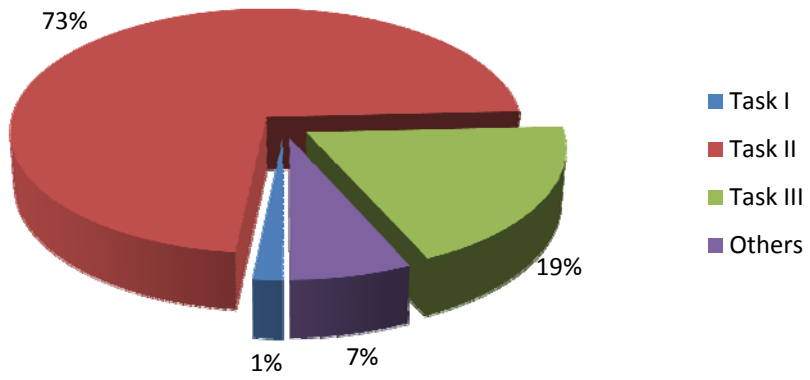
The JISAO/NOAA Cooperative Agreement funding for the nine months ending on March 31, 2011, totals $16,573,653 ($13,873,385 new award plus previous award amendment # 185, $2,700,268 received for Steve Riser in July 2010). JISAO's funding exclusive of the Cooperative Agreement for the last 9 months amounts to another $2,011,964. The charts below break down Cooperative Agreement funding by themes and tasks.



Themes



Tasks



JISAO's management team continued to work on the following initiatives over the past year to improve and strengthen JISAO as an organization:

- JISAO Staff Recognition Program
  - The State of Washington has put a freeze on allowing monetary awards to be given under this program. The program, created to award UW/JISAO employees at the same levels as the NOAA employees with whom they work, was highly successful and JISAO hopes to continue it when the freeze is lifted.
  - Recognized outstanding research and papers on JISAO website.
  - Presented UW service awards to JISAO employees.

- JISAO Outreach and Education Program
    - Continued to strengthen and broaden the success of the E&O program (see section above for details of the year's activities)
- Strengthening Communications
    - Continued joint quarterly meetings with JISAO and NOAA employees
    - Planning a 4th annual all-staff meeting on UW campus that includes all JISAO employees at UW and those who work at NOAA facilities.
    - JISAO administrator continued to hold weekly office hours at NOAA/PMEL, improving communications and collaboration between NOAA and UW personnel.
    - Upgraded information on JISAO website and continue to develop and improve communications through this site. Website is currently being re-designed to include all 7 scientific themes as outlined in the recompetition proposal.
    - Developed and debuted new Science in 180 video series.
    - Participated on both the NOAA and UW CoEnv communications teams to regularly share information and best practices.
    - Continued to develop JISAO's marketing and public relations efforts to communicate research and education goals and activities to partnering organizations as well as local, regional and national communities.
    - Added Facebook page to website.
    - Created better systems to track media coverage and publications of JISAO researchers.
    - Developed additional educational and public relations materials.
- Improving Organization and Infrastructure
    - Reviewed and streamlined staff assignments to better serve research and education needs.
    - Reorganized administrative and supervisory structure, including JISAO scientific and technical staff working at NOAA.
    - Thomas Ackerman, JISAO Director, is a member of the CoEnv Executive Committee and serves the College is various other capacities.
    - Mary Smith, JISAO Administrator, participates in both the CoEnv Administrator and Communications Groups.

Climate Research and Impacts

California NIDIS Pilot

PI
UW - Anne C. Steinemann

Task III

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

NOAA Goal

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

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

Objectives
To assist in the:

1. Design of NIDIS Pilot,
2. Implementation of Pilot,
3. Evaluation of Pilot.

Accomplishments:
This project has just started. These accomplishments relate to Project objective 1, for year one. Project objectives 2 and 3 will be conducted during the next two years of this three-year project.

The first NIDIS Pilot meeting was held in September 2010 in La Jolla, California. Together with federal agency representatives and key partners, planned the initial activities of a NIDIS pilot drought early warning system (DEWS) in California. Reviewed NIDIS objectives, governance, activities, the drought portal, and results of the recent NIDIS executive committee meeting. Also discussed the regional pilot drought early warning system in the Upper Colorado River Basin, and in the Southeast, including organization, strategies for engagement, future steps and lessons learned.

For details and more information, please visit the NIDIS website at:
http://www.drought.gov/portal/server.pt/community/drought_gov/2010_CA_Scoping_Workshop

Ship Time for Modeling Favorable Habitat Areas for *Alexandrium Catenella* in Puget Sound and Evaluating the Effects of Climate Change

PI
UW - Eric P Salathé

Other Personnel
UW - Neil Banas, Cheryl Greengrove, Julie Masura
NOAA - Stephanie Moore, Vera Trainer, John Stein
WHOI - Don Anderson

Themes
Climate Research and Impacts
Marine Ecosystems
Ocean and Coastal Observations

Task II

NOAA Primary Contact
Stephanie Moore, North West Fisheries Science Center

NOAA Goal

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

Description
The project will to determine year-to-year variations in the distribution and abundance of A. catenella resting cysts, identify optimal conditions for cyst germination and growth of cells, model favorable habitat areas for A. catenella, and determine how favorable habitat areas might change in a warmer climate.

Objectives
This award is to support vessel time on the Clifford Barnes as part of the NOAA ECOHAB project "Modeling favorable habitat areas for *Alexandrium catenella* in Puget Sound and evaluating the effects of climate change".

Accomplishments
A series of cruises are currently underway.

Tropical Atmosphere-Ocean Interaction

PI
NOAA - M. McPhaden

Other Personnel
UW - Patrick Berk, Sonya Brown, Daniel Dougherty, Curran Fey, Gregory Foltz, Willian Higley, Chase Latta, Korey Martin, Dai McClurg, Ben Moore, Linda Stratton, Dongxiao Zhang, David Zimmerman
NOAA - Paul Freitag, Steve Kunze, Douglas MacIntyre, Patricia Plimpton, Andy Shepherd

Task II

NOAA Primary Contact
Climate Program Office

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

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 the scientists' 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 all 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.

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

Objectives

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

Accomplishments
Research carried out at JISAO and elsewhere using data from the TAO/TRITON, PIRATA and RAMA arrays depends critically on the collection, quality control, archival, and web-based display and dissemination of mooring data sets. At JISAO, considerable effort is devoted to providing easy access to high quality multi-variate time series through the TAO web page (*http://www.pmel.noaa.gov/tao/*). Between July 2010 and February 2011, TAO web pages received more than 10 million hits and delivered more than 122,000 mooring data files to the international community. The researchers are also developing a new set of web pages specifically for RAMA, highlighting the international partnerships involved and progress towards implementation of this new observing system.

The team deployed 1 new ATLAS Flux mooring in the Indian Ocean at 12°S, 55°E from the South African fisheries vessel *Algoa* in October 2011. This mooring represents progress in a developing collaboration between JISAO, NOAA and the Agulhas and Somali Current Large Marine Ecosystems (ASCLME) Project for the development of RAMA, which is now 61% complete.

Satellite observations were analyzed suggesting that the intensity of El Niño events in the central equatorial Pacific (CP) has almost doubled in the past three decades, with the strongest warming occurring in 2009–10. This is related to the increasing intensity as well as frequency of the so-called CP El Niño events since the 1990s. While sea surface temperature (SST) in the CP region during El Niño years has been increasing, those during neutral and La Niña years have

not. Therefore, the well-documented warming trend of the warm pool in the CP region is primarily a result of more intense El Niño events rather than a general rise of background SST. Results were published in Lee and McPhaden (2010).

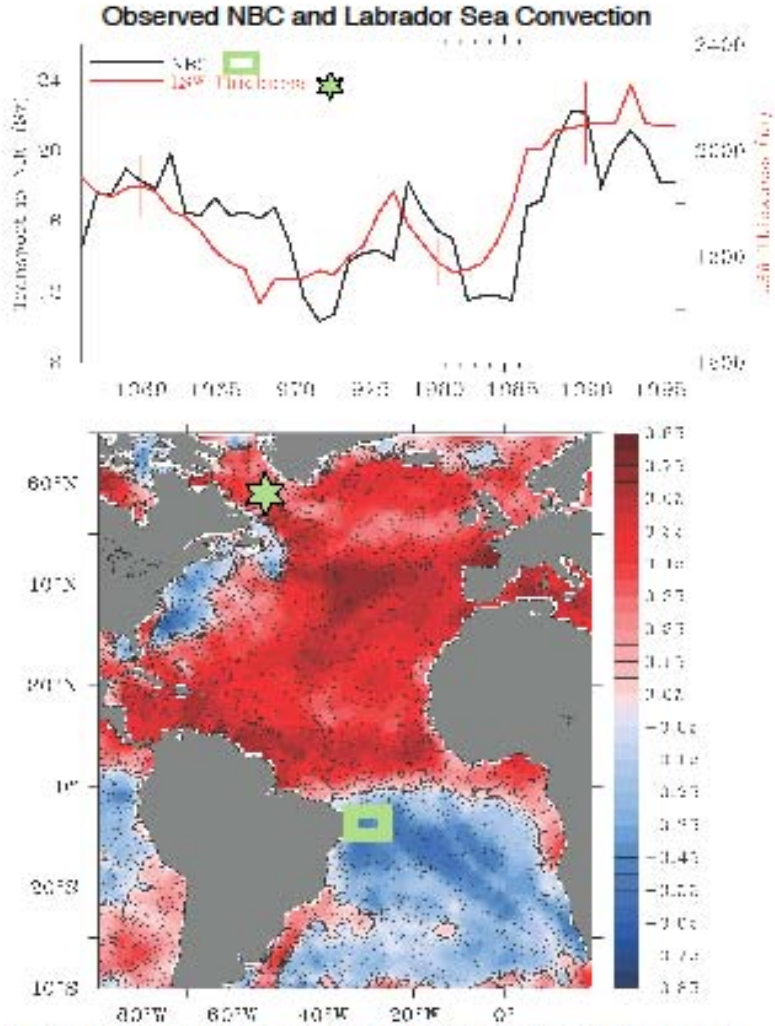
The scientists examined interannual variability in the equatorial Indian Ocean using observations and a continuously stratified linear long-wave ocean model driven by European Centre for Medium-Range Weather Forecasts winds. Their focus is on the relationship between wind stress, zonal velocity, and sea surface height (SSH) in association with the Indian Ocean dipole (IOD). The model correctly simulated the dominant pattern of variability associated with the IOD in which SSH anomalies near the equator tend to tilt zonally in phase with zonal wind forcing. Both observations and the model also showed that surface zonal velocity on the equator tends to lead zonal wind stress by about 1 month on interannual time scales. This phasing occurs because velocity anomalies reverse before the wind anomalies reverse during the decay of IOD events. The model simulations indicated that this reversal of velocity earlier than winds is caused by reflected Rossby waves radiating from the eastern boundary. These results have important implications for understanding the evolution of IOD events because of the role of zonal advection in determining interannual variations in equatorial Indian Ocean sea surface temperature anomalies. Results were published in Nagura and McPhaden (2010).

Interaction between the tropical Atlantic meridional and Niño modes was investigated using observations and a quasianalytical linear equatorial wave model. It was found that equatorial zonal wind stress anomalies associated with the boreal spring meridional mode generate eastward propagating equatorial Kelvin waves in the central and eastern Atlantic Ocean, where variability associated with the Niño mode is strongest. These same wind stress anomalies force westward propagating equatorial Rossby waves that reflect at the western boundary into eastward propagating Kelvin waves during boreal spring and summer. The boundary-generated Kelvin waves are of the opposite sign to those directly forced by the winds earlier in the spring, so they tend to damp the Niño mode during boreal summer. The interaction between the boreal spring meridional mode and the summer Niño is therefore mediated by directly wind-forced equatorial Kelvin waves and the delayed negative feedback from western boundary reflections of wind-forced Rossby waves. Results were published in Foltz and McPhaden (2010a).

The North Brazil Current (NBC) connects the North and South Atlantic, and is the major pathway for the surface return flow of the Atlantic Meridional Overturning Circulation (AMOC). The team calculated the NBC geostrophic transport time-series based on 5 decades of observations near the western boundary off the coast of Brazil. Results reveal a multidecadal NBC variability that lags by a few years Labrador Sea deep convection. The NBC transport time series is coherent with the Atlantic Multidecadal Oscillation (AMO) in sea surface temperature, which also has been widely linked to AMOC fluctuations in previous modeling studies. The team's results thus suggest that the observed multidecadal NBC transport variability is a useful indicator for AMOC variations. The suggested connection between the NBC and AMOC is assessed in a 700-year control simulation of the GFDL CM2.1 coupled climate model. The model results are in agreement with observations and further demonstrate that the variability of NBC transport is a good index for tracking AMOC variations. Concerning the debate about whether a slowdown of AMOC has already occurred under global warming, the observed NBC transport time series suggests strong multidecadal variability but no significant trend. Results are

in press and will be highlighted contribution in J. Geophys. Res. (Zhang, Msadek, McPhaden, and Delworth, 2011: Multidecadal Variability of the North Brazil Current and its Connection to the Atlantic Meridional Overturning Circulation).

The Atlantic Meridional Mode (AMM) is the dominant source of coupled atmosphere–ocean variability in the tropical Atlantic, characterized by a hemispheric sea surface temperature (SST) gradient and cross equatorial surface winds that reinforce SST anomalies in both hemispheres. The AMM provides a theoretical framework for understanding the nature of regional patterns of precipitation and Atlantic hurricane variability. Although the wind-evaporation-SST (WES) feedback reinforces the existing meridional SST gradient when either phase of the AMM is excited the AMM is thermodynamically damped and thus requires external forcing to persist as is observed. However, there is little consensus as to what physical mechanisms may excite the AMM and thus govern regional coupled climate variability. Here the team use observations and a physical model to show that the AMM is excited by variability in African dust outbreaks via the dust radiatively-forced SST anomalies on interannual to decadal time scales. Their analysis suggests that SST anomalies resulting from the aerosol direct effect persist in time via the WES feedback that defines the AMM. They conclude that the AMM and the state of the tropical Atlantic are directly tied to land surface processes over West Africa via dust emission. These results suggest that human activity may already be altering regional climate due to land use change and underscore the importance of resolving uncertainty in modeling land surface processes and dust emissions in order to estimate the regional response to future climate change. Results are in review by Nature Geosciences (Evan, Foltz, and Zhang 2011: African dust forces the dominant ocean-atmosphere variability in the tropical Atlantic).



Observed correlation of NBC and SST resembles the spatial pattern of Atlantic Multidecadal Oscillation

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

PI
UW - Ignatius Rigor

Other Personnel
UW - Mark Ortmeyer

Themes
Climate Research and Impacts
Ocean and Coastal Observations

Task III

NOAA Primary Contact
John Calder, Arctic Research Office

NOAA Goal
3. Serve Society's Need for Weather and Water Information

Description
Dramatic changes in Arctic climate have been noted during the past two decades. Observations from the International Arctic Buoy Programme (IABP) have played a significant role in the detection of this change. For example, using IABP data, Walsh et al. (1996) showed that sea level pressure (SLP) has decreased; Rigor et al. (2000) showed that surface air temperature (SAT) has increased; and in concert, the circulation of sea ice and the ocean have changed so as to flow less clockwise (Steele and Boyd, 1998; Kwok, 2000; and Rigor et al. 2002). In addition to studies of Arctic climate and climate change, observations from the IABP are also used to validate satellites, for forcing, validation and assimilation into numerical climate models, and for forecasting weather and ice conditions.
The Polar Science Center, Applied Physics Lab of the University of Washington (PSC/APL/UW), and the National Ice Center (NIC) co-manage the US Interagency Arctic Buoy Program (USIABP), which coordinates the US contributions to the IABP. The USIABP purchases and deploy buoys using a pool of funds provided by NOAA, and contributions from other US agencies (Coast Guard, National Aeronautics and Space Administration, National Science Foundation, Naval Oceanographic Office, and the Office of Naval Research. Funds from this particular USIABP grant are focused on monitoring the Eurasian Basin of the Arctic Ocean. This progress report highlights USIABP activities and accomplishments during the last year.

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

Accomplishments
1. USIABP Buoy Purchases and Deployments in 2010

- One Polar Arctic Weather Station (PAWS) deployed by PSC at the North Pole Environmental Observatory (NPEO) in April 2010.
- Two eXpendable Ice Beacons (XIB) deployed from the US ice breaker Healy in September, 2010.
- Two Airborne eXpendable Ice Beacons (AXIB) deployed during the USCG Arctic Domain Awareness Flights in September, 2010.
- Fifteen Surface Velocity Program (SVP) Barometer Upgrade buoys, which will be deployed during the summer of 2011.
- One PAWS buoy which will be deployed by PSC at the NPEO in April 2011.

2. IABP Coordination

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

As of February 28, 2011, 14 of the 42 IABP buoys were purchased by the USIABP (Figure 1), and 21 were deployed by logistics secured by the USIABP.

This year, the IABP plans to deploy over 100 buoys. The scientists' deployment plans for the Spring and Summer of 2011 may be viewed at *http://iabp.apl.washington.edu/overview_deploymentplans.html*.

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

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

3. Outreach

Press Interviews and Articles (reverse chronological order):

- Renee Schoff: Winter storms don't undermine global warming science, climate experts say, McClatchy Newspapers, Jan. 30, 2011 (*http://www.miamiherald.com/2011/01/30/2041803/winter-storms-dont-undermine-global.html*).
- Andy Revkin: Polar Scientists Discuss Polar Bear's Fate, Dot Earth Blog, New York Times, Dec. 20, 2010 (*http://www.miller-mccune.com/environment/measuring-the-melting-arctic-sea-ice-18321*).
- Bruce Dorminey: Measuring the Melting of Arctic Sea Ice, Miller-McCune, July 4, 2010 (*http://www.miller-mccune.com/environment/measuring-the-melting-arctic-sea-ice-18321)*.

Pacific Science Center

Polar Science Weekend (PSW)

Since 2006, the Polar Science Center has been cultivating a relationship with Seattle's Pacific Science Center (PacSci) a hands-on science museum with the highest attendance of any museum in Washington State. The team's initial meetings led to the conception and execution of the first annual 'Polar Science Weekend' (PSW, see *http://psc.apl.washington.edu/psw/*), a 4-day event in March 2006 hosted by the Pacific Science Center, in which scientists from the Polar Science Center presented

demonstrations, lectures, activities, and exhibits about the polar regions and current research. More than 5000 visitors attended the initial event, and attendance has grown to over 20000 visitors in 2009.

The scientists supplied buoys for the Measurement Technology exhibit, in which visitors could examine and touch a variety of instruments used for making observations of the polar environment. The exhibit was staffed by Rigor and others from the Polar Science Center, who answered questions from visitors and showed graphs of the data collected by the instruments.

For the 2010, the team focused on improving the "hands on" science demonstrations at the PSW. For example, in order to demonstrate the forces driving sea ice motion, they built an ice tank in which visitors can control the speed and direction of the winds and ocean currents (Figures 2 & 3). This demonstration helped explain the animations of buoy drift and how changes in wind may affect the distribution and age of sea ice on the Arctic Ocean.

The Polar Science Weekend gives the researchers 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.

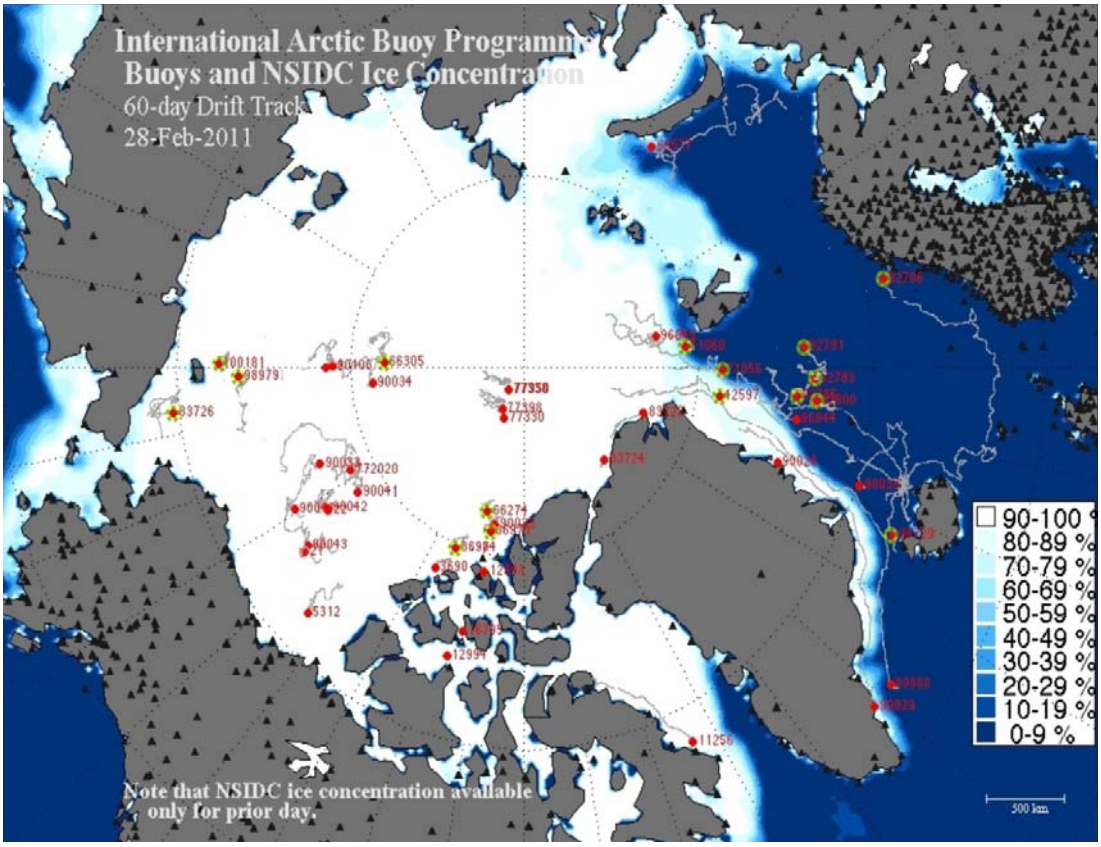


Figure 1. Map of buoys reporting from the Arctic Ocean on February 28, 2011. Buoys marked with yellow and green dashed circles were purchased using funds from this and other grants for the USIABP.

Figure 2. Young scientists controlling the drift of "sea ice" by adjusting the speed and direction of the winds and ocean currents in a hands on demonstration at the Polar Science Weekend at the Pacific Science Center in February 2010.

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

PI
UW - Stephen C. Riser

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

JISAO Themes
Climate Research and Impacts
Ocean and Coastal Observations

Task III

NOAA Primary Contact
Dr. Steve Piotrowicz, OAR-CPO

NOAA Goal

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

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

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

Accomplishments

During the past year, the team deployed 142 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 4 winter seasons. Some of the floats deployed in the past year (about 15) were deployed in the Southern Ocean, for the third year in a row. These floats used new software that allowed them to operate for extended periods under seasonal Antarctic ice. All of the Antarctic floats used the Iridium communication system, and many carried dissolved oxygen sensors.

Center for Science in the Earth System

PIs
UW - Nathan Mantua, Amy Snover, Edward Miles (through July 31st, 2010)

Other Personnel
UW - Jessica Beetz, Derek Booth, Jeff Deems, Tim Essington, Richard Fenske, David Fluharty, Rich Gwozdz, Alan Hamlet, Richard Hoskins, Daniel Huppert, Elizabeth Jackson, Jim Johnstone, Adrienne Karpov, Catherine Karr, Patrick Keys, Ann Marie Kimball, Dennis Lettenmaier, Zenobia Levy, Jeremy Littell, Guillaume Mauger, Marketa Elsner McGuire, Don McKenzie, Vimal Mishra, Todd Mitchell, Amber Moore, Stephanie Moore, Robert Norheim, Crystal Raymond, Jonathan Reum, Erin Rogers, Roger Rosenblatt, Eric Salathé, Rick Steed, Anne Steinemann, Qiuhong Tang, Ingrid Tohver, Michael J. Wallace, Michael Warner, Lara Whitely Binder, Sasha Wittmann
NOAA - Harrison, D. Edmund
PNNL - Ruby Leung, Michael Scott
WSU - Chad Kruger, Claudio Stockle

Themes
Climate Research and Impacts
Marine Ecosystems

Task III

NOAA Primary Contact
Chet Ropelowski, CDEP
Adam Parris, RISA/CPO

NOAA Goals
1. Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
2. Serve Society's Need for Weather and Water Information

Description
As part of the Center for Science in the Earth System (CSES), the Climate Impacts Group (CIG) conducts integrated research on the impacts of climate variability and change on the U.S. Pacific Northwest (PNW). It does this by combining and integrating expertise in climate dynamics, hydrology and water resources, forests and aquatic ecosystems, coastal systems, institutional and policy analysis and stakeholder engagement for the study of PNW climate, impacts, and decision support. The CSES also researches the methodologies for accomplishing climate research, and researches the application of climate information in regional decision-making processes in support of the regional aspects of an eventual National Climate Service. Outreach and education are important elements in making contact with, understanding, and working with our stakeholders.

Objectives

1. Enhance global understanding of climate dynamics.
2. Enhance understanding of the role of climate in the functioning and management of coastal and ocean resources.
3. Enhance regional capacity to plan for and respond to climate impacts by evaluating climate impacts on Pacific Northwest resources and institutional arrangements, and supporting use of climate information in decision-making processes.
4. Support climate impact studies for the Pacific Northwest.
5. Support NOAA and other climate research committees.

Accomplishments

The 2010-11 reporting period was an extremely productive year for the CSES. Major research accomplishments, examples of stakeholder collaboration, and tool development in support of the objectives listed above include the following:

- *Columbia Basin Climate Change Scenarios Project (Hamlet, ongoing)* - Climate change is projected to have considerable impacts on Pacific Northwest water resources. Recognizing this, resource managers have expressed growing interest in incorporating climate change impacts into long-range planning. The wide-scale availability of hydrologic scenarios to support climate change planning has been limited, until recently. To address this need, the CIG worked with major water management agencies in the Pacific Northwest to develop hydrologic climate change scenarios for approximately 300 streamflow locations in the Columbia River basin and selected coastal drainages west of the Cascades. Study partners include the WA State Department of Ecology, the Bonneville Power Administration, Northwest Power and Conservation Council, Oregon Department of Water Resources and BC Ministry of Environment. The scenarios, provided to the public for free via the website *(http://www.hydro.washington.edu/2860/),* allow planners to consider how hydrologic changes may affect management objectives. Using climate change scenarios from the 10 best global climate models for the Pacific Northwest from the IPCC AR4 and three different statistical downscaling approaches, the study provides hydrological data for 77 climate change scenarios designed to support water resources planning as well as terrestrial and aquatic ecosystems research. The draft study results are already being used by a wide range of regional stakeholders including the USGS, Bonneville Power Administration, U.S. Bureau of Reclamation, U.S. Army Corps of Engineers, U.S. Forest Service, U.S. Fish and Wildlife Service, Boise Aquatic Research Laboratory, and the National Marine Fisheries Science Center.

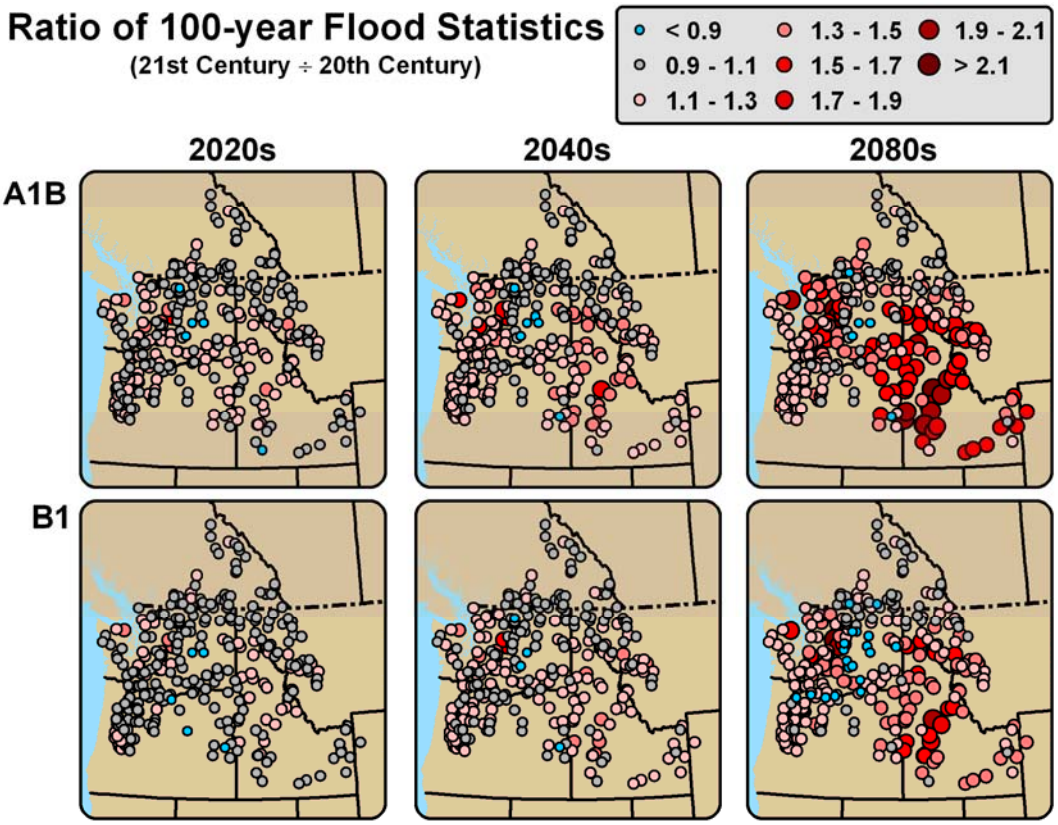


Figure 1. The change in the 100-year flood ratio (future: historical) for the PNW. The top panel shows the results from the A1B emissions scenario and the bottom panel shows the B1 scenario. The maps from right to left show the results from the 2020s, 2040s and 2080s. Data generated from the Columbia Basin Climate Change Scenarios Project.

- *Washington State Climate Change Impacts Assessment (ongoing)* - As noted in the 2009-10 annual report, the CSES was able to leverage $1.5 million in funding from the Washington State legislature in July 2007 to conduct the most detailed assessment of climate change impacts to Washington State to date. Sectors evaluated for the two year project, known as the Washington Climate Change Impacts Assessment, were the following: agriculture, coasts, energy, forests, hydrology and water resources, human health, salmon, and urban stormwater infrastructure. Adapting to climate change is also addressed. A major focus for CSES in the 2009-10 reporting year was completing the various analyses required for the Washington Assessment. This included downscaling meteorological and hydrologic scenarios to the 1/16th degree scale (30 km^2 grids) for the first time, and running these data through sector-specific models to assess climate change impacts in individual sectors. The results of the assessment were submitted to the State of Washington as a series of papers and accepted by the peer-reviewed journal *Climatic Change* for a special issue on the Washington Assessment (2010). The assessment is also providing the basis for the Washington State's adaptation planning process, which CIG is supporting through its conclusion in December 2011.

- *Anthropogenic Stresses on Marine Ecosystems (Miles, ongoing)* - This project, currently in its building stage, seeks to connect the world of science with that of policy-making in the context of the combined effects of ocean acidification and increased warming of the surface ocean on marine ecosystems. The problem is treated as one of creating responses to multiple stresses on a global scale in which there is considerable regional and local variability. The argument is made that while this combination of stressors constitutes a global problem, it cannot be managed effectively at the global scale. The alternative offered is the design of a path to creation of a regionally focused global network for linking research and monitoring to development of policy options and evaluation of management strategies. The project is designed to constitute the "end" link in a fully integrated chain of activities at the University of Washington and elsewhere, which proceeds from fundamental research to monitoring and thence to the identification and evaluation of policy options.

- *Meteorological Processes and Regional Climate Impacts (Salathé, ongoing)* - The U.S. Pacific Northwest is characterized by complex terrain and land-water contrasts, which produce strong spatial gradients in the regional climate and in the atmospheric processes controlling that climate. Global climate models indicate large-scale patterns of change associated with global warming, but they cannot capture the effects of narrow mountain ranges, complex land/water interaction, or regional variations in land-use. The CSES Climate Impacts Group, in collaboration with researchers in the Department of Atmospheric Science, has developed a state-of-the-art high resolution regional climate model for the Pacific Northwest. This project is aimed at addressing the shortcomings of statistical downscaling and coarse-resolution regional models and account for physical interactions in the climate system at all spatial scales. Several important climate parameters can only be captured in high-resolution model since they involve fine-scale interactions within the regional climate system. These include the frequency of extreme events such as intense precipitation, heat waves, wind storms, and droughts. Furthermore, modeling land-surface processes, such as snowpack and soil moisture, require simulating the interactions between the atmosphere and land surface over decadal times. These issues are critical to understanding the impacts of climate change on the region.

- *Future Climate of the California Current System (CCS) (Mitchell, Mantua, Salathé, ongoing)* - The IPCC results for projected changes in the Oregon upwelling region are equivocal. The projected changes are small, but since the sign of these changes vary among the models, the model output requires more scrutiny. What is well known is that the region is expected to show a temperature increase that will be concentrated in the upper ocean. The team is reevaluating IPCC forecasts for sea surface temperatures (SSTs) and surface winds, the latter by evaluating projections for surface pressure fields and downscaling those to regional-scale upwelling wind fields. Scenarios for future oceanographic conditions in the CCS are being generated by combining upwelling and upper ocean temperature change scenarios, which can provide at least semi-quantitative climate change projections to match input variables needed to generate ecosystem impacts scenarios for species in this region. The work to-date shows an average enhanced spring upwelling during the 21st century, and the analyses to be performed in

2011 are to compare the magnitude of this change to the model decadal variability during the 20th and 21st centuries. Observational analyses for the 20th century do not show a secular change in the winds. The results for spring are being tested for sensitivity to the calendar months included in the analysis and for the robustness of the results to different analysis techniques.

- *Coastal Upwelling: Past, Present, and Future (Mitchell, Mantua, Salathé, Johnstone, ongoing)* - The failure of the 2005 upwelling season along the Oregon and Washington coast continues to focus interest in understanding how large-scale atmospheric climate variability influences upwelling along the west coast of the U.S. and in coastal upwelling regions around the globe. In support of a NOAA-led effort to understand the 2005 upwelling episode, a historical upwelling index was developed from sea-level pressure records, and the index used to document the regional scale of the phenomenon. The scientists are analyzing satellite-derived and *in situ* observations, including 20C atmospheric re-analyses, and outputs from global IPCC models, as well as dynamically downscaled IPCC scenarios, to document changes in the large-scale atmospheric circulation during the upwelling seasons (May-June-July for the Northern Hemisphere, and December-January-February for the Southern Hemisphere).

- *North Pacific Climate Variability (Mantua, Mitchell, ongoing)* - Fluctuations in north Pacific sea surface temperature (SST) are dominated by the seasonal cycle and, on year-to-year and decadal timescales, fluctuations are characterized by temperature departures of one sign along the Gulf of Alaska and the west coast of North America and temperature departures of opposite sign in the central north Pacific. This pattern of variability, with the global mean SST removed, is defined to be the Pacific Decadal Oscillation (PDO). Fluctuations in the PDO are one of the major modes of SST variability, and it has proven to be useful in interpreting fluctuations in northeast Pacific salmon populations, the strength of upwelling along the west coast of the U.S., and the climate of North America. Recent years have seen broad-scale increases in northeast Pacific SST that are not captured by the PDO pattern. The goal of this project is to understand the role of secular changes in basin- and global-mean SST on the PDO, and to estimate the contribution of PDO-variability to the global-mean land and sea temperature. As an ongoing service to a variety of stakeholders the team also updates the JISAO version of the PDO index every month and archives these data on the web at *http://jisao.washington.edu/pdo/PDO.latest*.

- *Global, National and Regional Climate Data Sets (Mitchell, ongoing)* - CSES provides a large collection of gridded instrumental data sets (primarily temperature and precipitation, but also pressure and winds, and others) on the World Wide Web (WWW) as a resource to the UW, national, and global community *(http://cses.washington.edu/data/data.shtml)*. A large number of data sets are available on the WWW, but they are often distributed in formats that cannot be ingested into commonly used analysis software.

- *Direct Impacts of Climate on Forest Growth, Disturbance and Function (Littell, ongoing)* - Stakeholders in Pacific Northwest forests are a diverse group, ranging from the timber

industry to forest managers on public lands to outdoor enthusiasts. Principal concerns of these groups include potential declines in forest productivity, changing forest species composition, and loss of wilderness values and biodiversity. The group is using basic research in climate-vegetation relationships to provide estimates of future changes to forests of the PNW in direct response to changing climate. They are also investigating the linkages between climate (precipitation, temperature, water balance deficit, and soil moisture) and area burned by fire in different ecosystems of the western U.S. Results to date suggest that land managers, both private and public, will need to develop adaptation strategies to manage changing ecosystems.

- *Simulating the Effects of Climate-Driven Changes in Disturbance Regimes and Productivity on Net Ecosystem Carbon Balance of Forested Landscapes (Raymond, McKenzie, completed)* - The goal of this research is to develop a landscape model that can incorporate the multiple pathways through which climate change can affect net biome production of Pacific Northwest forested landscapes. The central element to model predictions is the effect of changing fire regimes, specifically predicted annual area burned, on the distribution of forest age classes across the landscape. The researchers use the predictions of Littell et al. (in press) to estimate future area burned. The effects of these scenarios (the team expect a shift toward younger age classes) can then be evaluated to determine the cumulative impact on carbon stores and fluxes. The scale of the landscapes to be evaluated will be management units (10^4 – 10^6 hectares). Therefore, this research will aid land managers in determining how net biome production within the boundaries of management units may be affected by future changes in disturbance regimes and productivity.

- *Hydrologic Effects of 20th Century Warming and Climate Variability in the Western U.S. (Hamlet, Lettenmaier, Salathé, completed)* - Historic observations are the basis for relating climatic variability to hydrologic processes, and provide the foundation for constructing and evaluating hydrologic models based on these physical relationships. Using models, it is possible to more fully analyze the impacts of climate in the observed record, and also to project the impacts of climate forwards in time with lead times ranging from a few months up to a century or more. The project has produced a series of publications exploring the effects of 20th century warming and climate variability on a number of important hydrologic and water resources variables using both observed and simulated data.

- *UW West-wide Hydrologic Forecast System and Surface Water Monitor (Lettenmaier, Mishra, ongoing)* - Over the last decade, great strides have been made in land surface modeling at regional to continental scales. The North American Land Data Assimilation System (NLDAS) has developed new approaches for estimating current land surface moisture conditions (e.g. soil moisture, snow and runoff) as well as retrospective reconstructions of the same variables. These science-based products were motivated by a need to improve initialization of numerical weather prediction models, but have many other potential applications both in research and operations. The University of Washington Westwide Hydrologic Forecast System and Surface Water Monitor (SWM) meld these advances into a system that serves both hydrologic forecast and drought

management objectives. The University of Washington Westwide Hydrologic Forecast System (now being transformed into National Hydrologic Prediction System) and Surface Water Monitor (SWM) meld these advances into a system that serves both hydrologic forecast and drought management objectives.

- *West-Wide Drought Forecasting System: A Scientific Foundation for NIDIS (Steinemann, ongoing)* - The scientists are developing a drought forecast and nowcast system for the western U.S., which will serve as a scientific framework for prediction and assessment of agricultural (soil moisture) and hydrologic (streamflow) drought in the region. It will also provide science-based indicators that are critical for the National Integrated Drought Information System (NIDIS). The researchers specific objectives are the following:
  i. Implement a version of the Variable Infiltration Capacity (VIC) model that represents near-surface groundwater directly;
  ii. Assimilate observations not presently used in the West-Wide system that are highly relevant to drought;
  iii. Produce probabilistic forecasts of drought persistence and recovery using ensemble prediction methods that incorporate climate forecasts out to one year; and
  iv. Work with various water agencies to incorporate the resulting drought forecasts and nowcasts into drought information systems and water management decisions.

  A key objective of this project to detect the onset of drought and drought recovery earlier was met in two case studies, the State of Washington and the Yakima River Basin.

- *Paleoreconstructions of Pacific Northwest Streamflow (Littell, Hamlet, Mantua, Lutz, ongoing)* - Paleoclimatic streamflow reconstructions derived from proxy records (such as tree rings) play an important role in water resources planning and management. In Idaho, for example, an unprecedented (in the historic record) five-year drought has severely stressed existing water resources and water resources policy. What is the return interval of such extreme events? Longer records based on paleoclimatic reconstructions can provide a better understanding of the probability of distributions of such extreme events by dramatically increasing the temporal sample size. This reporting year has resulted in preliminary reconstructions of streamflow at 12 gages in the Columbia system and the development, with Connie Woodhouse (UAZ), of a PNW page for the TreeFlow web pages. A publication has been submitted (Lutz et al.) on incorporating a reconstruction of winter precipitation into the VIC hydrologic model. In the final year of the project, the group has developed 22 reconstructions of streamflow back to at least 1650 at gages around the Pacific Northwest. Figure 2 shows the paleoreconstructions of summertime streamflows for the Yakima basin compared to the simulations generated by the VIC model. A manuscript is currently in preparation on the results of this work.

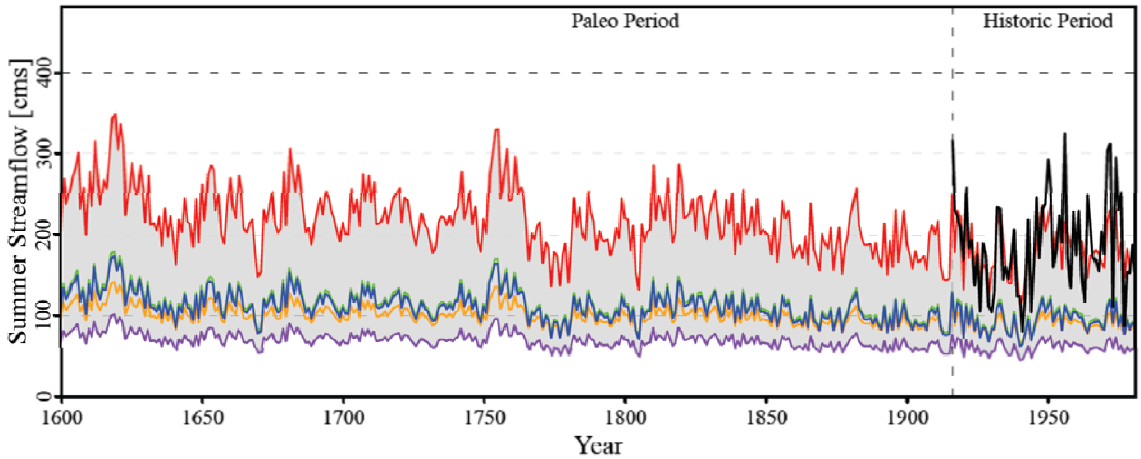


Figure 2. Colored lines indicate paleoreconstructions of streamflows using tree-rings and black line represents VIC-generated streamflows for the Yakima River basin.

- *Climate Wildfire Relationships in the West: Historical and Future Climate Impacts on Fire Area Burned* (*Littell, ongoing)* - The goal of this work is to advance the team's understanding of climate and hydrologic forcing of fire on two fronts. First, they will test established models of climate and fire that predict area burned by extrapolating them into the future at the ecoprovince scale. Second, they will continue to work to develop hydrologic predictors of area burned (potential and actual evapotranspiration, soil moisture, deficit) that better capture the vegetation and fuels bases for fire-climate relationships.

- *Landscape Scale Change in Forest Composition and Structure due to Climate Change, Hydrology, Wildfire, and their Interactions (Gwozdz, McKenzie, completed)* - Wildfire disturbance is important in shaping the composition and structure of inland Pacific Northwest forests. Climate plays a strong role both in shaping the fire regime, and in determining the successional trajectory of post-fire forests, so that as the climate changes, fire regimes and the composition and structure of post-fire forest are also likely to change. Predicting how forests will look and function in the future is difficult, however, because of the complex interactions between climate, hydrology, fire, and forest growth. The scientists are linking state of the art models of hydrology (DHSVM) and forest landscape disturbance and succession (LANDCLIM), and projecting forest landscape change under a range of climate scenarios developed by CIG. This integrated modeling system will represent the major feedbacks between climate, hydrology, and fire in influencing forest succession. Such projections will aid in the development of adaptation plans for fire, forest, wildlife, and freshwater resource management.

- *Global, National and Regional Climate Data Sets (Mitchell, ongoing)* - The project provides gridded data fields in a "common data format" that can be read by GIS and widely used geophysical software. Several large domain data sets have also been subsetted for subregions such as the Pacific Northwest. The WWW page also provides time series of climate variables that were developed at JISAO, for example monthly Sahel precipitation, several indicators of El Nino/Southern Oscillation indices, and Washington coast sea

surface temperatures, that are of interest to both local and foreign researchers. All of the time series are easily ingested by Excel software. This project has also resulted in the development of a manual of netCDF operator examples for common manipulations of and calculations with CDF files. MATLAB scripts are being developed to write CDF files in the newest version of this software that will be ingestible in common software.

- *Investigations of summer climate variability along the U.S. Pacific coast (Johnstone, Mantua, Mitchell, Mauger, ongoing)* - The team are extending recent investigations into the variability of California fog to other aspects of summer Pacific coastal climate and the northwest region in particular. They are evaluating a large compilation of daily-scale observations on a multitude of coastal climate factors, including cloud heights, inversion strength, pressure, upwelling wind (reanalysis and buoy data), and land and ocean temperatures. Upwelling episodes that affect marine ecology, stratus surges and heat waves that affect coastally-adapted forest species, and strong inversions that affect urban air quality. Their occurrence is largely regulated by ocean-atmosphere conditions over the NE Pacific that vary on time scales of both weather and climate, involving the position of the North Pacific High and the temperature of the underlying ocean (itself largely regulated by the atmosphere). While much prior work has investigated Pacific ocean-atmosphere climate variability in winter, this research is focused primarily on the summer season, which is relatively unexplored on climate time scales. The following four study areas are being investigated:
  i. Variability of summer subtropical highs and connections to eastern boundary climate;
  ii. Intraseasonal-to-interannual variability of coastal fog events on the U.S. Pacific coast;
  iii. Variability of summer stratus in the U.S. Pacific Northwest; and
  iv. Season-specific atmospheric forcing of the PDO.

- *Climate Impacts on Harmful Algal Blooms in the PNW (Mantua, Moore, Salathé; ongoing)* - Paralytic shellfish toxins are produced by the harmful dinoflagellate species *Alexandrium catenella* and accumulate in filter feeding shellfish. Consumption of contaminated shellfish causes a serious condition called paralytic shellfish poisoning that can result in death. This objectives of this project are to:
  i. Evaluate the role that climate and oceanographic variability plays in the frequency and distribution of Harmful Algae Blooms (HABs) in Puget Sound;
  i. Quantify the degree to which environmental monitoring and/or prediction can be used to skillfully predict the risks for HAB events to contaminate shellfish in Puget Sound;
  ii. Quantify the temporal and spatial patterns of variability in Puget Sound oceanographic properties; and
  iii. Identify favorable habitat areas for the growth and germination of this HAB species in Puget Sound and quantify the effects of climate change.

  In 2010, funding was secured from NOAA's Ecology and Oceanography of Harmful Algal Bloom (ECOHAB) Program to develop a forecast to identify which areas of Puget Sound are at risk of experiencing blooms of *A. catenella* and to examine the effects of climate change on these areas.

- *Modeling Favorable Habitat Areas for Alexandrium Catenella in Puget Sound and Evaluating the Effects of Climate Change (Salathé, Mantua, ongoing)* - The main objectives of the project are to determine year-to-year variations in the distribution and abundance of A. catenella resting cysts, identify optimal conditions for cyst germination and growth of cells, model favorable habitat areas for A. catenella, and determine how favorable habitat areas might change in a warmer climate.

- *Assessing the Vulnerability of West Coast Fisheries to Climate Change (Whitely Binder, Snover, ongoing)* - CIG is working with West Coast Sea Grant programs and other partner agencies to host a workshop in May 2011 assessing the vulnerability of three West Coast fisheries to climate change. The fisheries are whiting, groundfish (specifically sablefish and canary rockfish), and Dungeness crab. This workshop will combine the expert knowledge of managers, scientists, industry, NGOs, and tribes associated with these fisheries for applying and testing vulnerability assessment frameworks 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.

- *Assessing Pacific Northwest Hydrologic Extremes (Hamlet, ongoing)* - Assessing hydrologic extremes (e.g. extreme peak and low flows) has many important applications for infrastructure design, emergency water resources planning, and support of ecosystem services. T he physically based, macro-scale Variable Infiltration Capacity hydrologic model, implemented at $1/16^{th}$ degree resolution (each grid cell is about 5km by 6km), is currently being used to estimate hydrologic change over the PNW. Unlike the traditionally used regression equations, these kinds of tools incorporate downscaled global climate models to simulate runoff processes. This study will also investigate the implications of changing daily precipitation statistics simulated by regional climate models on natural flood risk in the Pacific Northwest. Two main components of this project include the following:
  i. Using physically based hydrology models to improve fine scale estimates of the 100-year flood (Q_{100}) in complex mountain terrain.
  ii. Estimating changes in daily precipitation intensity and flood risk in the Pacific Northwest using regional climate simulations.

- *Climate Change in Endangered Species Act Processes (Snover, Mantua, ongoing)* - Through a series of 6-8 case studies across the United States, this project aims to explore the trade-offs, uncertainties, and stumbling blocks, and to develop tools and best practices for incorporating information about climate change into Endangered Species Act (ESA) decision processes. CIG scientists are collaborating with NOAA-Fisheries scientists (coordinated by NOAA's Northwest Fisheries Science Center) by participating in the analyses for the NW case studies and providing guidance on climate model output – downscaling, scenario availability, and associated uncertainty, and on developing processes for considering climate change in decision-making. The goals of the project are to help decision-makers (such as those at NOAA and USFWS) understand the differences between varying scientific approaches related to climate change and, ultimately, to improve their ability to implement the ESA in a changing world.

- *Climate Impacts on Marine Forage Fish and Jellyfish in Puget Sound (Essington, Reum, ongoing)* - The pelagic ecosystem of Puget Sound is tightly coupled with the seasonal dynamics of freshwater runoff and thermal stratification, both of which have direct bearing on primary production, which quickly travels up the food chain. Forage fish represent a key species in the transfer of energy from small zooplankton to larger fish, marine birds and mammals so identifying potential responses to climate signals are a key priority to support an ecosystem-based management of Puget Sound. Here the team focus on several, related questions:
  i. What have been the long term dynamics of herring throughout Puget Sound, and do geographically isolated populations respond synchronously to putatively large-scale climate forcing,
  ii. What is the nature and magnitude of competitive and predator-prey interactions between forage fish and jellyfish, the latter of which are highly sensitive to climate, and
  iii. How are the dynamics of Pacific Herring populations in Puget Sound related to environmental and biological drivers?

- *Using NOAA Climate Forecasts with Hydrologic Assessment to Reduce Drought Vulnerability and Improve Water Management in Washington State (Steinemann, ongoing)* - The purpose of this research is to develop and implement climate and hydrologic forecasts for water management in the States of Washington and California, to assess the net economic benefits of this forecast information, and to serve as a model implementation of the National Integrated Drought Information System (NIDIS).

- *California NIDIS Pilot (Steinemann, ongoing)* - The California NIDIS Pilot will be planned and launched over the next two years. In this recently funded project, the PI will provide leadership in the design, implementation, and evaluation of the both the process and the pilot study, maintaining close collaboration with NIDIS personnel and stakeholders. Specific areas of activity will include the design of the California NIDIS Pilot and implementation strategy, the evaluation of the pilot and overall process, and the evaluation of drought indicators, triggers, and early warning system. Results of this work will contribute not only to California, but also to the larger NIDIS effort, ensuring innovations through the pilot study that can be transferable to the nation. For details and more information, please visit the NIDIS website at:
  http://www.drought.gov/portal/server.pt/community/drought_gov/2010_CA_Scoping_Workshop

- *State Drought Planning in the Western U.S. (Steinemann, ongoing)* - The overall goal of the project is to work together with state drought managers to investigate, evaluate, and improve the integration and value of drought information for reducing drought hazards through state drought planning and decision-making. The project investigates three main components of the overall goal:
  i. The integration of NOAA climate information into drought plans and state drought decision-making, and the valuation of that information;
  ii. The ways that early warning systems can help to reduce drought impacts and vulnerability, and the information needed to take actions, both shorter-term responses and

longer-term adaptations;

iii. The translation of drought information (e.g., nowcasts and forecasts) into drought indicators and triggers, and the assessment of its use and value.

A survey (for telephone interviews) has been developed this past year, together with participants from the RISAs and the National Drought Mitigation Center, and pre-tested with water managers, and will be implemented in the coming year to assess the use and value of drought information by state drought managers in each of the 19 Western Governors' Association states.

- *Technical Advising: Columbia River Basin Universities Consortium (Whitely Binder, ongoing)* - The Columbia River Treaty (CRT) has shaped management of the Columbia River System's flood control and hydropower benefits since it was signed by the United States and Canada in 1964. In 2024, two provisions of the Treaty will expire, impacting how flood control is implemented. Hydropower benefits will also likely be affected. Any decision to terminate or renegotiate the CRT must be declared by September 2014. The Universities Consortium, including the CIG, on Columbia River Governance was formed to develop to offer a neutral, academic framework for supporting decisions concerning the CRT.

- *Technical Advising: National Wildlife Federation LCC Papers (Whitely Binder, ongoing)* - On behalf of the North Pacific Landscape Conservation Cooperative (NPLCC), the National Wildlife Federation is producing two reports that assemble information from the peer-reviewed science and agency literature on the impacts of climate change on species, habitats, and natural systems within the NPLCC geography (southern Alaska to northern California, west of the Cascade crest). The purpose of these reports is to provide NPLCC leaders, participants, and stakeholders a platform for considering issues and making decisions about LCC activities and priorities. CIG is serving in an advisory role to help guide production of the papers and ensure the papers accurately reflect and frame our best understanding of science regarding climate impacts to species, habitats, and natural systems. Both reports will be completed in summer 2011.

- *Technical Advising: Washington Department of Transportation Vulnerability Assessment (Whitely Binder, ongoing)* - In 2010-2011, the Washington Department of Transportation (WSDOT) will pilot test a Federal Highway Administration model for assessing the impacts of climate change on transportation infrastructure. The CIG is providing technical assistant in the form of guidance on available data, interpretation of relevant science, presentation at workshops for WSDOT staff, and technical review of project documentation. The pilot test will be completed by fall 2011.

- *Technical Advising: National Association of Regional Councils Building Climate Resilience Project (Whitely Binder, ongoing)* - The National Association of Regional Councils has initiated a two-year project to investigate the readiness and needs of local government and regional land use planners and decision-makers for planning for climate change. CIG is participating on the Advisory Council for the project. Funding for *Building Community Resiliency: Engaging Local Governments, Regional Land Use Planners and*

Decision-Makers in Climate Change Adaptation is being provided by the National Oceanic and Atmospheric Administration (NOAA).

- *Technical Advising: Washington State Adaptation Planning (Whitely Binder, Littell, Hamlet, ongoing)* - In 2009, the Washington State Legislature passed legislation requiring development of integrated climate change response strategy to support adaptation planning needs by state and local agencies, public and private businesses, nongovernmental organizations, and individuals. The strategy is due December 2011. To facilitate development of the integrated strategy, the Washington Department of Ecology and partner agencies convened four multi-stakeholder Topic Advisory Groups (TAGs). The CIG provided technical assistance to the TAGs, which met from February 2010 through February 2011.

- *Technical Advising: River Management Joint Operating Committee (RMJOC) (Hamlet, Elsner, ongoing)* - In 2009, the three federal action agencies (BPA, Corps and Bureau of Reclamation), under the auspices of the RMJOC, initiated a 2-year project to investigate potential climate change impacts to the Federal Columbia River Power Supply. The objective of this project is to collect and review scientific data pertaining to potential climate-related temperature, precipitation and stream flow changes, which could affect both power production and fish and wildlife populations in the Northwest. The end product of this work will be a common set of climate-change data that can be used for both power system and fish & wildlife analyses. This data along with federal analyses of potential impacts will be publicly available through an internet web site. The CIG has provided guidance to this process, providing temperature, precipitation and stream flow data and technical assistance for selecting and analyzing a set of 9 climate change scenarios for the 2025 and 2045 time periods.

- *Impacts of Regional Climate Change on the Pacific Northwest White Water Recreation Industry (Hamlet, Mickelson, ongoing)* - Commercial rafting in the Pacific Northwest (PNW) generates tens of millions of dollars in revenue each year. However, a shift towards earlier streamflow timing has been observed throughout western North America in the second half of the 20th century that has been attributed to regional warming. This trend in earlier streamflow timing, and projections for continued shifts in future decades due to climate change, is of concern to rafting operators within the industry because future summer streamflow levels could drop below critical levels for rafting rivers within the PNW. Using daily projections of 21st century streamflows for the PNW, the group will investigate how regional climate change might impact five rivers that are heavily used for white water recreation. Based on information gathered from interviews with river operators, they make preliminary projections of losses in revenue due to trip cancellations or increases in backcountry flights to access trip starting points (put-ins) farther downstream when streamflow is sub-optimal. Finally, they discuss prospects for adaptation to projected warmer climate and altered streamflow regimes.

- *Climate Outlook: Interpreting the Present Regional and Global Climate (Mitchell, ongoing)* - A monthly report on Pacific Northwest (PNW) climate is published on the WWW in which the regional climate of the past month is described and interpreted in terms

of the historical record, and the NOAA Climate Prediction Center seasonal temperature and precipitation forecasts are interpreted for the PNW. The observations discussed are the temperature and precipitation over land, temperatures and winds along the coast, and seasonal variables such as summer wildfires, early winter floods, and winter and early spring snowpack. The El Niño / Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO) influence the region's climate, and the status and prognoses for these phenomena are documented and interpreted. A quarterly presentation is also WWW-published and presented at the Climate Impact Group seminar series that summarizes and interprets the global climate and its variability during the previous season and calendar year.

- *Annual Climate and Water Fall Forecast Meetings (CIG team, ongoing)* - Every fall, the Climate Impacts Group at the University of Washington hosts meetings summarizing the seasonal climate forecast and water resource outlook for the Pacific Northwest (PNW) for the upcoming water year. The meetings also highlight new research on PNW climate variability and change, implications for PNW resource management, and decision support tools for managing climate impacts. The information presented at these meetings provides resource managers the opportunity to consider how climate variability and change may affect near-term and long-term management decisions in the PNW. This was the 14th year for the WA/OR climate and water fall forecast meeting and the 10th year for the Idaho meeting.

- *Presentations and Webinars on Climate Impacts Science and Adaptation (CSES team, ongoing)* - Presentations continue to be a major outreach tool for CIG researchers and staff. CIG researchers and staff give more than 100 invited presentations annually on a variety of topics related to PNW climate impacts, CIG research, and adaptation. The audience for these presentations is diverse in type and expertise. Audiences include elected officials; senior and technical-level federal, state, and local government resource managers and government staff; NGOs; professional associations (e.g. American Water Works Association); private sector business and industry; tribal governments; students; researchers; and the general public. During the 2010 – 2011 reporting year, the CIG contributed to the following webinars:
  i. *Climate Change and Changing Hydrologic Extremes* (December 2010) (Hamlet) - In December 2010, CIG and the Washington Department of Ecology co-hosted a 3 hour webinar/seminar designed to will help planners and policymakers have a better understanding of the nature of changing hydrologic extremes, including changing flood risks and low flows. For more information, see: *http://cses.washington.edu/cig/outreach/workshops.shtml*
  ii. *Integrating Climate Change with Forest Vegetation Models for Adaptation Planning* (July/August 2010) (Littell) - Evaluating the potential impacts of climate change on forest management and planning objectives is essential to ensuring that these objectives can be met in the coming decades. For more details, see: *http://cses.washington.edu/cig/outreach/webinars/vegmodel710.shtml*
  iii. *Pacific Northwest Hydrologic and Climate Change Scenarios for the 21st Century* (March 2010) (Hamlet, Salathé) - In spring 2010, the CIG completed its most comprehensive downscaling effort to date with finalization of an unprecedented

database of hydrologic climate change products for the Columbia River basin and selected coastal drainages in the PNW. For more information, see: *http://cses.washington.edu/cig/outreach/webinars/scenarios0310.shtml*

- *Work with the Media (CSES team; ongoing)* - CSES continues to be a resource for local and national media on stories related to climate change. At least 10 unique stories featuring CSES research or CSES researchers were printed between August 2009 and January 2011, including multiple on-air (radio and television) media interviews.

- *CSES Website, Newsletter, and Listserve (Whitely Binder, Tohver and CSES team; ongoing)* - CSES continues to make improvements to the CIG website (*www.cses.washington.edu/cig*) to increase its utility as an information source for PNW decision makers and resource managers. This includes monthly updates of the PNW climate outlook *(http://www.cses.washington.edu/cig/fpt/cloutlook.shtml*), continued use of the CSES list-serve for distributing information on CSES research and meetings to more than 1,100 subscribers, and production of a quarterly electronic newsletter (*http://www.cses.washington.edu/cig/outreach/newsletter.shtml*).

- *Swinomish Climate Change Strategy Initiative (Mantua, Tohver, Whitely Binder, completed)* - To help prepare for climate change, the Tribe received funding from the Administration for Native Americans to develop an appropriate and comprehensive response strategy and action plan addressing impacts of climate change on the Reservation community, with potential for wider application as a model for other tribes and jurisdictions. The CSES is serving as a consultant in this project. The scope of work for CSES consists of the following:
  i. Review of technical and scientific data and reports available on climate changes issues, as requested, and assistance with interpretation of same, as applicable to conditions or environmental elements that may be present in the vicinity of the Swinomish Indian Reservation.
  ii. Review of tribal analysis of local conditions and environmental elements, as based on application of scientific data and/or scenarios to the Reservation, and advising as possible on validity of methodology.
  iii. Review of documents produced under this project to advise on scientific validity and accuracy of methodology, such documents to include strategy planning documents and actions plans.

  Advising on other technical and scientific issues related to the above as may be necessary to ensure accurate and/or valid reporting of facts and issues, within the scope of this project.

- *Planning for Climate Change Adaptation Training Class (Whitely Binder, completed)* - CIG, the NOAA Coastal Training Program, the Padilla Bay National Marine Estuarine Research Reserve (NERR), Washington State Sea Grant, and King County continued refining and hosted two training classes for coastal managers and planners on adapting to climate change. The training covered the fundamentals of how to plan for climate change, how to conduct a vulnerability assessment, how current state regulations address climate change, and how other governments are taking on the challenge of preparing for climate

change. Presentations also covered key data sources and specific strategies for engaging stakeholders in climate change preparedness. The training sessions were first attended in 2009 and are being replicated by other US Coastal Training Programs around the country.

- *Seattle City Light Climate Change Analysis (Snover, Salathe, Hamlet, completed)* - In November of 2009 the CIG agreed to provide Seattle City Light with information about climate change effects on regional climate, streamflow, and stream temperature in order to support City Light's assessment of impacts of projected climate change on its operation at the Skagit and Boundary hydroelectric projects, on future electricity load in its service territory, and on resident fish populations. In June of 2010, a series of presentations was delivered to the Seattle City Light managers to disseminate the results of the study. The results were also provided in data format and in a comprehensive report detailing the following:
  i. Climatic extremes (precipitation, temperature and combinations of these events) projected from regional climate models.
  ii. Streamflow simulations for requested sites along the Skagit and Pend Oreille Rivers.
  iii. Stream temperature projections for selected sites on the Skagit River and its tributaries (Figure 3) and on the Pend Oreille River.
  iv. Streamflow extreme projections under climate change scenarios.

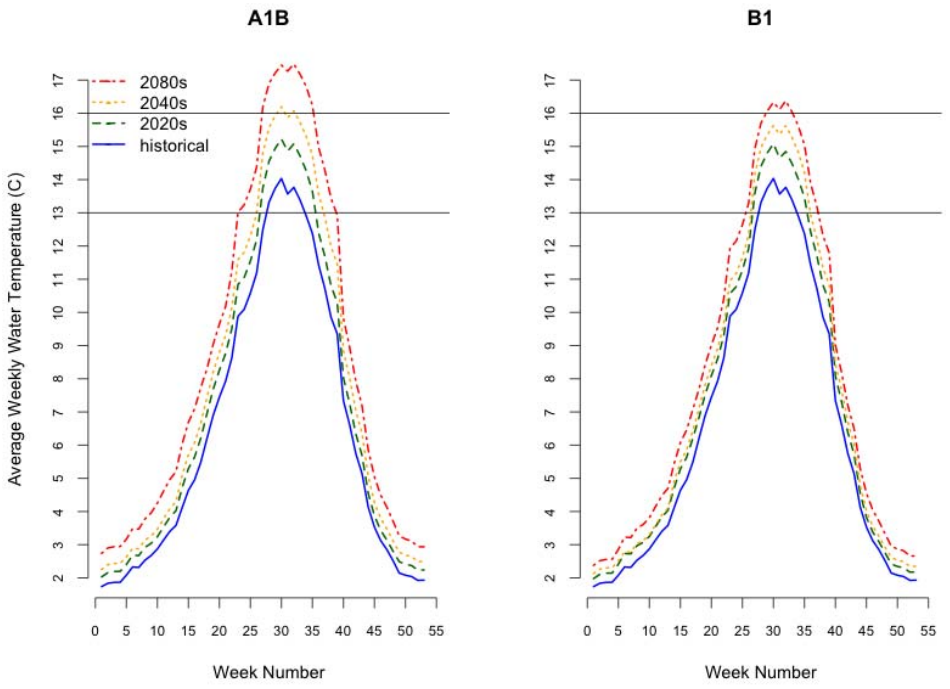


Figure 3. Average weekly water temperatures for Canyon Creek, a tributary to the Skagit River, for the historical period and 21st century projections. Horizontal black lines indicate thermal thresholds set by the WA Department of Ecology for salmon and bull trout habitat.

- *Adaptation Case Study Database (Whitely Binder, ongoing)* - Communities interested in preparing for climate change frequently express the need for examples of how adaptation strategies are being implemented in other communities. To support this need, the CIG has developed an adaptation case study database (CASES) that allows interested individuals to search for examples from communities of similar size, climate impacts concerns, and geographic region. The database is populated as follows:
  i. CIG development of case studies from communities known to be planning for climate change; then through
  ii. Voluntary submittal of case studies by communities to the site. These voluntary submittals will be sought through list-serves and other mechanisms for promoting the site to national and international audiences.

- *K-12 Hydrology and Climate Studies (Hamlet, Tohver, Elsner, Vano - completed)* - CIG hydrologist Alan Hamlet prepared a series of demonstrations and lectures on hydrology and climate targeting K-5 students at Salmon Bay Elementary School in Seattle. Using a physical river basin model made of epoxy-covered plywood with a fleece "soil"; four elementary school classes explored watershed function and the role of soil and snow as storage mechanisms in PNW watersheds. In a follow on lecture, the classes explored the causes of interannual climate variability and climate change and its implications for snowmelt watersheds. Students measured cool season and warm season runoff for a rain dominant basin, a snowmelt basin with substantial snowpack (represented by Tupperware containers on the slopes of the basin model), and finally for the snowmelt basin in a warmer climate. The model demonstrates the loss of water availability in summer associated with snowpack loss in a way that almost anyone can understand.

- *Reconciling Projections of Future Colorado River Streamflow (Vano, Lettenmaier, completed)* - Within the Upper Colorado River Basin, reductions in naturalized streamflow (water management effects removed) by the mid 21st century have been projected to range from 6 to 45% in published studies, and a recent analysis of future P-E (a proxy for runoff) suggests an "imminent transition to a more arid climate in southwestern North America". While the range of projections may be of intellectual interest and stimulate scientific debate, to users and decision makers at the federal level, in the seven basin states, and internationally, providing what appears to be conflicting information on future conditions is a serious impediment to drought and climate change planning. To better understand the reasons for the wide range of projections, the team has undertaken a systematic intercomparison of methodologies and models to understand why different modeling approaches produce such different levels of flow reduction. From the models, they have also evaluated the sensitivity of runoff to temperature changes as fractional changes in annual runoff per °C of (uniform) temperature increase. Temperature sensitivities cannot easily be inferred from observations, however the model sensitivities at Lees Ferry range from about 3 to 10% per °C for equal changes in daily maxima and minima (which implies no change in downward solar radiation in the method used to prescribe model forcings), whereas the range is about 5 to 18% for a one degree uniform increase in daily temperature when the daily minima were unchanged (constant dew point). Ongoing work is diagnosing the spatial distribution of elasticities and sensitivities across the basin for the five models, and is extending the analysis to smaller subcatchments of the Colorado.

Ensemble-Based Regional Data Assimilation

PI
UW - Cliff Mass

Task III

NOAA Primary Contact
Sam Contorno, National Weather Service

NOAA Goals

2. Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
3. Serve Society's Need for Weather and Water Information

Accomplishments
This project has partially supported two students during this period: Reid Wolcott and Luke Madaus. Reid completed his thesis on the use of ensemble-based data assimilation for assimilating coastal radar data. This work was written up in his M.S. thesis (finished during the summer quarter). Luke Madaus is a new student beginning September and has mainly taken courses during the past eight months and is currently deciding on an appropriate thesis topic.

Environmental Chemistry

JISAO Atmospheric Chemistry - Aerosol Program

PIs
UW - David Covert
NOAA - Tim Bates, Patricia Quinn

Other Personnel
UW - Drew Hamilton, James Johnson
NOAA - Derek Coffman, Kristen Schulz

Task II

NOAA Primary Contact
A.R. Ravishankara - Climate Office
J. Meagher - Health of the Atmosphere

NOAA Goals
2. Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
3. Service Society's Need for Weather and Water Information

Description
The PMEL-JISAO Atmospheric Chemistry - Aerosol Program is designed to quantify the spatial and temporal distribution of natural and anthropogenic atmospheric aerosol particles and to determine the physical, meteorological and biogeochemical processes controlling their formation, evolution and properties.

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

Accomplishments
1. The PMEL-JISAO Atmospheric Chemistry - Aerosol Program participated in CalNex 2010 in May/June 2010. Research onboard the *R/V Atlantis*, which was led by the PMEL/JISAO, included 36 scientists from a dozen institutions. *R/V Atlantis* worked between San Diego and Sacramento with extensive measurements made in the Ports of Los Angeles, Long Beach, San Francisco, and Oakland; Santa Monica Bay; Monterey Bay; and Santa Barbara Channel. Data from the project were reduced and made available to the scientific community this year, *http://saga.pmel.noaa.gov/data/PrePlot.php?cruise=CALNEX* .
   The cruise track gave the team the opportunity to measure different air masses and how the aerosol changed with time in that air mass. Examples from the data set show:
   a. the physical and chemical characteristics of the “background marine” aerosol advecting into California,

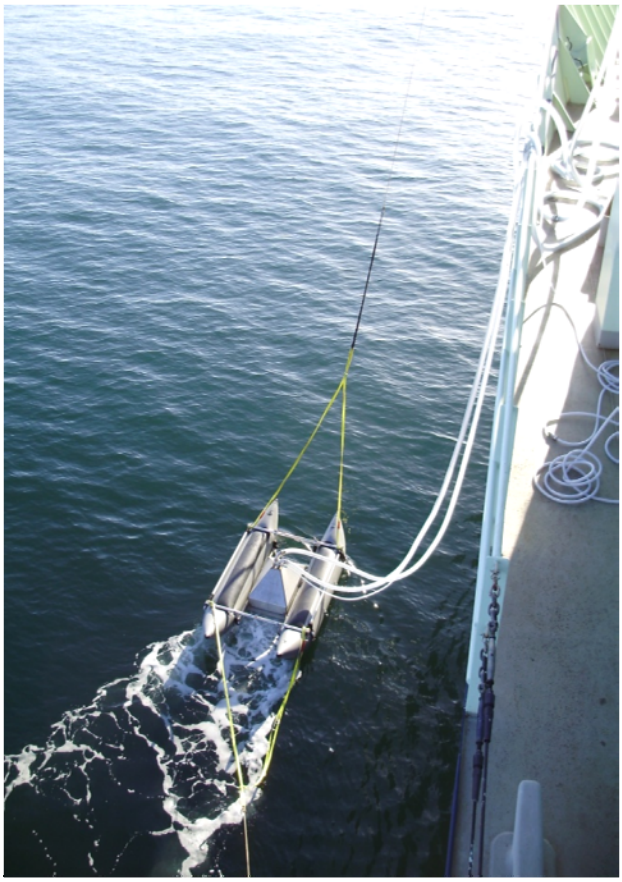
b. the input of newly formed particles from the free troposphere into the marine boundary layer (MBL),
c. the physical and chemical properties of the aerosol advecting from Southern California out to Santa Monica Bay,
d. aerosol source vectors within the harbor of Los Angeles/Long Beach, and
e. the daily formation of new particles in the boundary layer in the Sacramento – San Joaquin River Delta.

These data provide:

a. aerosol boundary conditions for chemical transport models, and
b. direct evidence for the processes/sources of particles to the MBL.

2. The oceans are a major source of aerosol number and mass to the atmosphere. Over the remote oceans, coarse-mode sea-salt particles dominate aerosol light scattering. Recent measurements suggest that direct emissions of ocean-derived particles also control the aerosol number concentration and thus the aerosol cloud condensation nuclei concentration. Measurements of atmospheric aerosols over the ocean include particles directly emitted from the ocean and particles produced by gas phase reactions in the atmosphere, making it difficult to distinguish between the two sources. During CalNEX the scientists made measurements of particles directly emitted from the ocean using a newly developed in-situ particle generator/sampler (SeaSweep). Bubbles were generated 1 meter below the ocean surface alongside the research vessel *Atlantis* off the coast of California and swept into a hood/vacuum hose to feed a suite of instruments on board the ship measuring aerosol physical, chemical, optical, and cloud nucleating properties. The number size distribution of the directly emitted (nascent) particles had a dominant mode at 55-60nm (dry diameter) and a secondary mode at 200-300nm. The aerosol was not volatile at 230°C. This temperature rules out ammonium sulfate and nitrate as significant components of the nascent aerosol but does not distinguish between particulate organic matter and sea salt. The organic component of the nascent aerosol volatilized at a temperature between 230 and 600°C. The nascent aerosol was not enriched in Ca, K, or Mg above that found in surface seawater. The submicrometer organic aerosol was primary composed of carbohydrates based on FTIR analysis. The nascent organic aerosol concentration did not increase in regions of higher surface seawater chlorophyll. The method of generating particles at the ocean surface using the SeaSweep shows promise for assessing the sources, composition, size, and cloud-nucleating properties of ocean-derived aerosol.

3. The PMEL/JISAO atmospheric chemistry group has been working with their international partners in Norway, Italy, Germany, and Russia to plan a joint field campaign in Svalbard, Norway for April 2011. The Coordinated Investigation of Climate-Cryosphere Interactions (CICCI) initiative seeks to improve the understanding of processes controlling the distribution of black carbon (BC) in the Arctic atmosphere, the deposition of BC to snow and ice surfaces, and the resulting climate impacts. The data will provide a scientific basis for strategies to mitigate warming in the Arctic. The field campaign will be conducted from Unmanned Aerial Systems (UAS) and ground based measurements.



Sea Sweep deployed off the port side of the *R/V Atlantis*.

PMEL/JISAO unmanned aerial system (UAS) on catapult launcher ready for a test flight at the Yakima training center. The aerosol measurement package is in the bubble top on the plane with the aerosol inlet protruding forward. The test flights are in preparation for the field campaign in Svalbard, Norway in April 2011.

Marine Carbon Program

PIs
UW - Laurie Juranek
NOAA - Richard Feely, Christopher Sabine, Simone Alin

Other Personnel
UW - Katie Shamberger, Geoffrey Lebon, Andrea Fassbender, Sylvia Musielewicz, Cynthia Peacock, Nancy Williams
NOAA - Dana Greeley, Cathy Cosca, Dave Wisegarver, Stacy Jones, Adrienne Sutton

Task II

NOAA Primary Contact
Pacific Marine Environmental Laboratory

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

Description
The Marine Carbon Program (MCP) provides a mechanism for research collaboration between PMEL scientists, JISAO scientists and other University of Washington staff with common interests in the marine carbon cycle and its interactions with atmospheric CO_2 and climate. The program focuses on multi disciplinary research involving atmosphere-ocean CO_2 exchange fluxes, water column CO_2 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
1. Determine the air-sea exchange of CO_2 from measurements collected on research ships, volunteer observing ships and moorings.
2. Determine the distribution and transport of CO_2 into the ocean interior from measurements collected onboard NOAA and UNOLS research ships.
3. Determine 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 S4P cruise:* PMEL is leading the logistics and providing the equipment and personnel for the S4P cruise which departed McMurdo Station in Antarctica on February 20, 2011. This is a 70 day cruise with special requirements because the entire cruise is south of the Antarctic Circle (e.g. no over the side waste disposal). Post cruise processing will begin shortly after the cruise is completed.
2. *Service 24 CO_2 moorings:* The moored CO_2 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 CO_2 systems:* Two new CO_2 moorings are planned for deployment during the year.
4. *Perform required maintenance on underway CO_2 systems:* The scientists maintain 4 underway CO_2 systems that require regular servicing.
5. *Prepare new underway CO_2 system:* The team has plans to install one new underway system on a ship next year.
6. *Collect and analyze discrete samples from the Pacific Northwest:* The group has continued working with a number of their colleagues around the Pacific Northwest to collect and analyze discrete carbon samples. This includes participating in two cruises in Puget Sound in collaboration with UW's Puget Sound Regional Synthesis Model program and a cruise from San Francisco to Newport with their NMFS and OSU colleagues in Newport.

Accomplishments

1. Conducted final DIC data processing for two legs of the Clivar/CO_2 Repeat Hydrography Section P6 in the Pacific and the one leg cruise A13.5 in the Atlantic. All data have been submitted to the Carbon Dioxide Information Analysis Center.
2. Maintained 4 underway CO_2 systems.
3. Deployed and/or maintained 24 moored CO_2 systems.
4. The group has continued analyzing discrete samples collected on a number of cruises conducted with their collaborators including a cruise along the West Coast of North America with Canadian collaborators; sampling the Newport Hydrographic Line with OSU and NOAA NMFS colleagues based in Oregon; collecting and analyzing samples during mooring maintenance cruises with their colleagues at NOAA's Olympic Coast Marine National Sanctuary; and samples 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.

Research Highlight

A significant impetus for ocean biogeochemical research over the last few decades has been to better understand the ocean's role as a sink for CO_2 released by human activity. A new article by Sabine and Tanhua (2010) summarizes the latest research on ocean storage of CO_2 in the second volume of Annual Reviews of Marine Science.

An unprecedented global carbon survey in the 1990s inspired the development of several approaches for estimating anthropogenic carbon inventories in the ocean interior. Most approaches agree that the total global ocean inventory of anthropogenic CO_2 was around 120 Pg C in the mid-1990s. Today, the ocean carbon uptake rate estimates suggest that the ocean is not keeping pace with the CO_2 emissions growth rate. There are many uncertainties in the future ocean carbon storage. Continued observations are necessary to monitor changes and understand mechanisms controlling ocean carbon uptake and storage in the future.

In order to study the interactions of ocean acidification and other natural and human induced processes on pH and aragonite saturation state changes in a coastal estuary, Feely et al. (2010) collected carbon system parameter samples on the University of Washington PRISM cruises in the Strait of Juan de Fuca, Puget Sound and Hood Canal onboard the *R/V Thompson* and EPA

Ship *Bold* in February and August 2008, respectively. The combined effects of ocean acidification, upwelling, mixing and hypoxia lower the pH and aragonite saturation state in the subsurface waters to values that are substantially lower than what would be expected from atmospheric CO_2 increases alone. Ocean acidification can account for 24-49% of the pH decrease in the deep waters of Puget Sound. The remaining change in pH between when seawater enters the sound and when it reaches this deep basin results from remineralization of organic matter due to natural or anthropogenically stimulated respiration processes within Puget Sound. Over time, however, the relative impact of ocean acidification could increase significantly, accounting for 49-82% of the pH decrease in subsurface waters for a doubling of atmospheric CO_2. These changes may have profound impacts on the Puget Sound ecosystem over the next several decades.

Chlorofluorocarbon Tracer Program

PI
NOAA - John Bullister

Other Personnel
UW - Rolf Sonnerup
NOAA - David Wisegarver

Task II

NOAA Primary Contact
Pacific Marine Environmental Laboratory

NOAA Goals

2. Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
3. Serve Society's Need for Weather and Water Information

Themes
Climate Research and Impacts
Environmental Chemistry
Ocean and Coastal Observations

Description
The concentrations of Chlorofluorocarbons (CFCs), along with a number of other anthropogenic compounds like CO_2, 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 provides a unique description of the time-integrated circulation of the ocean on decadal time scales. 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, and in quantifying the role of the oceans in the uptake of climatically important traces gases such as CO_2, and improving predictions of climate change for the upcoming century. Finally, the tracer data themselves have made important contributions to data-based estimates of oceanic uptake of anthropogenic CO_2, decadal ventilation timescales, changes in ventilation, and ocean biological cycling rates.

Recently, the group has pioneered efficient methods for measuring sulfur hexafluoride (SF_6) 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 of ocean CO_2 uptake and ocean acidification from CFCs. In addition, the availability of concurrent CFC and SF_6 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, for example as estimated from satellites or from ocean general circulation models.

The overall goals of the Chlorofluorocarbon program are as follows:

1. A key goal of the Chlorofluorocarbon Tracer Program is to document the transient invasion of CFCs and other tracers (including sulfur hexafluoride- SF_6) 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. A second key goal of this program is to 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 important biogeochemical processes, like biological carbon export from the sea surface.
3. A third goal is to use the CFCs, in conjunction with other available ocean tracers, to constrain ocean circulation and carbon cycling models. Such tests are essential for detecting problems and for suggesting methods for improving the models.

Objectives

1. Continuing development of improved techniques for analyzing CFCs, SF_6 and other compounds in atmosphere and ocean from the same samples. The scientists are developing methods for routine inclusion of the measurement of dissolved nitrous oxide (N_2O). N_2O plays an important role in the nitrogen cycle in the ocean.
2. Monitoring of oceanographic processes through collection, display and analysis of CFC, SF_6 and hydrographic data.
3. Using CFC and SF_6 observations to improve estimates of the uptake of anthropogenic carbon dioxide in the ocean.
4. Using combined CFC and SF_6 observations as a means of testing and evaluating large-scale numerical models of the ocean.
5. Participate on oceanographic expeditions as part of the CLIVAR Repeat Hydrography Program.
6. Present the results at meetings and publish them in scientific journals.

Accomplishments

1. The team completed CFC and SF_6 measurements on the A13.5 CLIVAR Repeat Hydrography expedition in the South Atlantic Ocean in March-April 2010. The CLIVAR expeditions repeated a hydrographic section occupied roughly 25 years earlier.
2. The team completed 2 occupations of the Hawaii Ocean Time-Series (HOT) site during the past year. On these occupations they explored methods to concurrently measure dissolved N_2O with the CFCs and SF_6. On one occupation they measured abyssal carbon-tetrachloride (CCl_4).

3. Presented results from these projects utilizing CFCs and SF_6 data to improve estimates of ventilation and circulation rate changes and CO_2 uptake in the North Pacific Ocean
4. Developed and presented results from a new approach for estimating biological Carbon production in the open ocean using O_2 and concurrent CFC and SF_6 measurements
5. Evaluated the constraints that ocean C-13 measurements place on 3-D ocean carbon cycle models, and submitted these for publication:

   "^{13}C constraints on ocean carbon cycle models", by Rolf E. Sonnerup and Paul D. Quay, submitted to *Global Biogeochemical Cycles*, October 2010.

Organize and Host 2010 Marine Debris Microplastics Workshop

PI
UW - Joel Baker

Other Personnel
UW - Julie Masura, Christopher LaRocque, Kim Davenport

Task III

NOAA Primary Contact
Courtney Arthur, Marine Debris Program

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

Description
The purpose of this project was to organize and host the 2nd International Workshop on Marine Microplastic Debris in 2010. Many participants from the 2008 International Workshop were invited, insuring continuity in the discussion. In addition, experts with experience in conducting environmental risk assessments for 'emerging' materials such as nanoparticles, were invited. While the first International Workshop focused on understanding field observations and standardizing field and laboratory methods, the 2010 workshop placed recent observations within a risk assessment framework in order to better understand the impacts of plastic debris.

Objectives
The objectives of the workshop were:
1. To review and discuss that latest field and laboratory studies of the occurrence, distribution, sources, and effects of marine microplastics,
2. To employ the risk assessment framework to evaluate the impacts of microplastics on marine ecosystems, and
3. To delineate information gaps and necessary research and monitoring needs.

Accomplishments
The 2nd International Workshop on Microplastic Debris was held at the Center for Urban Waters in Tacoma, Washington on 5-6 November 2010. The workshop featured thirteen presenters, with a total of 38 participants over the two days. The first day of the workshop included two technical sessions with associated poster presentations: Measurement and occurrence of microplastics in the environment; Effects of microplastics on the environment.
The second day focused on a guided group discussion on the topic of applying risk assessment principles to the microplastics problem. The workshop concluded with an opportunity for workshop participants to join UW Tacoma researchers for a short cruise in Commencement Bay where techniques for sampling microplastics from surface water were demonstrated.

Participants at the workshop were asked to rank the relative importance of a number of facets of marine microplastics, ranging from what is known about sources to quantifying the risks of microplastics to marine organisms. There was a diversity of views, and this exercise framed the larger discussion of potential next steps in microplastics monitoring and research. The workshop's participants generally felt that the environmental risk assessment paradigm is a proper framework in which to evaluate marine microplastics, but that the considerable lack of quantitative information, especially about effects on organisms, will likely limit the utility of risk assessment in the short term. Participants attempted to characterize research needs by geographic region (urban, coastal, open ocean, etc.).

Julie Masura displaying the sampling net prior to lowering into the water.

Sampling net being lowered into the water as workshop participants look on.

Sampling net skimming the water surface as it is pulled behind the *Indigo* in the Foss Waterway, Commencement Bay, with the Tacoma skyline in the background.

Workshop participants looking at water samples just collected.

Participants listen to a presentation during the workshop.

The *Indigo* docked at the Center for Urban Waters, in preparation for the water sampling demonstration.

Nutrients

PI
UW - Calvin Mordy

Other Personnel
UW - Peter Proctor, Fred Menzia

Task II

NOAA Primary Contact
Dennis Moore, Pacific Marine Environmental Laboratory (PMEL)

NOAA Goal

1. Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem Based Management

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

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

Objectives
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. And make this data available to the climate and carbon research community.
   The data are used for:
   i. Measuring spatiotemporal trends in biogeochemical properties
   ii. Model calibration and validation
   iii. Carbon inventory and transport estimates

iv. Deep and shallow water mass and ventilation studies

Accomplishments

The team measured nutrients on the Repeat Hydrographic Line A13.5 in the Atlantic Ocean in the spring of 2010. Approximately 3125 individual measurements were made of dissolved nitrate, phosphate, and silicic acid in the water column along this section (see figures). Quality control of the data set has been completed, and final data is available and archived at the CCHDO website: *http://whpo.ucsd.edu/data_access/show_cruise?ExpoCode=33RO20100308* These nutrient data are being compared with nutrient measurements made about 25 years earlier (1983/1984) along the same section. These data will 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. Dr. Mordy was also a contributing author for the IPCC Fifth Assessment Report on Climate Change (AR5).

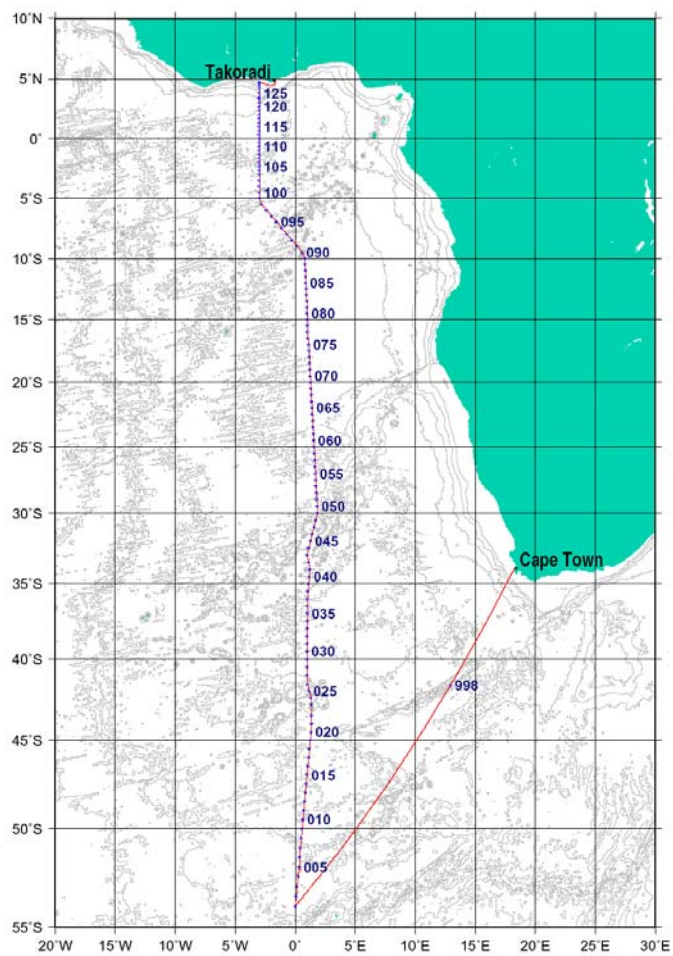


Figure 1. Cruise track of the CLIVAR repeat hydrographic cruise A13.5 with station numbers in blue.

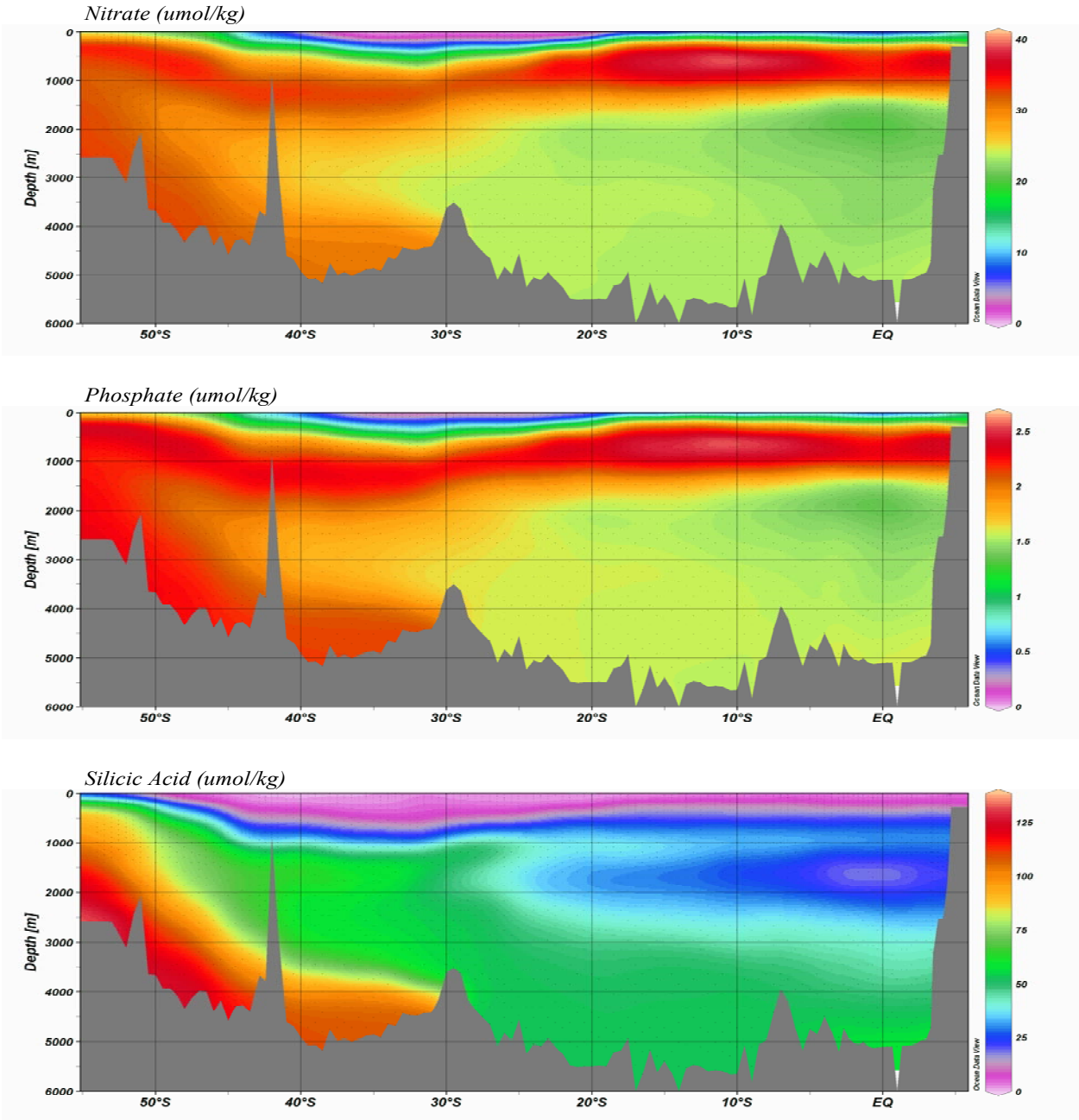


Figure 2. Sections of nitrate, phosphate and silicic acid along the A13.5 cruise track.

The International Global Atmospheric Chemistry (IGAC) Core Project Office

PI
UW - Sarah J. Doherty

Other Personnel
UW - Megan L. Melamed, Collen C. Marquist

Themes
Environmental Chemistry
Climate Research and Impacts

Tasks II and III

NOAA Primary Contact
Tim Bates, PMEL

NOAA Goal

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

Description
The International Global Atmospheric Chemistry (IGAC) project is jointly sponsored by the International Geosphere-Biosphere Programme (IGBP) and the Commission on Atmospheric Chemistry and Global Pollution (CACGP) 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 a 19 member international Scientific Steering Committee and IGAC's parent organizations IGBP and CACGP. The IGAC Core Project Office is hosted by JISAO and funded by NASA, NOAA, and NSF. IGAC carries out its activities via five main pathways:

1. Leading scientific initiatives: 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.
2. Endorsing scientific tasks: Scientific tasks are research activities with a specific set of goals that can be achieved in a 3-4 year timeframe. The international atmospheric chemistry community can propose tasks to the IGAC SSC. The proposed tasks are reviewed and endorsed annually and on an as-needed basis by the IGAC SSC.
3. 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.
4. 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).

5. Communications/Networking: This covers a myriad of activities, including biennial conferences, a newsletter (mail to ~3500 researchers around the world), webpage, and miscellaneous networking activities conducted throughout the year.

Objectives

International coordination and collaboration are essential to address the atmospheric chemistry issues facing society. IGAC promotes and facilitates efforts that address three fundamental objectives:

1. To accurately determine global distributions of both short and long lived chemical species in the atmosphere and to document their changing concentrations over time.
2. To provide a fundamental understanding of the processes that controls the distributions of chemical species in the atmosphere and their impact on global change and air quality.
3. To improve the scientific community's ability to predict the chemical composition of the atmosphere over the coming decades by integrating our understanding of atmospheric processes with the response and feedbacks of the Earth System.

Accomplishments

IGAC co-sponsored a workshop on Megacities and Coastal Zones that specifically looks at how atmospheric chemistry in coastal urban areas affects and is affected by interactions with the coastal marine environment. A report from the workshop is in preparation and will constitute a contribution to the wider Megacities and Coastal Zone IGBP Synthesis.

IGAC co-sponsored a meeting on the Africa Monsoon Multidisciplinary Analysis – Atmospheric Chemistry (AMMA-AC) IGAC Task led by IGAC SSC member Abdourahamane Konare. The meeting contributed to the international interdisciplinary science plan for the larger AMMA 2010-2020 project.

IGAC sponsored a third author meeting of the Bounding Black Carbon Report under the IGAC Atmospheric Chemistry and Climate (AC&C) Initiative. The Bounding Black Carbon Report is in the final editing phase and should be submitted for publication by June 2011.

IGAC sponsored a meeting for the IGAC/WMO Assessment of Atmospheric Chemistry in Mega-cities Initiative. The initiative is in the final stages of writing an assessment on atmospheric chemistry in megacities. The assessment will be published summer 2011.

IGAC co-sponsored a meeting of the lead organizers of the IGAC/iLEAPS/GEWEX Aerosols, Clouds, Precipitation, and Climate (ACPC) Initiative. The meeting resulted in a research science plan for the ACPC Initiative.

This meeting was followed by a SAT-ACPC meeting, which is a new component of ACPC to address specifically how satellite-based measurements can be used to improve the researchers' understanding of the role of aerosols in precipitation processes.

The IGAC SSC approved and is now sponsoring the first IGAC National Working Group in China.

The major event of 2010/2011 was the jointly held biennial IGAC/CACGP Open Science Conference on "Challenging the Future".
Major themes of the conference were:

1. Climate chemistry interactions
2. Observing atmospheric composition
3. Chemistry at the interface
4. Trace gas and aerosol source strength
5. Pollutant transformation and loss.

The conference had ~370 participants, with 65 oral presentations and over 400 posters. As with all IGAC conferences, there was a major focus on young scientists. The IGAC Core Project Office coordinated the funding to support the participation of 47 young scientists. Six of the young scientists won the conference-wide poster competition.

IGAC continues to produce a scientific newsletter that is distributed internationally to ~3500 scientists and to support a web page (*http://igac.jisao.washington.edu/)*

Marine Ecosystems

West Coast Groundfish Stock Assessment

PI
UW - André Punt

Other Personnel
UW - Kotaro Ono, Jeff Rutter, James Thorson, Motoki Wu

Task III

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

NOAA Goal

1. Protect, Restore & Manage the Use of Coastal & Ocean Resources Through Ecosystem-based Management

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). The objectives are to (i) 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, to (ii) 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, to (iii) build expertise among scientists conducting management-related research for west coast groundfish in the application of state of the art methods, and to (iv) provide support, training, and mentoring for graduate students in the field of quantitative fisheries science.

Objectives

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

Accomplishments

Dr. André Punt completed the analyses of the impact of climate-induced forcing of recruitment on the ability of rebuilding analyses to provide management advice. This study showed that the current approach to conducting rebuilding analyses is relative robust to such forcing and that modifying the approach to conduct rebuilding analyses to account for climate-induced forcing did not lead to a markedly better ability to satisfying management objective.

Mr. Motoki Wu (UW MS student) developed an operating model to evaluate the performance of methods of estimating meta-analysis-based priors for the steepness parameter of the stock-recruitment relationship. He also implemented an estimator based on the Deriso delay-difference model which can estimate spawning stock size and recruitment from simulated data. Given ideal conditions, this estimator is able to extract these quantities exactly. Mr. Wu is also begun to develop a web-site for the Stock Synthesis program, in collaboration with researchers at the NWFSC (Dr. Richard Methot & Dr. Ian Taylor).

Mr. James Thorson (UW Ph.D. student) further developed an agent-based model simulating habitat selection for solitary and shoaling individuals of Pacific rock fish. This agent-based model was conceived to explore the statistical properties of mixture distribution models, which account for extraordinary catch events in bottom trawl data, as well as the efficacy of alternative sampling methods such as autonomous underwater vehicles.

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

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

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

PI
UW - André Punt
NOAA - Anne Hollowed

Task III

NOAA Primary Contact
Anne Hollowed, Alaska Fisheries Science Center

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

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 groundfish fishery management plans for the GOA and BSAI. Methods will also be developed to estimate uncertainty buffers for species or species groups within these fisheries using the P* and decision theoretic approaches and these methods will be linked into the multispecies interaction model. Finally alternative management strategies will be evaluated and presented to the relevant management bodies.

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

Accomplishments
This project was not active during the award period and has been delayed until 2011. The PI anticipates that the activities will begin 2011 when a Post doctoral Research Associate is anticipated to join the project.

Improving Assessment Methods: Developing and Evaluating Alternative Estimators of Survey

PI
UW - André Punt
NOAA - Jim Ianelli

Task III

NOAA Primary Contact
Jim Ianelli, Alaska Fisheries Science Center

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

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

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

Accomplishments
This project was not active during the award period and has been delayed until 2011. The PI anticipates that the activities will begin March-April 2011 when a Postdoctoral Research Associate is anticipated to join the project.

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

PI
UW - André Punt

Other Personnel
UW - Ian Taylor

Task III

NOAA Primary Contact
Richard Methot, Northwest Fisheries Science Center

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

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

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

Accomplishments
Objective (1) was satisfied through the release of simulation testing tools in a software package available to all SS users. The methods enabled by this software were initially applied to Objective (4), which is a core problem in stock assessment, and the results of this research were described in a manuscript (listed in Appendix 9 Publications). The software was also the subject of a tutorial presented at the UW/NOAA Fisheries Think Tank in January, 2011. Progress toward objective (2) continued throughout the year and will be presented as part of a proposed symposium at the Annual Meeting of the American Fisheries Society in September, 2011. A manuscript based on this research is expected to be completed from this research during 2011.

Objective (3) was accomplished through collaborative work on spatial extensions of SS and the setup of movement within spatial fisheries models. This collaboration led to two working papers (listed in Appendix 9 Publications) presented at scientific working groups.

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

PIs
UW - Ray Hilborn
NOAA - Anne Hollowed, Elizabeth Clarke

Other Personnel
UW - Matt Baker

Themes
Marine Ecosystems
Protection and Restorations of Marine Resources

Task III

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

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

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

Objectives
1. Compare shifts in mean trophic level across ecosystems in surveys, stock assessments and catches.
2. Evaluate the correlation between species, trophic levels and functional groups and productivity over time.
   Analyses will investigate:
   i. Temporal trends and variability in productivity of individual stocks as well as production for the ecosystem as a whole.
   ii. The correlation structure of surplus production, either by species, trophic levels, or functional group (pelagic/demersals).
   iii. Variability in productivity within and among species and functional groups for the four focal ecosystems as well as productivity summed over all stocks within an ecosystem.

3. Assess the extent to which environmental changes or impacts of fishing drive productivity. Analyses will evaluate:
    i. Environmental impacts on productivity.
    ii. The extent to which productivity has been driven by abundance, environmental regime changes, or random fluctuations.
    iii. The extent to which productivity is explained by changes in abundance, environmental regime shifts or a mixed model for each unit of analysis (e.g. stock, trophic level or functional group).
    iv. The correlation in breakpoints across species or groups for significant regime shifts.
    v. Correlations between productivity units of analysis (i.e. determine whether fishing pressure causes productivity to shift from demersal stocks to pelagic stocks or from high trophic levels to low trophic levels).
    vi. Evidence for ecosystem-wide changes in productivity (i.e. determine whether productivity is impacted by fishing and whether surplus production of fisheries responds to increasing fishing pressure).

Accomplishments

1. Exploration of data: accessed and explored NOAA trawl survey database (RACEBACE), gained familiarization with Oracle and SQL code/scripts, and developed data queries and extraction.
2. Reviewed relevant literature related to ecosystem analyses; regime shifts, physical forcing, climate impacts and fishing impacts on exploited marine ecosystems; population and community resilience; analyses of structure and dynamics of marine food webs, species-centric approaches focused on population dynamics of single species vs. trophic-centric approaches; biogeography of Bering Sea; community composition and dynamics in Bering Sea.
3. Defined temporal and spatial boundaries for initial analyses in the Bering Sea ecosystem, according to north/south latitudinal gradients and 50m isobaths (inner, middle, outer domains), accounting for inter-annual movement and infusion of cold pool and identified years and trawl surveys with consistent gear use (1982-2010).
4. Coordinated regular communication with collaborators at NOAA Northeast Fisheries Science Center analyzing North Atlantic ecosystems to ensure a common approach and assignment of ecosystem metrics, developed calendar for further discussions and discussed logistics related to face-to-face meetings and data-sharing.
5. Developed updated species assignments for trophic levels: will participate in GLOBEC meetings with Resource Ecology and Ecosystem Modeling team to determine updated estimates of species assignments for trophic levels based on diet analyses.
6. Developed preliminary approaches to analyses including:
    i. Determining the presence of synchronous (positively correlated) or asynchronous (negatively correlated) patterns among surplus production (recruitment, growth, natural mortality) in stocks, and the evidence for either inter-annual variability in overall fishery production or ecosystem stability despite inter-annual fluctuations in the productivity of individual stocks. These analyses will provide insight as to whether the components of the ecosystem are more variable than the aggregate and at

what scale (i.e. determine the finest scale at which we see stability within the ecosystem).

ii. Approach to correlation analyses relating fish distribution/abundance to environmental variability (mean temperature and presence/absence/extent of cold pool).

iii. Approach to correlation analyses relating fish distribution to population density.

iv. Approach to calculate/contrast centers of distribution for each taxon (via CPUE-weighted mean latitude, annual basis).

v. Approach to calculate/contrast relative abundance of species within functional groups (annual basis) and correlation with environmental variables and catch rates.

vi. Develop regressions to examine community-level response variables on annual mean bottom temperature.

vii. Develop regressions to examine individual species response variables on annual mean bottom temperature.

viii. Relate species-specific responses (distribution – slopes of CPUE-weighted mean latitude by year; abundance –) to commercial status (exploited/not exploited).

ix. Quantify shifts in biological response variables over time based on trawl survey data, including: probability of occurrence by taxon (binomial presence/absence); catch-per-unit effort (kg/km2); local species richness (taxa per haul); and mean trophic level of catch (CPUE weighted mean across taxa).

x. Determine if ecosystem stability is enhanced by complexity (i.e. components within trophic levels are more variable in their dynamics than aggregate groups).

xi. Determine the taxonomic scale at which compensation is expressed and taxonomic scale at which stability is evident.

xii. Define metrics for evaluating functional redundancy and resilience within system.

xiii. Examine classification of functional groups definitions in contrast to whether covariance in species dynamics is positive negative or not significant.

xiv. Examine residual covariance between species after the effects of fishing effects are removed.

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
UW – David A. Armstrong

Task III

NOAA Primary Contact
Bill Karp, Alaska Fisheries Science Center,
John Stein, Northwest Fisheries Science Center

NOAA Goal
5. Mission Support

Description
To partnership with The Northwest Fisheries Science Center and Alaska Fisheries Science Center to develop increased capacity in The School of Aquatic and Fishery Sciences to enhance teaching and research in stock assessment and resource management

Objectives
Hire and support tenured track faculty member at the University of Washington, School of Aquatic and Fishery Sciences.

Accomplishments
The School of Aquatic and Fishery Sciences hired Trevor A. Branch as an assistant professor tenure track. Professor Branch began employment September 16, 2010. The School has an active search underway for a resource economist.

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

PIs
UW - Miriam Doyle, Nicholas Bond
NOAA - Jeff Napp

Other Personnel
NOAA - Kathryn Mier, Morgan Busby, Janet Duffy-Anderson, Ann Matarese

Task II

NOAA Primary Contact
Jeff Napp, NOAA Alaska Fisheries Science Center

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

Description
Varieties of projects are being carried out in conjunction with the NOAA Alaska Fisheries Science Center's Recruitment Processes and EcoFOCI Groups. Specifically, early life history aspects of recruitment processes among Gulf of Alaska and Eastern Bering Sea fish species are being investigated. Data are from ongoing (since 1972) collections of ichthyoplankton samples and associated oceanographic and climate measurements in both regions.

Objectives
Project 1. Larval fish abundance and physical forcing in the Gulf of Alaska.
This research documents interannual variation in late spring abundance of numerically dominant larval fish species in the Gulf of Alaska (GOA), and explores links between time-series of larval abundance and physical oceanographic and climate variables. Links between the species and the physical variables are interpreted from the perspective of fish life history strategies and contribute to a mechanistic understanding of physical forcing on early life history aspects of recruitment processes in the GOA ecosystem.

Project 2. Life history groups of fish species as proxies for population response to environmental change in the Gulf of Alaska (GOA), and other Large Marine Ecosystems (LMEs) of the U.S.
This project involves testing the hypothesis that groups of fish species with similar life history and ecological traits encounter common patterns of environmental exposure that result in a similar recruitment response to oceanographic and climate variability, particularly during their pelagic early life history. Multivariate statistics and analytical methods will be applied to time series of GOA fish species adult and early life history abundance metrics in conjunction with time-series of oceanographic and climate variables, within and among species life history and ecological groups. The proposed research is also being developed to allow its application in

other U.S. Large Marine Ecosystems where ichthyoplankton, fisheries, climate and oceanographic data have been collected concurrently for decades.

Project 3. Participation in the GOA-IERP research program.
The overall goal of the Lower Trophic Level (LTL) component of the new NPRB research initiative, the Gulf of Alaska Integrated Ecosystem Research Program (GOA-IERP) is to determine how physical transport mechanisms influence lower trophic level production, and subsequently the survival and recruitment of five species of ground fish (walleye pollock, Pacific cod, arrowtooth flounder, sablefish and Pacific ocean perch) targeted by the GOA-IERP Upper Trophic Level program. Doyle is responsible for compilation, analysis and interpretation of ichthyoplankton data pertaining to these species from historical sampling in the western Gulf of Alaska by the EcoFOCI research program.

Project 4. Early life history of Pacific sand lance (Ammodytes hexapterus) in the Gulf of Alaska and Southeast Bering Sea .
As a key forage species, it is important to understand the ecology of Pacific sand lance and to investigate the potential stability or vulnerability of populations in these regions in relation to the oceanographic environment. A review of its early life history ecology is being undertaken based on EcoFOCI historical ichthyoplankton collections.

Accomplishments
Project 1.
Late spring larval fish abundance data continue to be accumulated annually and are now available through 2009. The time-series of physical variables is being updated and developed in conjunction with scientists from the EcoFOCI research program at NOAA's Pacific Marine Environmental Laboratory. With extension of the data time-series, links between species abundance and the physical variables will be re-examined (as in Doyle et al., 2009) for consistency or variability, and this investigation will be a major contribution to the following life history groups proposed project.

Project 2.
Initial identification of major life history gradients and delineation of species groups, among GOA fish species, has been carried out by performing ordination on a data matrix of species by life history and ecological traits (numerically expressed). This pilot project has yielded an effective potential framework for evaluating the exposure and response of GOA species to the pelagic environment during early life (Doyle and Mier, in prep.). Testing the hypothesis will continue with the investigation of time series of fish species adult and early life history abundance metrics in conjunction with time-series of oceanographic and climate variables, within and among species life history groups. A collaborative research proposal has been submitted to NSF, for funding through the CAMEO 2011 program, to seek support for the application of this research protocol in a comparative analysis of life history driven response to environmental change among fish species in the Gulf of Alaska and Northern California Current ecosystems.

Project 3.
Work on the GOA-IERP project commenced in October 2010. Contributions have been made to the development of the Lower Trophic Level sampling program for the spring, summer and fall of 2011. Synthesis of historical ichthyoplankton data collections from the western GOA is continuing for the purpose of understanding the early life history dynamics of the key project species.

Project 4.
A review of the early life history ecology of Pacific sand lance is continuing based on ichthyoplankton samples collected in the Gulf of Alaska and Southeast Bering Sea from 1972 to the present (Figure 1). Two manuscripts are planned and the first is in preparation:
1. A review of the early life history ecology of *Ammodytes hexapterus* (Pacific sand lance) in the Gulf of Alaska and SE Bering Sea (Doyle, in prep.);
2. Larval drift of Pacific sand lance in relation to circulation patterns in the Gulf of Alaska – dispersal pathways and ecological implications.

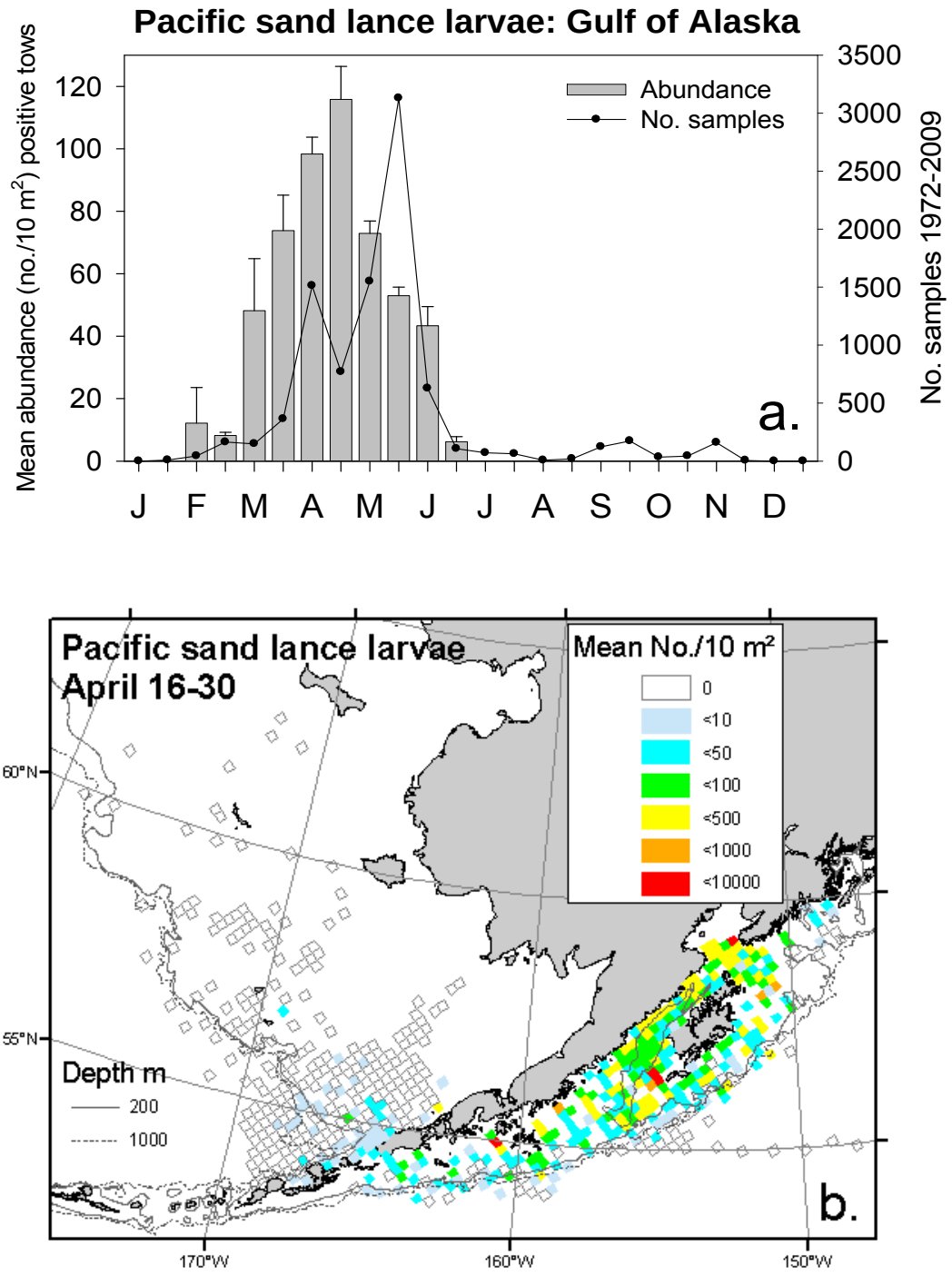


Figure 1. Summary information for Pacific sand lance larvae from EcoFOCI ichthyoplankton collections, 1972-2009: a) seasonal patterns in larval abundance (weighted by year) in the Gulf of Alaska, b) distribution pattern of larvae during spring peak in abundance in the Gulf of Alaska – weighted mean abundance in each 20 x 20 km grid square was calculated with data stratified by year.

Ecosystems and Fisheries-Oceanography Coordinated Investigations (EcoFOCI)

PI(s)
UW - Nicholas Bond
NOAA - Phyllis Stabeno

Other Personnel
UW - Wei Cheng, Albert Hermann, Nancy Kachel, Scott McKeever, Calvin Mordy, Peter Proctor, Lisa Sheffield Guy, Margaret Sullivan, Muyin Wang
NOAA - Jeff Napp, Carol Ladd, Jim Overland

Themes
Climate Research and Impacts
Environmental Chemistry
Marine Ecosystems
Protection and Restorations of Marine Resources
Ocean and Coastal Observations

Task II

NOAA Primary Contact
Phyllis Stabeno, PMEL

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

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

Objectives
1. *Monitoring of the oceanographic ecosystem through analysis and processing of data from the North Pacific mooring array, satellite tracked drifters, and shipboard measurements.*

Biophysical moorings are maintained in the Bering Sea, providing critical information on the response of the environment to changes in climate. JISAO scientists contribute to maintaining these moorings, expanding the instruments on moorings to measure zooplankton abundance and oxygen, and introducing new technology to enable these moorings to report in real time.

2. *Disseminating data through websites, presentations, publications and workshops.*
   JISAO scientists contribute to the maintenance of web pages including those that presented ecosystem research operations aboard the USCG *Healy* (an NSF-funded cruise). JISAO scientists author and co-author numerous publications each year and present their findings at variety of regional, national and international meetings.
3. *Participating in cruises to examine the variability in physical and chemical oceanic processes that impact the North Pacific and Bering Sea ecosystems.*
   JISAO scientists take a leading role in studies of North Pacific ecosystems. They participate on cruises as chief scientist and party chief. JISAO scientists are leaders in the measurements of nutrients, chlorophyll, and oxygen.
4. *Projecting impacts of climate change.*
   JISAO scientists are involved in an effort to apply simulations of future climate (IPCC AR4 models) to issues related to marine ecosystems. The output from these models is being used to force local dynamical models of the North Pacific Ocean and Bering Sea, and to make projections based on empirical methods.
5. *Making data and analysis results available to Fishery Management Councils and other resource managers.*

Accomplishments

EcoFOCI's first ocean observing system in the Arctic.

The first CHAOZ (CHukchi Acoustic, Oceanographic, and Zooplankton) cruise took place on board the F/V *Alaskan Enterprise*. This program incorporates biophysical moorings, hydrographic measurements and numerical climate models to examine the changing ecosystem of the Chukchi Sea where future offshore oil development activities may occur. The moorings were deployed in conjunction with passive listening devices for monitoring marine mammals. The cruise began in Nome, AK on August 24, 2010 and ended in Dutch Harbor on September 20, 2010. This program marks EcoFOCI's first ocean observing system in the Arctic. In summary, a total of 20 passive acoustic and 7 oceanographic moorings were deployed, 50 hydrographic and zooplankton stations were conducted, 24 hour passive acoustic monitoring (via sonobuoy deployments) occurred, and over 1,750 miles were surveyed for marine mammal and bird observations. The measurements of currents will provide information on mesoscale variability over the shelf and will be important ground-truth for oil spill models in the region. Direct observations of ice thickness will be used to provide understanding of how climate change relates to ecosystem shifts, and for potential impacts on oil development. The observations will be compared with the simulations from global climate models to determine how well these models characterize the physical environment of the region. The Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) of the Department of the Interior is supporting this program.

Bering Sea Project completed.

The EcoFOCI group completed the final field year of the large multi-year project (BSIERP-BEST; *http://bsierp.nprb.org/*) that began in 2007. The objective of this research was to enable scientists to predict the effects of global climate change on the Bering Sea. JISAO scientists played a critical role in the success of the field studies - 16 cruises in four field years (April 2007-September 2010). At least one JISAO scientist was on each cruise. These cruises supported process studies and long-term monitoring programs seeking to better understand the mechanisms important to the marine ecosystem of the Bering Sea shelf. JISAO scientists are also developing procedures for using IPCC model output as forcing for regional ROMS simulations, which in turn will be linked to numerical models for the biological system. These activities undertaken as part of EcoFOCI will provide the foundation for integrated ecosystem approaches to predicting and managing marine resources in Alaskan waters. Analysis of observations from this year will be presented at the annual investigators meeting for the Bering Ecosystem Study during 22-24 March 2011 in Anchorage, Alaska.

Gulf of Alaska Integrated Ecosystem Research Program launched.

The EcoFOCI program has become involved in a major multi-institution project in the Gulf of Alaska funded by the North Pacific Research Board (NPRB). EcoFOCI's role in the Gulf of Alaska Integrated Ecosystem Research Program (GOA IERP; *http://gulfofalaska.nprb.org/)* is to determine how physical transport mechanisms influence lower trophic levels, and subsequently the survival and recruitment of five species of groundfish (walleye pollock, Pacific cod, arrowtooth flounder, sablefish, and Pacific Ocean perch). JISAO scientists will play 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. Two mooring cruises to SE Alaska were completed during 2010. Mooring deployment in 2011 is scheduled for late March (JISAO scientist S. McKeever). A research cruise during 14 April – 1 May 2011 (including JISAO scientists N. Kachel [chief], C. Mordy, & P. Proctor) will describe the physical and biological oceanographic conditions in the highly productive eastern Gulf of Alaska and integrate this information with concurrent surveys of upper trophic levels as part of GOA IERP. This cruise will take place aboard the *R/V Thomas G. Thompson* (Seattle – Kodiak) and deploy CTD, bongo, neuston, Multinet or MOCNESS, and satellite-tracked drifter equipment.

EcoFOCI joins Bering Sea Ecosystem Synthesis Team.

EcoFOCI (including JISAO scientists N. Bond and L. 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. A joint scoping workshop was held on August 3rd with other key providers of

ecosystem indices to identify the goal and the process to be followed to implement the change. A second workshop to winnow the suite of key ecosystem indices to a set of 10 (out of > 200) was held on 29 September 2010. A third workshop held on 14-15 October used these key indices to create the synthesis. This forecast was incorporated into the Ecosystems Considerations Chapter (ECC; *http://access.afsc.noaa.gov/reem/ecoweb/Index.cfm)* of the Stock Assessment and Fishery Evaluation reports and delivered to the North Pacific Fishery Management Council by ECC authors Stephani Zador (JISAO and AFSC/REFM) and Sarah Gaichas (AFSC/REFM). The ECC has now transitioned from a collection of indices with a small amount of synthesis to a volume that emphasizes ecosystem synthesis and provides advice to both the SSC and the Plan Teams. EcoFOCI scientists will continue 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 will meet with the lead authors of the individual assessment chapters (Plan Team reports) to discuss how and which climate indices can be incorporated directly into the single stock assessments for 2011.

Arctic Sea Ice.

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

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

PI
UW - Christian Torgersen
NOAA - Andrew Dittman, George Pess,

Other Personnel
UW - Jeremy Cram, Ryan Klett, and Darran May
NOAA - Don Larson

Task III

NOAA Primary Contact
Andrew Dittman, Kathleen Jewett, Northwest Fisheries Science Center

NOAA Goal
2. Protect, Restore & Manage the Use of Coastal & Ocean Resources Through Ecosystem-based Management

Description
This study examines the linkages between habitat quality and spawning site selection in an intensively monitored supplementation program in the Yakima River. Salmon supplementation programs are designed to increase natural production of self-sustaining spawning populations in habitat that is underutilized. When hatchery fish simply replace or interfere with wild fish on the same spawning grounds, supplementation will be unsuccessful. In a watershed where hatchery and wild fish coexist and habitat is limited, straying from target habitat might lead to considerable overlap and interaction between hatchery and wild spawners. As part of an ongoing NOAA study on salmon homing and spawning site selection in coordination with the Yakama/Klickitat Fisheries Project spring Chinook supplementation program, the scientists are examining the relationships between spawning site selection and fine-scale variation in aquatic productivity associated with floodplain complexity and groundwater-surface water exchange. This work builds upon previous basin-scale assessments of gradients in physical habitat quality. Ultimately, the team's goal is to develop predictive models that will provide guidance regarding the use of supplementation within a watershed in the context of current habitat quality and future habitat restoration efforts.

Previous work has shown that hyporheic connectivity influences salmon spawning distribution in large rivers, but these patterns have not been evaluated in small to medium-sized rivers downstream of headwater reservoirs, such as those in the upper Yakima basin. Technological advances in predicting salmon behavior have been made by applying thermal and lidar remote sensing to map water temperature and bed form topography, but as of yet no attempts have been made to link this information with spatially explicit data on groundwater exchange. In this study, data will be used from a combination of prior studies and ongoing work conducted by federal, state, and tribal agencies. Extensive work on groundwater exchange, stream temperature, and channel morphology has been conducted in the upper Yakima River by the

USGS and the U.S. Bureau of Reclamation using lidar and thermal mapping. An annual survey of salmon redds and carcasses have been conducted throughout the entire upper Yakima basin by NOAA and tribal/state agencies for multiple years. Surveys of thermal variation and groundwater exchange will be used to identify reaches for intensive study of salmon spawning behavior and channel morphology.

This project provides partial support for doctoral student Jeremy Cram and Master's student Ryan Klett in the UW School of Forest Resources.

Objectives

The objectives of this project are to:

1. Assist with selection and sampling of representative study locations for fine-scale habitat assessments in the upper Yakima River basin,
2. Assess and identify physical and biological indicators of highly productive versus unproductive areas for critical salmon life history stages,
3. Identify and map hyporheic contributions to river flow and thermal regimes,
4. Develop predictive models of spawning site selection that incorporate different life history habitat requirements, and
5. Assist with analysis and validation of spawner survey sampling techniques.

Accomplishments

Extensive surveys of aquatic habitat and fish distribution were conducted in over 160 km of mainstream, tributary, and floodplain habitats in 2007. In 2008, 82 sites, each composed of 10 cells, were intensively surveyed using a stratified random design to quantify habitat type, channel width, depths, velocity, temperature, cover availability, gradient, conductivity, relative cover of substrate types, and fish abundance. The combination of spatially continuous surveys with discontinuous, intensive data will facilitate analysis of fish-habitat associations at multiple spatial scales. Longitudinal profiles of bathymetry and temperature were also generated for the entire upper Yakima River from surveys conducted in 2009 using a submersible pressure transducer probe that recorded depth and temperature every two seconds while being towed behind a raft. All field data have been mapped in a geographical information system (GIS) to facilitate spatial analysis.

Preliminary results on this work have been presented at the Yakima Basin Science and Management Conference in 2008 and 2009 and at the annual meetings of the Oregon and Washington-British Columbia chapters of the American Fisheries Society.

Graduate students Jeremy Cram (PhD) and Ryan Klett (M.S.) conducted extensive data analysis for their projects and assisted in annual carcass surveys in collaboration with Dittman on the Yakima River. The students used multivariate ordination techniques and nonparametric regression to investigate spatial patterns in their data. Jeremy Cram examined the potential effects of habitat quality on homing patterns of female salmon and found that salmon were less likely to spawn in reaches in which they were acclimated as juveniles if higher quality spawning habitat was available elsewhere. An important result of Ryan Klett's research indicated that although there was not a strong relationship between egg-to-fry survival and fine sediment

intrusion in spawning substrates, fine-sediment infiltration patterns varied substantially at fine and coarse spatial scales.

Research proposals were prepared, submitted, and presented for peer review by Jeremy Cram (PhD student) and Ryan Klett (MS student). Field work on fine sediment infiltration in chinook salmon redds in the Yakima River was completed in fall/winter 2009/2010 by Ryan Klett. Jeremy Cram presented preliminary results at the 2010 Water Center Annual Review of Research at the University of Washington. Both Jeremy Cram and Ryan Klett presented preliminary results at the Yakima Basin Science and Management Conference in 2010 in Ellensburg, WA.

All stated objectives were met, and the students are progressing according to schedule. Jeremy Cram has already received an internal review of his manuscript "Tradeoffs between homing and habitat quality for spawning site selection by hatchery-origin Chinook salmon". Co-authors include Torgersen, Dittman, Pess, Klett, Pearsons, and May. Revisions are currently being completed, and the manuscript will be submitted to the Canadian Journal of Fisheries and Aquatic Sciences in March.

Awards

Jeremy Cram received the best student presentation award at the 2010 Water Center Annual Review of Research. Additional research funds for the project were acquired through a competitive proposal submitted to the U.S. Geological Survey State Partnership Program to fund the PhD research by Jeremy Cram.

Northwest Fisheries Science Center and University of Washington Undergraduate Intern Program

PI
UW - Janice DeCosmo

Other Personnel
UW - Tracy Nyerges,

Task III

NOAA Primary Contact
Kathleen Jewett, Northwest Fisheries Science Center

NOAA Goal

1. Protect, Restore & Manage the Use of Coastal & Ocean Resources Through Ecosystem-based Management

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
Between 5-12 internship positions are anticipated annually under this project, for UW students to work with NWFSC's several research divisions. These academic year internships will also offer summer quarter option, with varying number of hours. One of the internships will also include fieldwork and travel during the summer. Selected interns will commit between 10 and 19.5 hours per week during the academic year and up to forty hours per week during summer and interim periods to their research projects. The number of 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. In addition to providing internships that give undergraduates experience in fisheries science research, the program also aims to provide other professional development for interns, such as learning how to network with other scientists, presenting their projects in poster format at NWFSC and/or at the UW undergraduate research symposium. 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 ten students participated in the internship program. Three of the interns presented their research results at the annual UW undergraduate research symposium in May, 2010. All of the interns participated in networking activities and poster sessions at NWFSC.

Name	Major	Start date
David Berman	Aquatic and Fishery Sciences	1/11/2011
Stanley Biryukov	Pre Science	7/30/2010
Kyle Frischkorn	Biochemistry	6/2/2009
Brian Harmon	Aquatic and Fishery Sciences	12/22/2010
Sarah K. Hu	Aquatic and Fishery Sciences	1/4/2010
Soram Hong	Chemistry and Biochemistry	6/16/2009
Andrew Ostericher	Chemistry (ACS)	6/23/2010
Amanda Phillips	Aquatic and Fishery Sciences	11/17/2008
Juliana Stephan	Aquatic and Fishery Sciences, Biology (Physiology)	12/10/2009
Evan Yount	Microbiology	8/5/2010

Long Form Community Profile Development

PI
UW - Marc L. Miller

Other Personnel
UW - Kristin Hoelting
NOAA - Karma Norman

Themes
Marine Ecosystems
Protection and Restorations of Marine Resources

Task III

NOAA Primary Contact
Karma Norman, Northwest Fisheries Science Center

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

Description
The graduate research assistant (RA) provided services to support the ongoing "Fishing Community Profiles for the West Coast" project, including the development of the text and necessary graphs and other illustrations for the final detailed 'long form' community profiles of fishing communities in Washington state. The fishing community profiles were designed to provide fisheries policy-makers with detailed socioeconomic information about a set of communities in Washington, Oregon and California such that the social impacts of major policy shifts (e.g. the shift to a 'catch-share' system of fisheries management) could be tracked and predicted. Such 'communities' data' is integral to effective ecosystem-based management, particularly in marine ecosystems which involve human dimensions. The RA reviewed and corrected data included in the profiles, edited all documents, participated in the development of mechanisms to distribute the profiles for public review and response, organized community points of contact for review of the documents, and conducted interviews and fieldwork in the selected communities.

Objectives
Communities targeted for long form community profiles were those of particular interest in the groundfish trawl rationalization process, and so;
1. ***The first objective*** was to review the draft long form profiles of six Washington communities that were produced during the prior year. The profiles Bellingham, Seattle, Westport, Neah Bay, Iwalco, and Anacortes and they were reviewed for accuracy and missing data. This objective was completed in a timely fashion.

2. A ***second objective*** was to do additional follow-up with necessary fieldwork and interviews in the selected communities to 'ground-truth' the data provided in earlier iterations of the community profiles. This objective was also completed.
3. A ***third objective*** involved the use the communities-focused guidance indicated in Magnuson-Stevens Act legal language to provide creative and long term research ideas for input in NOAA's ongoing communities research. This objective was also met.

Accomplishments

The project was conducted such that finalized versions of all fishing community profiles required by the scope of the policy change were completed, along with supporting documents for a planned NOAA Technical Memorandum. This accomplishment was in keeping with the three objectives outlined above, and also was completed in conjunction with the implementation of a newly developed survey of groundfish fishermen in the profiled communities, as well as development of measures of resilience in west coast fishing communities. The project thus served to inform and aid the Human Dimensions team at the Northwest Fisheries Science Center in expanding fishing social science projects for the 2011 and 2012 fiscal years.

Spatial Analysis of a Near-Surface Acoustic Backscatter Layer in the Eastern Bering Sea

PI
UW - John Horne

Other Personnel
UW - Mathieu Woillez

Task II

NOAA Primary Contact
Chris Wilson and Patrick Ressler, NOAA Fisheries, Alaska Fisheries Science Center

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

Description
This project characterizes a persistent, large-scale, near-surface acoustic backscatter layer, which is a common feature in acoustic survey data throughout the eastern Bering Sea. Spatial and temporal patterns in this backscatter may contain important information about the Bering Sea ecosystem.

Objectives
1. Develop a probabilistic method to classify acoustic data based on frequency-dependent backscatter (i.e. frequency response) and trawl data.
2. Validate the classification method by comparing known species clusters (e.g. walleye pollock, euphausiids) with results obtained from traditional acoustic classification methods.
3. Describe spatio-temporal patterns of the near-surface acoustic backscattering layer based on the resulting classification clusters.

Accomplishments
1. Because walleye pollock (*Theragra chalcogramma*) are the primary target species of the summer acoustic-trawl surveys in the eastern Bering Sea, relatively little sampling effort is directed to confirm identities of other species contributing to acoustic backscatter in the near-surface layer. Therefore, methods used to discriminate and classify species in multi-frequency acoustic data must incorporate the lack of trawl samples for species verification. A generalized Gaussian mixture model was developed to incorporate sparse trawl sampling. The model includes a classification framework in which some classes of organisms may be known and others unknown. Model component classes are first learned independently using concurrent acoustic and trawl sampling data for known classes (i.e. sampled locations, labeled data) and the remainder of the acoustic data are used to establish the unknown classes (i.e. unsampled locations, unlabeled data). Components are then merged, and semi-supervised learning is conducted with the complete set of labeled and unlabeled data.

Unlabeled data is associated with either known or unknown class components. Some unlabelled data will be classified as known and the known class components will update their parameters using an extension of the expectation-maximization (i.e. EM) algorithm. The remaining unlabelled data remain associated with unknown class components, whose parameters are also updated.

2. The mixture model classification algorithm was applied to acoustic survey data collected in the eastern Bering Sea during summers of 2004 and 2007-2008. The classification algorithm detected and mapped six groups with different acoustic frequency responses (Figure 1), where three of these groups were known. Two of the known groups corresponded to walleye pollock and euphausiids, the focal species of the surveys. The scientists' results for these classes were then compared to those from the survey that were determined by analysts, and to groups determined using a 'z-score' classification method. Groups defined by all methods agreed in most areas. When groups did not match, a mix of species typically occurred as was encountered during the 2004 survey. For this year, their classification results for walleye pollock were more similar to those delineated by the analyst than those from the 'z-score' classification method.

3. The mixture model classification identified and characterized species assemblages within the near-surface backscattering layer. Two near-surface clusters with distinct frequency responses composed this layer; one is attributed to jellyfish as a known class. The next logical step in this study is to use observed cluster frequency responses and spatial patterns to optimize a field sampling plan that will identify constituents within the layer. The spatial distribution of these groups could be tracked over time for use as an ecosystem monitoring index.

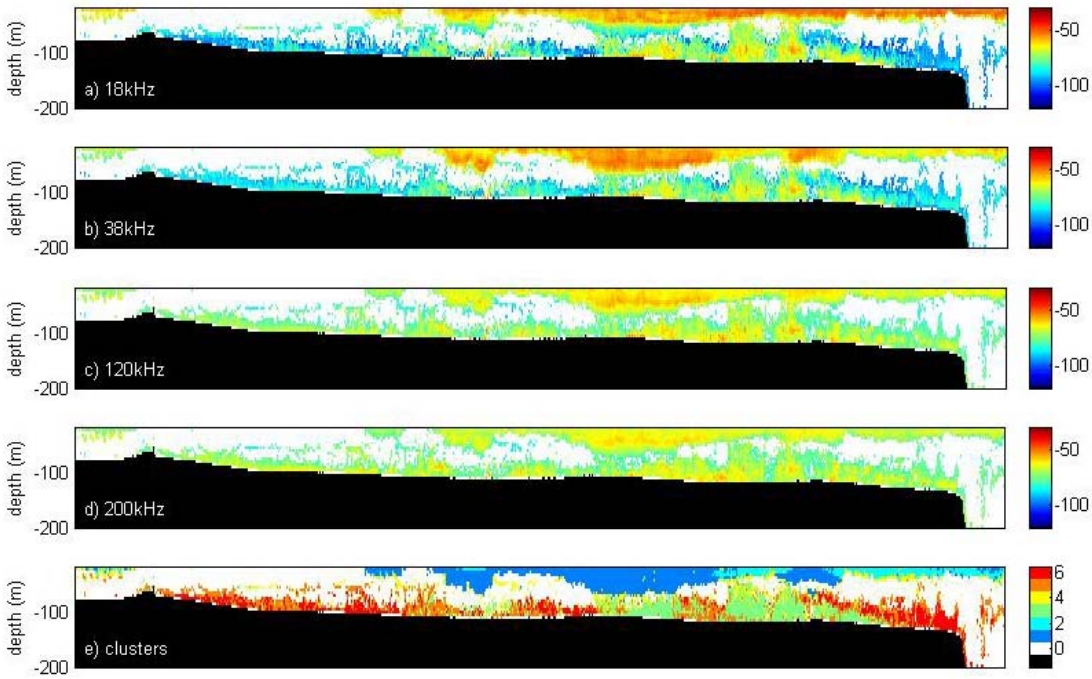


Figure 1: Volume backscattering strength (S_v in dB) at 18, 38, 120, 200 kHz (a, b, c and d) and (e) the corresponding clusters obtained by semi-supervised clustering based on a generalized Gaussian mixture model for a single transect during the 2007 summer survey in the eastern Bering Sea. Clusters 2, 3, and 6 correspond to the known classes, jellyfish, walleye pollock and euphausiids.

Non-Invasive Physiological Monitoring of Southern Resident Killer Whales

PI
UW - Samuel K. Wasser

Other Personnel
UW - Katherine L. Ayres

Task III

NOAA Primary Contact
Kathleen Jewett, Northwest Fisheries Science Center

NOAA Goal

3. Protect, Restore & Manage the Use of Coastal & Ocean Resources Through Ecosystem-based Management

Description
Investigate the effects of prey abundance and boat traffic disturbance on endangered killer whales. The Southern resident killer whale (SRKW) population is an important ecological and economic resource. As top predators, their population represents a measure of overall health of our oceans while their presence in the region supports a multi-million dollar tourist industry. The team is investigating the relative impacts of prey abundance and boat traffic on nutrition and disturbance in the SRKW using non-invasive hormone measures from killer whale fecal material. They collect SRKW scat samples with the aid of a specially trained detection dog. This past year the group has been finishing hormone and DNA analyses of the samples collected in 2009 and are nearly finished analyzing the results from all samples collected from 2006-2009. These analyses are being written up for peer-reviewed publication to address three objectives.

Objectives

1. Validate and describe the effectiveness of using a cetacean scat detection dog in complex estuarine environments.
2. Use fecal reproductive steroid measures to test differences in sex, age and reproductive status of free ranging killer whales.
3. Use fecal glucocorticoids (stress hormones) and thyroid hormone (nutrition hormones) to test the non-exclusive hypotheses that SRKW are food limited or disturbed by boat noise and/or behavior.

Accomplishments
1. Killer whale fecal sampling with a scat detection dog.
The researchers successfully collected 95 killer whale fecal sam ples in 2009 with the use of a scat detection dog. They are currently writing a manuscript that details the important steps involved in training and handling a cetacean scat detection dog in a complex environment such as the estuarine fjord that surrounds the San Juan Islands. Whale behavior state was found to be an important predictor of sampling success, with the highest sampling probability occurring when whales are engaged in social activities.

2. Assessing sex, age, and reproductive status using reproductive steroids.
In the last year, the team analyzed all samples for fecal progestins, testosterone and estrogens. They also recently received DNA data analyzed by their collaborators at NOAA-Northwest Fisheries Science Center for our 2009 samples. Using the DNA genotypes they were able to cross reference hormone concentrations with individual whales that have been photo-identified and censured for the last 40 years by the Center for Whale Research (CWR). The sample identities combined with life history data provided by CWR, enabled them to test sex, age and reproductive condition differences in reproductive steroids. Pregnant females had the highest progestin concentrations, as expected. Pregnant females also had higher testosterone levels than other female reproductive classes. Males show an increase in testosterone with age that also corresponds to age-related changes in body length found by Fearnbach et al. (*in press*). Testosterone may also be correlated with dorsal fin height, a trait likely to be under sexual selection in male killer whales.

3. Evidence of food limitation in Southern resident killer whales.
All samples were also analyzed for fecal glucocorticoids (GC) and thyroid hormone (T3) and the team are now exam ining their relation to prey abundance and boat traffic and hence associated psychological and nutritional stress in SRKW. The Fraser River Chinook salmon migrations are the largest remaining Chinook migrations in the SRKW population's home range. Hanson et al. (2010) found that approximately 90% of the SRKW diet consisted of Fraser River Chinook from May through September. The researchers temporally collected GC and T3 hormone measures from SRKW feces strongly suggest that prey abundance is a primary driver of physiological health and mortality of this vulnerable population.

Fecal GC measures are positively correlated with both psychological and nutritional stress, where as fecal T3 measures are negatively correlated with nutritional stress, independent of psychological stress. They found that SRKW GC levels are significantly negatively correlated with Fraser River Chinook salmon abundance from May through September. Fecal GC concentrations are lowest during the months when Fraser River Chinook salmon are most abundant in the Salish Sea (July and August) and highest in the winter (November and December) when west coast Chinook salmon migrations are less abundant. Winter is also when most SRKW deaths occur. Mean T3 concentrations at the time of SRKW Spring arrival in the Salish Sea inversely correspond to mortality during the immediate preceding winter. Fecal T 3 measures were significantly lower in 2008 when the SRKW experienced 8.4 % mortality compared to 2007 and 2009 when mortality was 2.3% and 0% respectively. Mean T3 concentrations were intermediate in 2006, when mortality was 6.8%. Moreover, these annual differences at time of arrival remained constant despite a progressive seasonal decline in T3 until the SRKW depart again in winter. Combined, these results suggest that abundance of winter salmon runs are by far the most important to killer whale survival and in certain years the abundant Fraser River Chinook runs are insufficient to compensate for the winter prey deprivation.

Possible interactions of vessel traffic with prey abundance on hormone levels are still being investigated based on the hypotheses that boat noise and/or behavior may affect the whales' foraging abilities or add psychological stress during times of low prey.

Publications for the Year

1. K. Ayres et al. (in preparation). Application of scat detection dogs to cetacean research.
2. K. Ayres et al.(in preparation). Assessing reproductive status of free ranging killer whales (*Orcinus orca*) using fecal hormone metabolites.
3. K. Ayres et al.(in preparation). Nutritional versus disturbance stress in endangered killer whales (*Orcinus orca*)

Fisheries Acoustic Research

PI
UW - John Horne

Task III

NOAA Primary Contact
Russ Nelson, Alaska Fisheries Science Center

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

Description
This project partially supports an Associate Faculty position at the University of Washington, School of Aquatic and Fishery Sciences (SAFS). Activities include research, supervision of graduate students and postdoctoral associates, and service. Research activities examine acoustic reflectivity properties of north Pacific and Bering Sea fish species, develop visualization tools to increase the understanding of using sound to examine fish populations, and investigate equipment and methods used to acoustically enumerate, size, and map fish distributions. Supervision of graduate students includes those employed by RACE and REFM divisions at the Alaska Fisheries Science Center (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 develop metrics to characterize acoustic data from ocean observatories.
3. To quantify distributions of pelagic fish in US Beaufort Sea waters.

Accomplishments
1. A total of five graduate students (3 Masters, 2 PhDs) and two postdoctoral associates were active during the reporting period. Three graduate students completed and published chapters from their research programs. Elizabeth Atwood revised and published a chapter from her Master's project entitled, "Influence of mesoscale eddies on ichthyoplankton assemblages in the Gulf of Alaska" in Fisheries Oceanography. Kresimir Williams published his first dissertation chapter entitled, "Length-selective retention of walleye pollock, *Theragra chalcogramma*, by midwater trawls" in the ICES Journal of Marine Science. And Steve Barbeaux has published part of his first chapter entitled, "Assessment of fishery induced abundance depletion from opportunistically collected acoustic data" in the proceedings from the ICES Annual Science Conference. Tracey Smart submitted "Influence of environment on walleye pollock eggs, larvae, and juveniles in the southeastern Bering Sea," to the Bering Sea Integrated Ecological Research Program's (BSIERP) special volume

in Deep-Sea Research II. Mathieu Woillez has completed analysis and is writing a manuscript describing the characterization and classification of near-surface acoustic backscatter in the southeastern Bering Sea.

2. An upward-looking, echosounder package (*www.acoustics.washington.edu/DEIMOS*) was deployed and operated at the MARS cabled ocean observatory (*http://www.mbari.org/mars/*) site at a depth of 875 m from March 2009 until August 2010. Goals of the project include demonstrating the viability of active acoustic packages in ocean observatories, examining temporal-dependent distributional variability in nekton, and quantifying bio-physical and predatory prey interactions in Monterey Bay. Initial analysis has developed a series of descriptive metrics, in conjunction with Masters student Sam Urmy, to characterize water column distributions of acoustically-detectable biomass throughout the time series. As an example, Figure 1 shows the echogram (time x depth biomass densities) from noon February 21 to noon February 23, 2010. Each panel below the echogram displays metric values or biomass indices at one minute resolution for the entire series. From top to bottom the variables include: index of aggregation (IA), center of mass (CM), equivalent area (EA), inertia (I), percent area occupied (P_{occ}), number of layers (N_{layers}), volume backscattering strength (S_v) and area backscattering strength (S_a). Changes in metric values coincide with changes in the vertical distribution and density in the water column. Coherence and phase of environmental covariates with biomass indices are also being quantified for the upper mixed layer, the vertically migrating layer, the stationary layer, and individual animals above the bottom. The intent is to quantify vertical bio-physical coupling between atmosphere-ocean properties and aquatic biomass.

3. In conjunction with scientists at the NOAA Alaska Fisheries Science Center and the University of Alaska, acoustic and trawl surveys were conducted in the outer continental shelf of the western Beaufort Sea to census fish and invertebrate species compositions and density distributions. The scientists contribution was to combine acoustics (38 kHz) with midwater trawling and CTD casts to characterize fish density distributions (20-500 m bottom depths) in the water column (i.e. pelagic), and to evaluate relationships between fish distributions and water column properties. Age-1+ polar cod (*Boreogadus saida*) was the dominant fish species, with peak densities of 155,000 #•ha-1 at bottom depths of 100-350 m. Age-0 fish (polar cod, sculpin (*Cottidae* family), and eelblenny (*Lumpenus sp*.)), dominated the pelagic biomass at bottom depths between 20 and 75 m, with peak densities up to 160,000 #•ha-1, but were also found in surface waters at bottom depths >75 m. Statistical models of density distribution and habitat descriptors varied for age-1+ polar cod and found no relationships for age-0 fish. In general, age-1+ polar cod were associated with cold, saline waters likely of Chukchi Sea origin and mirrored published foraging distributions for beluga whales (*Delphinapterus leucas*). Conversely, age-0 fish were found in warmer, fresher water, likely of ice melt and/or riverine origin, throughout the study area. This study provides a necessary baseline for the development of Arctic assessment surveys and management plans for polar cod. A manuscript entitled, "Distribution of polar cod and age-0 fish in the U.S. Beaufort Sea," has been accepted by Polar Biology.

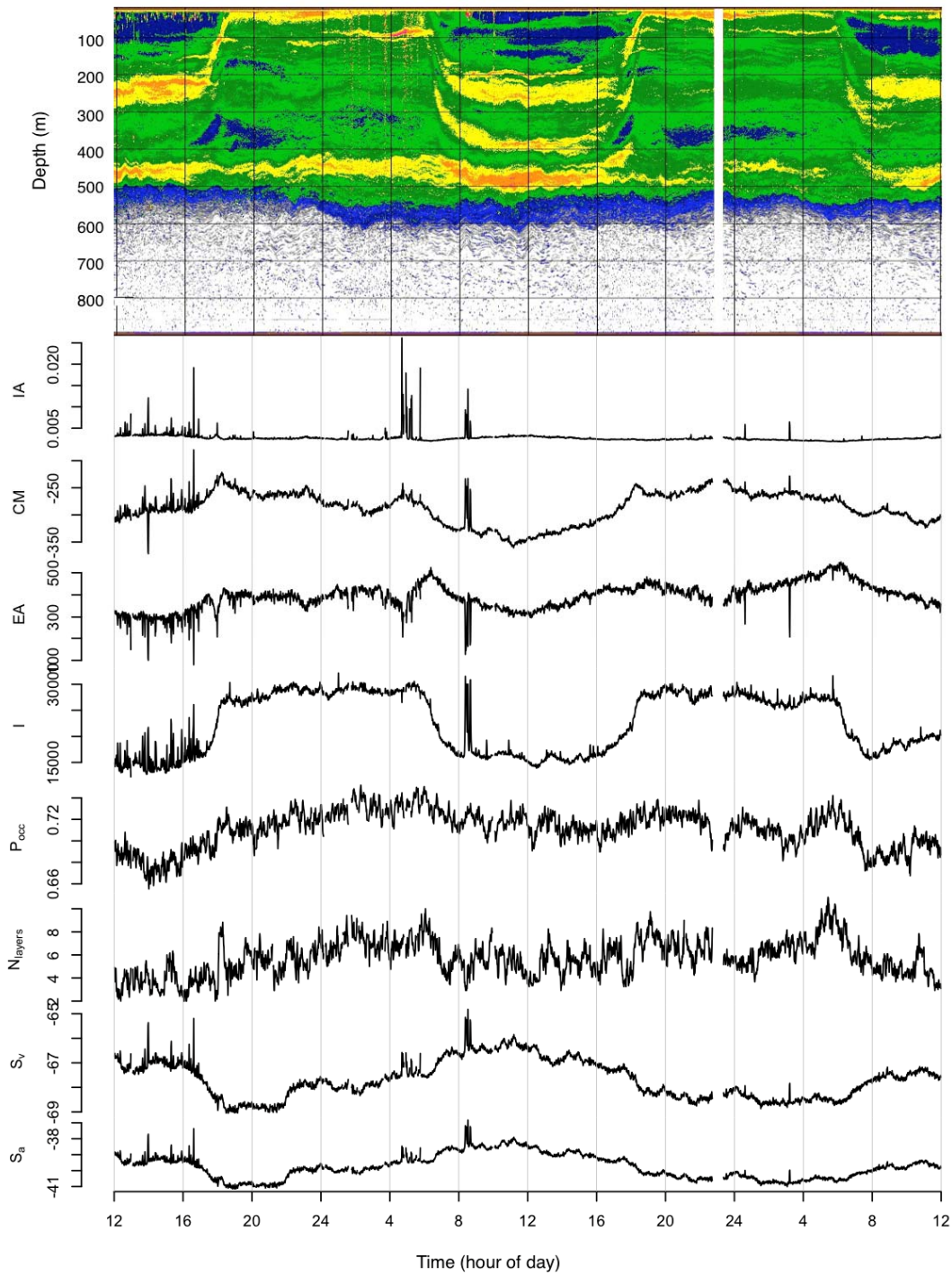


Figure 1. Echogram showing acoustic backscatter intensity from noon February 21 to noon February 23, 2010. Migrating animals move to the surface at dusk and form layers below 200 m during the day. The panels below track characteristics of the density distribution of backscatter at one minute resolution: index of aggregation (IA), center of mass (CM), equivalent area (EA), inertia (I), percent area occupied (P_{occ}), number of layers (N_{layers}), volume backscattering strength (S_v), and area backscattering strength (S_a).

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

PI
UW - Theodore W. Pietsch

Other Personnel
UW - David Drumm, Katherine P. Maslenikov
NOAA - James W. Orr, Robert R. Lauth, Duane E. Stevenson
California Academy of Sciences - Robert Van Syoc

Task II

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

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

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, the researchers will conduct a retrospective analysis of the bottom-trawl survey database to assess levels of confidence for each invertebrate species over survey years.

Objectives
1. A comprehensive annotated checklist of Alaskan invertebrates to be submitted for publication in the NOAA Professional Papers, a series available digitally over the internet and with a worldwide print distribution.

2. The results of the AFSC survey database assessment to be published in the local Technical Memorandum series, also freely available over the internet.
3. Synthesized results of this analysis will be incorporated into research publications planned for the primary literature.

Accomplishments

Since September 2010, when David Drumm, invertebrate systematist and post-doctoral appointee was hired, the checklist has been nearly completed for over 500 species. Complete coverage now includes five out of the six Mollusca classes (Bivalvia, 205 species; Aplacophora, 11 species; Polyplacophora, 54 species; Scaphopoda, 10 species; Cephalopoda, 32 species). With the exception of the Bivalvia, this list includes the higher-level taxonomic classification down to species name, synonyms, common names (if applicable), type locality, geographic distribution, and depth distribution. For bivalves, only the type locality remains to be added. Significant progress has also been made in other major groups, including the Hydrozoa, Asteroidea, and Crustacea. Three posters were produced illustrating the seastars of Alaska, all freely available at the AFSC home page ***http://www.afsc.noaa.gov/***. Already in this early stage of the project, significant discoveries have been made. The scientists have found range extensions for some decapod crustacean species. *Systellaspis braueri* (misidentified as *Notostomus* sp.) was collected in the Bering Sea just north of the Aleutian Islands. *Pagurus townsendi*, previously known from only four specimens collected in the 1800s, was found among vouchers collected by AFSC and is evidently very common along the eastern Bering Sea slope in deeper waters. During a visit by Drumm to the California Academy of Sciences to verify identifications, a previously misidentified tanaidacean crustacean was also found and may represent either a new species or a species not previously recorded from Alaska.

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

PI
UW - Kathleen M Stafford

Task III

NOAA Primary Contact
Catherine Berchok, National Marine Mammal Laboratory
Alaska Fisheries Science Center

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

Description
As part of a larger, Minerals Management Funded Study on the feeding behavior of bowhead whales in the vicinity of Barrow, Alaska, an acoustic recording component was incorporated with other sampling regimes undertaken by the National Marine Mammal Laboratory, the University of Alaska at Fairbanks and the Woods Hole Oceanographic Institution.
Passive acoustic detection and tracking is a proven tool for assessment of large whales in Alaskan seas (Moore et al. 2006). This may be the best method to effectively monitor seasonal occurrence over large spatial and temporal scales. Specifically, acoustic detection has proven a key addition to the census of bowhead whales during their spring migration past Barrow (Clark and Ellison 2000) and in relation to oil and gas development activities offshore Prudhoe Bay (Greene et al. 2004). More recently, gray whale calls have been detected year-round near Barrow on long-term recorders deployed in collaboration with the NSF/Shelf-Basin Interaction Study (Stafford et al. in press); this was the first evidence of gray whale occurrence in winter near Barrow. An array of moored passive acoustic receivers east and west of the study area will be able to detect bowhead calls as the whales enter and use the waters of the western Beaufort Sea. Year-round deployment will provide previously unattainable assessment of the seasonal occurrence of bowheads in the study area.

Objectives
1. Assess the seasonal occurrence of bowhead calls in the study area during the second field season (mid-August 2009 to mid-August in 2010).
2. Assess the annual occurrence of bowhead whale calls in the study season year-round starting in August 2009.
3. Correlate bowhead occurrence with results from oceanographic and prey sampling (e.g., temperature, salinity, florescence, and annual ice cover) to establish predictive variables for bowhead occurrence.

Accomplishments
Only data from the site at M3 were available for 2008-2009 due to instrument loss in 2009. The seasonal pattern of bowhead calls at this site can be seen in Figure 2, which shows the detections

of bowhead whales from 2008-09. No bowhead whales were detected from mid-November 2008 to mid-April 2009. The fall onset of ice arrival seems to drive the decrease in calls (i.e. the movement of whales out of the area). In spring, however, bowhead whales are heard even in nearly 100% ice concentration. This suggests that differ drivers, be they physiological or environmental, may be influencing migratory behavior in fall and spring.

In addition to bowhead whales, beluga whale calls were detected at M3 from 2008-2009. Like bowhead whales, beluga whales were not detected mid-winter (Figure 4).

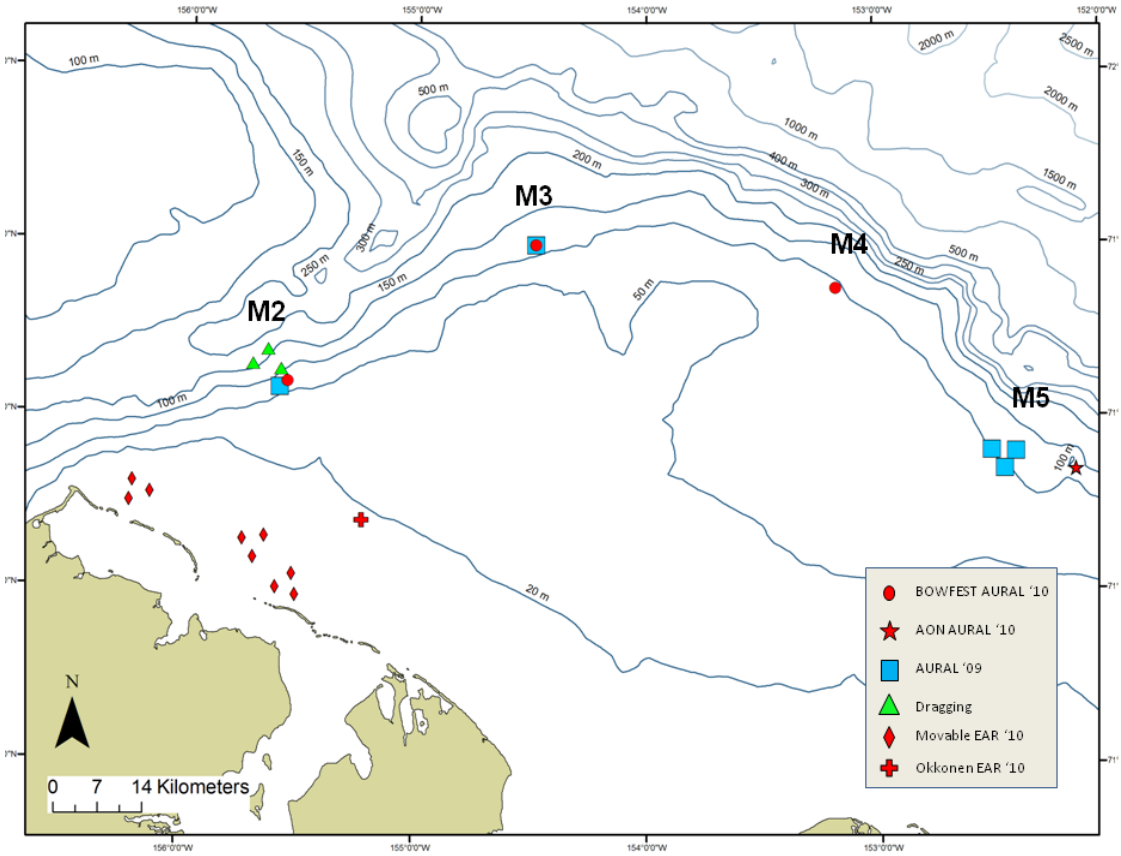


Figure 1. Locations of passive acoustic recorders during the 2010 BOWFEST field season.

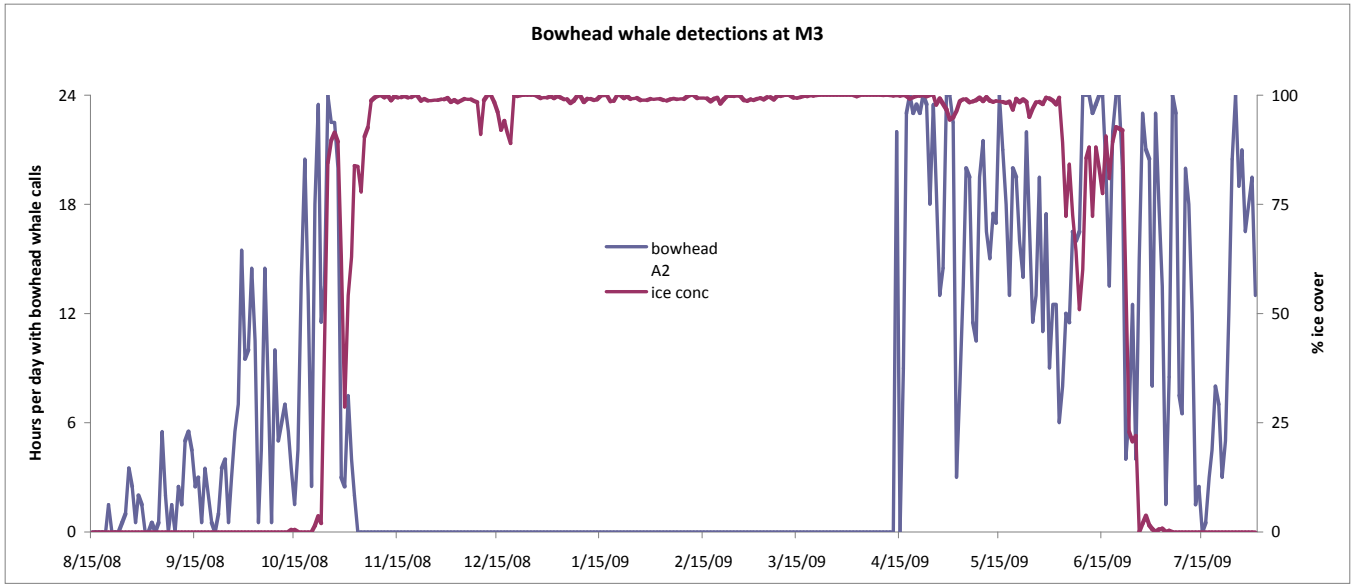


Figure 2. Bowhead whale detections with ice concentration 2009-2009.

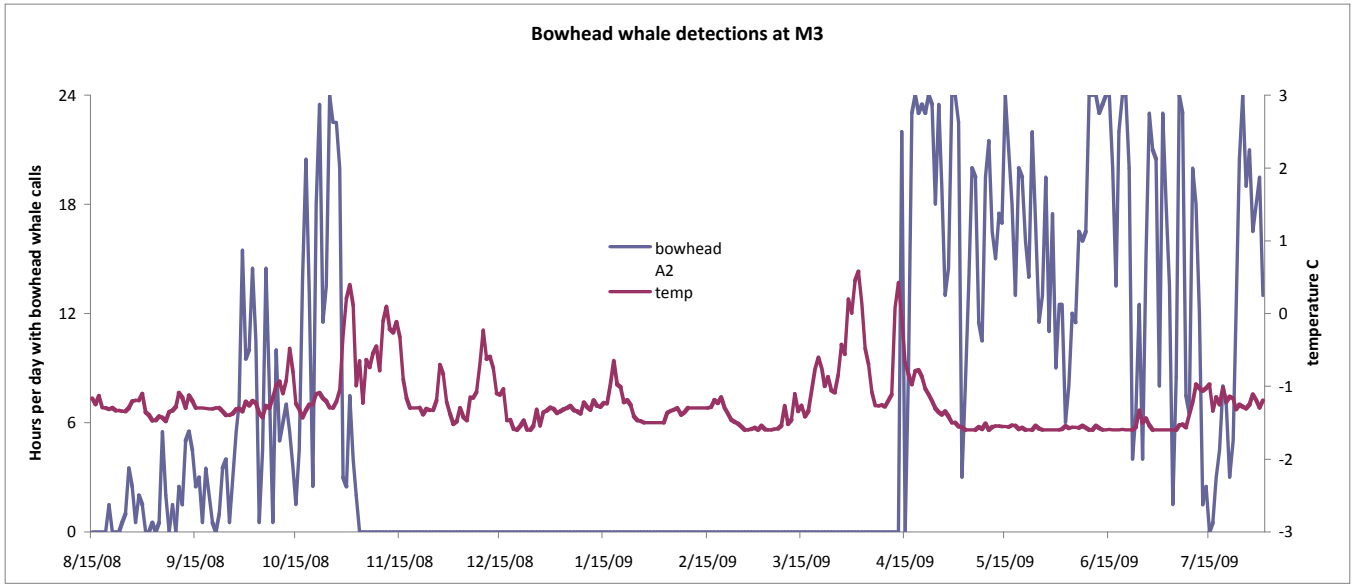


Figure 3. Same bowhead seasonal data with in situ water temperature by day.

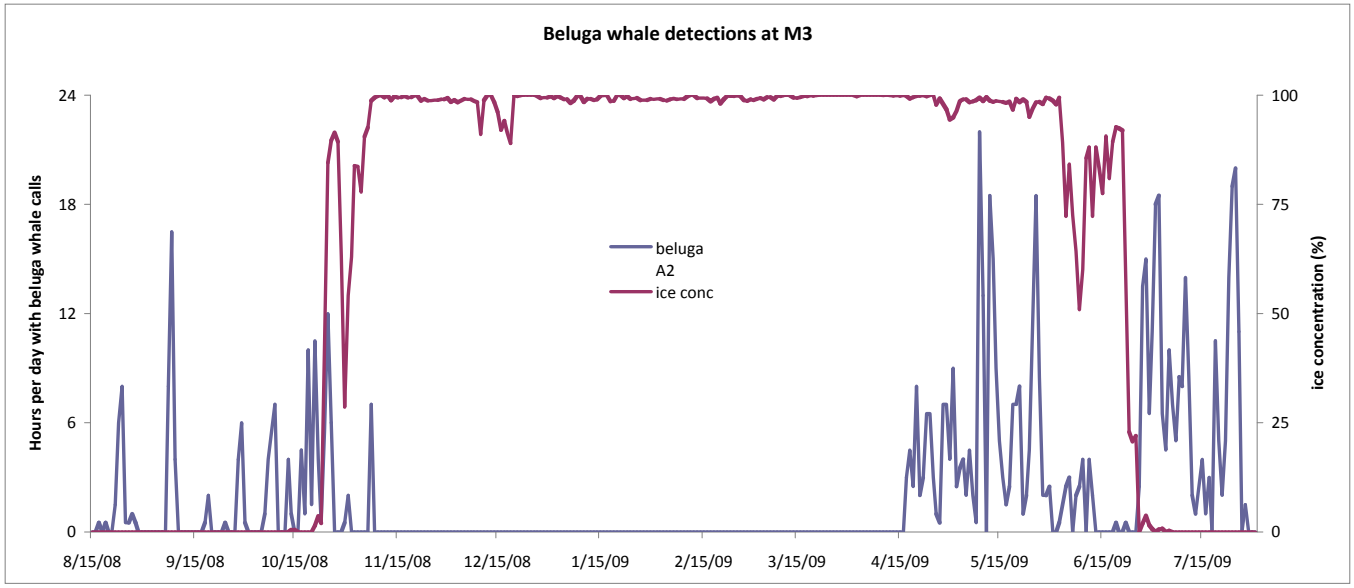


Figure 4. Beluga whale detections and ice concentration.

Publications

A manuscript on the seasonal detection of bowhead and beluga whales is in preparation

Presentations

K.M.Stafford, C. L. Berchok, D.K. Mellinger, and S.E. Moore (2010). "Ambient noise in the Alaskan Beaufort Sea 2007-2009," Alaska Marine Science Symposium, Anchorage, Alaska, 18-22 January 2010.

K.Q. MacIntyre and K.M. Stafford (2011). "Year-Round Passive Acoustic Monitoring Of Bearded Seal Vocalizations At Three Locations In The Beaufort Sea," Alaska Marine Science Symposium, Anchorage, Alaska, 17-21 January 2011.

Forecasting Walleye Pollock Recruitment in a Bayesian Framework

PI
UW - John Horne
NOAA - Jeff Napp

Task II

NOAA Primary Contact
Jeff Napp, NOAA- Fisheries, Alaska Fisheries Science Center

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

Description
This funding is intended to support post-doctoral research in collaboration between the University of Washington and the NOAA Alaska Fisheries Science Center's Fisheries Oceanography Coordinated Investigations (FOCI) program. Using FOCI databases and current knowledge, the research will focus on developing and validating a life-stage recruitment forecast model of walleye pollock (Theragra chalcogramma) in the Gulf of Alaska. The parameters of the model will be estimated using a Bayesian statistical framework. Posterior distributions for model parameters will be used to determine the probability associated with forecasts of future recruitment. A system of state equations that incorporate explicit descriptions of the progression through egg, early larvae, late larvae, juvenile and age-1 stages will be produced using FOCI's conceptual pollock survival or "switch" model. Life-stage equations will be related to biotic and environmental covariates, incorporating errors through a Bayesian formulation. Dynamic features of the life-stage recruitment model will be retained through stage-specific survivorship parameters that link life stages. Observation equations will relate the predicted states to measured quantities in the data set. Posterior predictive distributions will be used to evaluate model fit. Model results, which can be presented as relationships between abundance, spawning success, and climatic conditions, will be explored.

Objectives
The objective of this research is to develop a stage-based mortality model that predicts abundance of age-2 pollock in the Gulf of Alaska, and to quantify uncertainty in forecasts of age-2 pollock abundance.

Accomplishments
This project was not active during the award period due to the deaths of Bern Megrey and Alan Macklin, and the lack of a suitable Postdoctoral candidate. Jeff Napp, Janet Duffy-Anderson and other scientists from the Fisheries Oceanography Cooperative Investigations have agreed to join the research project to provide background on the early life history of walleye pollock. Carol Ladd from the Pacific Marine Ecology Laboratory (PMEL) has joined the project to provide physical oceanography expertise. The continued holdup of the project is due to the lack of a suitable research candidate.

Two international searches failed to secure a Postdoctoral research associate with suitable skills. An alternate strategy, offering a PhD research assistantship to a student in the UW Quantitative Ecology and Resource Management (QERM) program is being pursued. A student has been identified, interviewed, and introduced to the expanded research team. If this student decides to join the project, research activities will begin in summer quarter 2011.

Marine Biological Interactions in the North Pacific – Fish Interactions

PI
UW- Bruce Miller

Other Personnel
UW - Stephani Zador, George Whitehouse
NOAA - Kerim Aydin

Task III

NOAA Primary Contact
NMFS, Alaska Fisheries Science Center,
Resource Ecology and Fisheries Management Division

NOAA Goal

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

Accomplishments
In September-December 2010, Stephani Zador completed the 2010 Ecosystem Considerations Section of the North Pacific Fisheries Management Council (NPFMC) Stock Assessment and Fisheries Evaluation report (SAFE). This year, this work included the publication of results of an October, 2010 workshop of NOAA and JISAO researchers on the use of ecosystem indicators in the Eastern Bering Sea. The resulting work included an ecosystem "Report Card" that described conditions of climate and biology for the recent past and predicted near future as they pertained to the health, productivity and management of groundfish in the Bering Sea. Additionally, three new indices were added to the chapter this year, and 15 contributions were updated. The report card and ecosystem data are available as part of the report at *http://access.afsc.noaa.gov/reem/ecoweb/Index.cfm*.

George Whitehouse attended the North Pacific Research Board's Alaska Marine Science Symposium in Anchorage, Alaska on January 17- 21, 2011. He presented a part of his Masters' work in a poster entitled "Developing a trophic mass balance model of the eastern Chukchi Sea". From October 2010-March 2011, over 4,000 groundfish stomachs were analyzed in the laboratory. Preparations are underway for the summer field season, during which lab scientists on this project are expecting to participate in over 480 person-hours of research collections to be performed on board NOAA vessels in the Bering Sea and Gulf of Alaska.

Ocean and Coastal Observations

PMEL Ocean Climate Stations

PIs
UW - Nicholas Bond
NOAA - Meghan F. Cronin, Christian Meinig, Chris Sabine

Other Personnel
UW - Keith Ronnholm, Jennifer Keene

Task II

NOAA Primary Contact
PMEL

NOAA Goals

1. Protect, Restore & Manage the Use of Coastal & Ocean Resources Through Ecosystem-based Management
2. Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
3. Serve Society's Need for Weather and Water Information
4. Support the Nation's Commerce with Information for Safe, Efficient & Environmentally Sound Transportation

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 Figure 1), and beginning in late 2010, initiated a third station in the Agulhas Return Current region (Figure 2).

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 weathership 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 2010.

The new Agulhas Return Current (ARC) station was deployed in November at 38.5°S, 30°E equatorward of the Southern Indian Ocean's western boundary current extension, and in this way is similar to the KEO site. However because the African landmass terminates equatorward of the

Agulhas Return Current, the land-atmosphere-ocean interactions are expected to be fundamentally different at these two sites.

All three OCS stations have been or are being initiated during large collaborative process studies and have strong international partners. KEO was first deployed in June 2004 as part of the National Science Foundation (NSF) funded Kuroshio Extension System Study (KESS). At the conclusion of KESS, a partnership with the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) was formed and the mooring deployment and recovery operations have since 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. In order to expedite the initial ARC mooring deployment to coincide with the Agulhas Current Transport experiment led by Dr. Beal of RSMAS, the ARC mooring deployment is being funded through a NSF RAPID grant. Ship time for the ARC mooring deployment was provided by the Agulhas and Somali Current Large Marine Ecosystem (ASCLME) Project.

All OCS moorings carry a suite of sensors to monitor air-sea heat, moisture, momentum, and CO_2 fluxes, as well as the upper ocean temperature, salinity, and currents. Most surface and subsurface data are telemetered to shore in near-realtime and made available through the project website: *http://www.pmel.noaa.gov/OCS/* in a variety of formats including the standard OceanSITES data format. The OCS data are served through the PMEL OceanSITES Data Assembly Center (DAC) and also through the OceanSITES Global DAC (GDAC). A subset of the surface meteorological data are also made publicly available in near-realtime through the Global Telecommunications System, used by operational data centers. The data serve a broad community of researchers and operational centers in the US and internationally, with many of these studies being led by JISAO scientists.

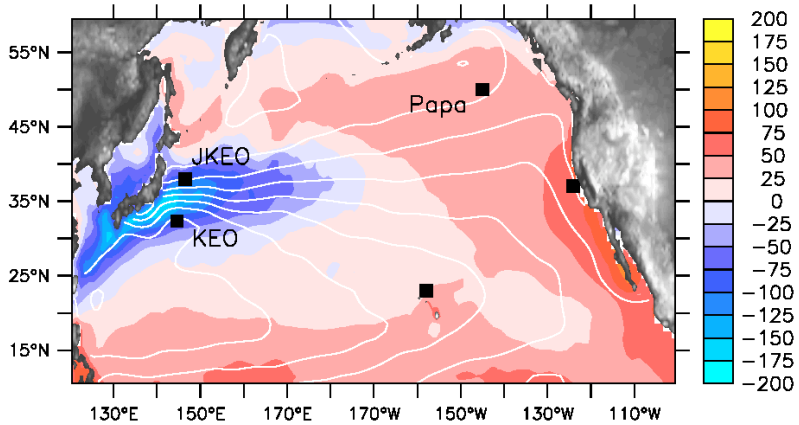


Figure 1. The network of OceanSITES reference stations in the North Pacific are shown relative to the mean net air-sea heat flux in Watts per meter square and mean sea level height contours.

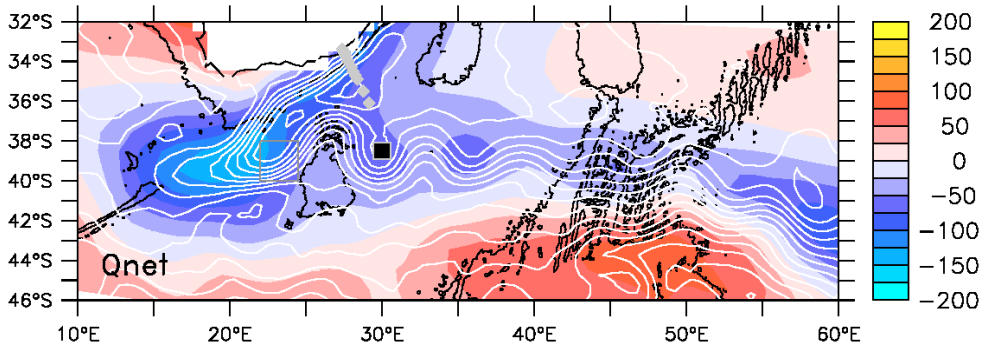


Figure 2. As in Figure 1, but for the greater Agulhas system. Black contours show the 0 and 3000m bathymetry. The black square indicates the ARC site, grey diamonds indicate Beal's ACT sites. The grey box indicates another ONR sponsored process study region.

Objectives

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

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

The OCS program's goals are to:

1. Provide calibrated surface meteorological and subsurface temperature, salinity, and currents at the OCS stations,
2. Access to OCS data and metadata in a format and through linked webpages to encourage broad use of data, and
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 2 cruises during FY11 reporting period in support of the KEO and ARC stations. In September 2010, JISAO employees Keith Ronnholm and Jennifer Keene, along with NOAA mooring specialist Rick Miller, successfully recovered the KEO mooring, damaged during typhoon Choi-Wan the previous September, and deployed a replacement mooring from the Japanese charter ship Kaiyo Maru #5. All subsurface sensors were recovered, thus providing invaluable data since the telemetry system operation was lost during the typhoon. As of March 1, 2011, the KEO-008 mooring continues to telemeter data from its sensors and data systems.

   On November 30, 2010, JISAO employee Jennifer Keene, along with NOAA personnel Rick Miller and Douglas Macintyre deployed the ARC mooring from the South African Fisheries Research Ship *Algoa* at 38.5°S, 30°E. Unfortunately, the ARC mooring broke loose on

January 16, 2011, and is currently drifting eastward in the meanders of Agulhas Return Current. It continues to transmit valuable data from its meteorological, CO2 and subsurface sensors. On March 1, 2011, it was located at 40.5°S, 48.5° E and, on average, it is moving eastward 20 nm/day.

2. A new employee, Jennifer Keene, was added to the JISAO team. She joined the OCS project with a background in buoy operations and a good working knowledge of oceanographic sensors.

3. The JISAO team has published 3 peer-reviewed articles; 2 peer-reviewed articles are in press; 1 article is under review; and several articles are in preparation. The scientists highlight one of these in the following accomplishment highlights.

4. On September 19, 2009, a category 1 typhoon (Choi-Wan) passed within 40 nm of the KEO mooring. Peak winds were measured at about 80 knots. Although the mooring sustained some damage, the data that it collected and telemetered to shore provided an unprecedented view of the ocean's rapid and sustained response to hurricane forcing. A paper detailing these observations has been published by JGR.

5. To aid in the dissemination of the measurements obtained by OCS moorings, a much enhanced data display and delivery web page was activated in FY11. Researchers can select the mooring, parameter and time period, and have the data plotted, or delivered in tabular form. *http://www.pmel.noaa.gov/ocs/disdel/disdel.html*

6. Cronin participated in the UW Program for Climate Change retreat in Friday Harbor in September 2010. Cronin was also invited to be keynote speaker at the UW School of Oceanography graduate student ("Toaster") retreat at Friday Harbor in February 2011.

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

Observing System Research Studies

PIs
UW - Andrew Chiodi
NOAA - D.E. Harrison, Steven Hankin

Other Personnel
UW - Kevin O'Brien, Karl Smith, Heather Koyuk, Mark Carson
NOAA - Ansley Manke

Themes
Climate Research and Impacts
Ocean and Coastal Observations

Task II

NOAA Primary Contact
D.E. Harrison, PMEL

NOAA Goals

1. Protect, Restore & Manage the Use of Coastal & Ocean Resources Through Ecosystem-based Management
2. Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
3. Serve Society's Need for Weather and Water Information

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
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. 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.

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

Specific Objectives Include:

1. Make datasets obtained from the global observing system for climate more accessible to the wider scientific community.
2. Investigate the utility of the global observing system for climate, with particular attention on characterizing anomalies relevant to understanding or forecasting US or global weather anomalies and projections of climate variability and change, and the implications of these results for needed observing system actions.
3. Identify new El Nino-Southern Oscillation (ENSO) indices that are more closely linked to U.S. and global weather anomalies than the indices in common use.
4. Estimating the uncertainty in our ability to measure changes in the efficiency of the planetary carbon sink.
5. Improving our understanding of the effects that La Nina and El Nino events have on year to year changes in atmospheric CO_2 concentration.
6. Closely examining decadal and longer global ocean temperature variability, long term temperature and climate-relevant-index trends and their uncertainty.
7. Analyzing observations and performing model experiments to better understand the mechanisms of equatorial waveguide warming and cooling on seasonal (annual cycle) and interannual (ENSO) time scales.

Accomplishments

1. *Interannual variability in the concentration of carbon dioxide in the atmosphere.*
   The effects of El Nino and La Nina events on the planetary carbon cycle are a primary driver of year to year changes in the concentration of CO_2 in the atmosphere, and offer what is probably the best opportunity for evaluating the performance of Earth System Models, which are key for predicting future concentration levels and their effects on climate. Using high-quality historical records of CO_2 concentration and contemporary definitions of El Nino and La Nina, the group has revisited the connection between these events and the carbon cycle, and found some interesting results, including some substantial and previously unrecognized differences between El Nino and La Nina effects on the carbon cycle in terms of their strength, seasonal duration and consistency from event to event ("robustness"). The researchers expect these results to be directly applicable to Earth System Model development. The illustration below summarizes some of the primary results. This work is in preparation for submission to a peer-reviewed scientific journal (Chiodi and Harrison, 2011).

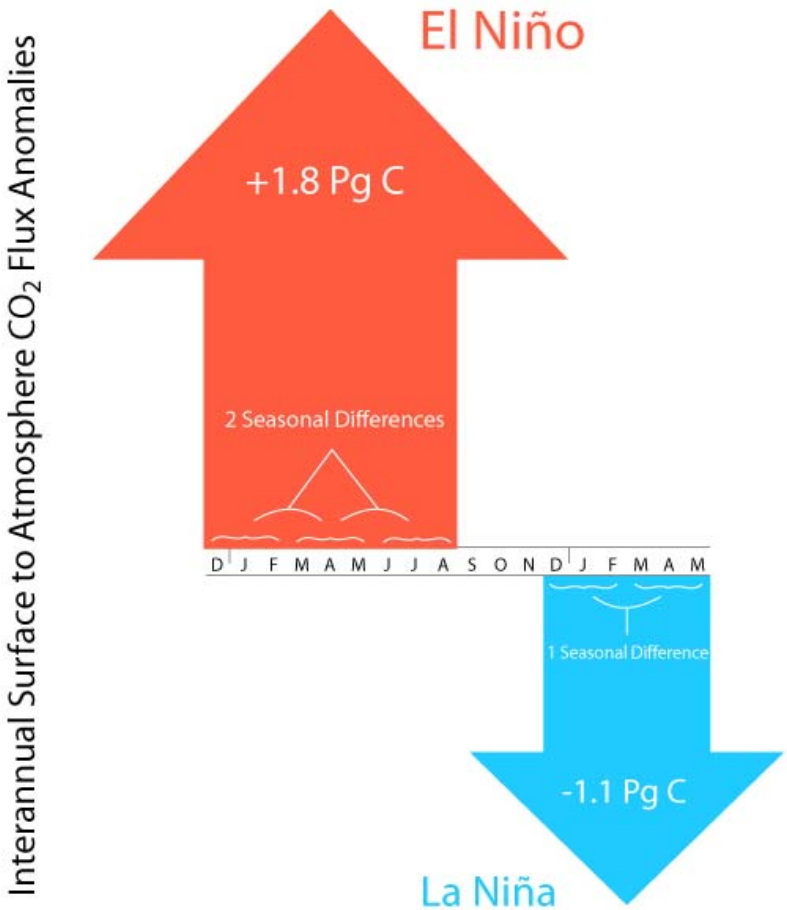


Figure 1. Summary of the average effects of El Nino and La Nina events on anomalies of year to year changes in the concentration of carbon dioxide in the atmosphere. The results show that the absolute growth rate of atmospheric carbon (~3 Pg C/yr average since 1960) is substantially enhanced during El Nino and decreased during La Nina events, on average, but effects are stronger and affect more seasons in the El Nino case.

2. *Prospects for determining changes in the efficiency of the planetary CO_2 sink.*
One of the most important questions facing the carbon and climate science community at present is whether or not the fraction of carbon dioxide emitted to the atmosphere by human activity that is taken up by natural planetary (ocean + land) processes ("airborne fraction") has been changing. The scientists have continued to explore this question and shown that present uncertainties in the amount of carbon that has been released by deforestation and other land use activities are too large and the natural interannual variability too strong to allow us to say whether sink efficiency is undergoing long term change or not. This is contrary to some high-profile papers that have recently been published. The groups work suggests that improving their knowledge about the lesser forms of carbon emissions (e.g. deforestation) within a few decades is crucial to gaining ability to measure this important aspect of the carbon cycle in the future. This work has been presented at national

conferences (e.g. 2010 Fall AGU Meeting, 12-16 December, San Francisco, CA). A paper stemming from this work is under consideration at Nature Climate Change.

3. *Regional-scale atmospheric circulation conditions during extreme summertime precipitation events in the forests of Eastern Washington and Oregon.*
   Although wintertime extreme precipitation events, especially those that have brought flood conditions to much of the highly populated areas of Western Washington and Oregon, have been more widely studied, the less well studied summertime events that occur along the flanks of the forested mountainous regions of Eastern Oregon and Washington are intrinsically interesting and important to forest (e.g. wild fire control, monitoring) and stream ecosystem management. Using a newly available U.S. gridded precipitation data set the group has documented the historical frequency of occurrence, seasonality and decadal scale trends associated with these events in these regions in the period since 1950. Analysis has been conducted to better understand the large scale atmospheric circulation conditions that are conducive to these precipitation events, with emphasis on finding results that may aid short (less than 2 weeks) and longer time scale (climate change projection) prediction efforts. Preliminary results are promising and suggest that such events can be broken into two basic types of event based on local 500mb atmospheric flow conditions (with possible sub-types) that have different character in terms of seasonality, interannual variability, net rainfall amount, and frequency of occurrence in a given location (with differences especially evident between mountain flanks and flatter, low-lying regions.) This work has been presented at national conferences (2010 Fall AGU Meeting) and is expected to be applicable to forest management efforts. A paper describing the initial results is in preparation (Bond et al., 2011).

4. *Estimating multi-decadal trends in ENSO. A case study using Darwin SLP.*
   The task of identifying which aspects of climate are undergoing very long term trends has received increased attention in recent decades. The researchers have used the long (135yr) high quality record of sea level pressure at Darwin, Australia, which is a very good proxy for the state of the El Nino-Southern Oscillation phenomenon, to illustrate some of the issues faced in such trend studies, and identify some of the qualities required from a historical record to yield reliable trend estimates.
   The team examined trends in this long record in several ways, considering long (> 90 years) segments and shorter multi-decadal segments typical of the recent era in which the use of satellite information has contributed importantly to their observational knowledge of the planet. They find that the distribution of multi-decadal trends includes nearly equal numbers of positive and negative trends, and many of these pass both students' and bootstrap tests of significance, even though the full-record trend is not statistically significant. This is not a useful length of record for estimating long term trends for this quantity. For ENSO, one would be very unlikely to be able to estimate the long term trend with only a single multi-decadal record. It's increasingly clear that very long-term, high quality records are necessary to determine which aspects of climate are undergoing very long term change. Results from this work have been presented at international meetings (11th International Meeting on Statistical Climatology, in Edinburgh, Scotland, 15 July 2010) and a paper is in preparation for submission (Chiodi and Harrison, 2011b). See figure below for some results.

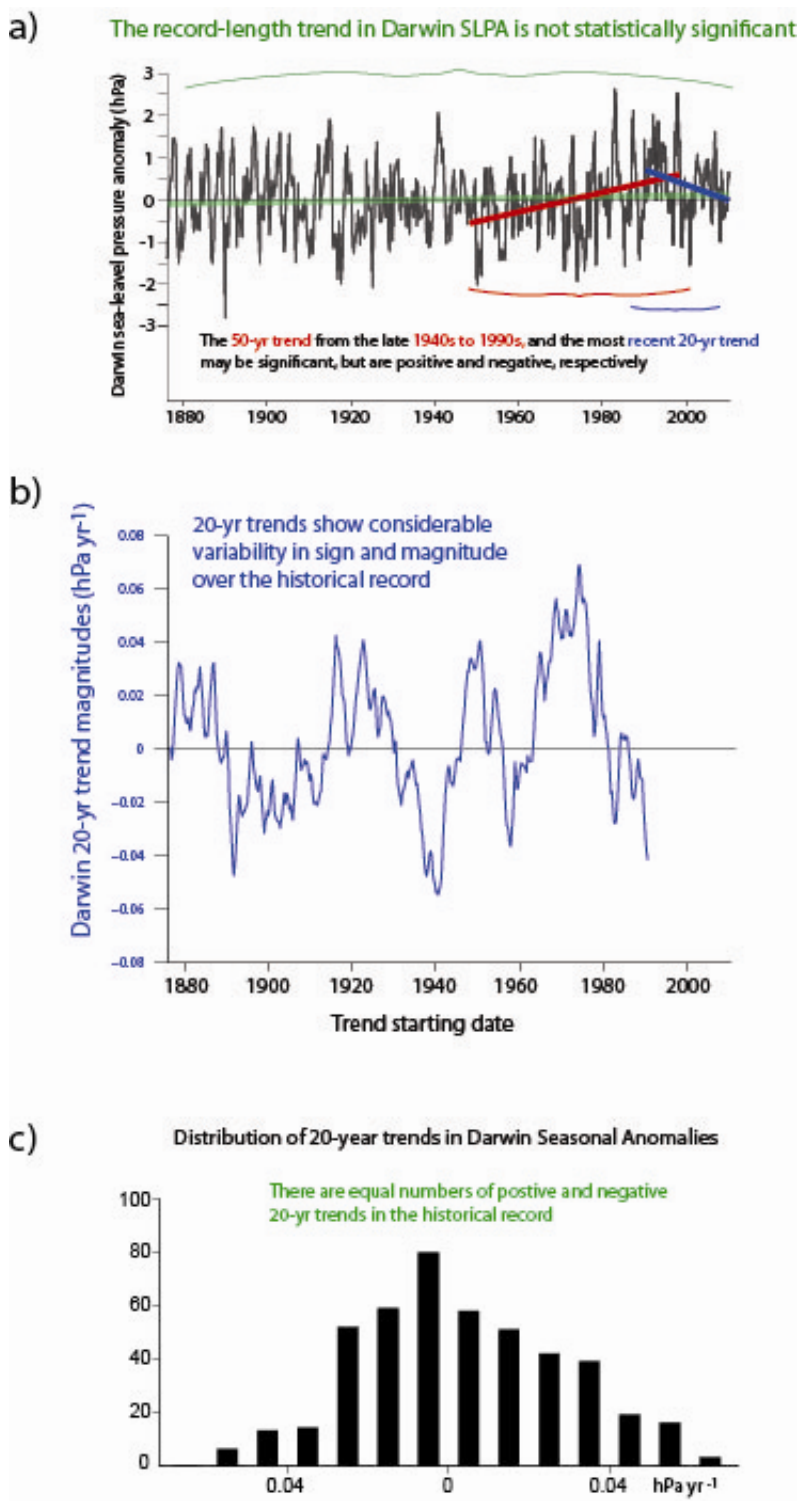


Figure 2. a) Darwin SLPA showing the best fit 135yr trend (green line), the 50 year trend with the overall highest statistical significance (red line) and the most recent 20 year trend (blue line). b) 20-yr Darwin SLPA trend magnitudes. c) Distribution of 20-yr Darwin trends; the number of positive trends equals the number of negative ones.

5. *Characterizing warm-ENSO events and the climate anomalies they drive using outgoing longwave radiation.*
   The team showed that outgoing longwave radiation (OLR) information can be used to form an operational warm-ENSO (El Nino) index that has stronger linkages to ENSO-type U.S. wintertime weather anomalies than are available using the common surface-marine-variable-based ENSO indices such as the Nino 3.4 or Southern Oscillation index. This OLR index has a distinctly event-like character, not seen in the commonly used ENSO indices, that makes determination of "event-status" based on OLR less ambiguous than in the surface-marine-based-index cases, which, according to current ENSO definitions, identify as "event-years" several recent warm-SST-anomaly years that have weather anomalies different from the conventional warm-ENSO-type (see publication Chiodi and Harrison, 2010a).

   Examination of atmospheric 500mb geopotential height anomalies (z500) from numerical weather prediction models, along with seasonal precipitation and temperature anomalies shows that significant and robust atmospheric circulation, temperature and precipitation anomalies are driven over the continental U.S. in years distinguished as "El Nino events" by OLR. This confirms the commonly held belief that ENSO drives important weather anomalies over the U.S. Groups of years considered "El Nino" based on some other ENSO indices, however, that are not particularly distinctive based on OLR behavior, do not show such anomalies, suggesting that much of the recent confusion about what years really are "El Nino years" in terms of U.S. weather impacts is due to using an "El Nino" definition that is too broad; that is defining as "El Nino" years in which the forcing from the tropical Pacific is too weak to dominate over other types of weather variability. Average atmospheric circulation anomalies over the U.S. for these two types of "El Nino years" are compared in the figure included below. This work clarifies where in the U.S. and under what tropical Pacific anomaly conditions the scientists can expect to experience the type of seasonal weather patterns conventionally thought to be driven over the U.S. during warm-ENSO events. This information is directly useful to seasonal weather prediction efforts. This work is in preparation for submission to the refereed literature (see Chiodi and Harrison 2011c.)

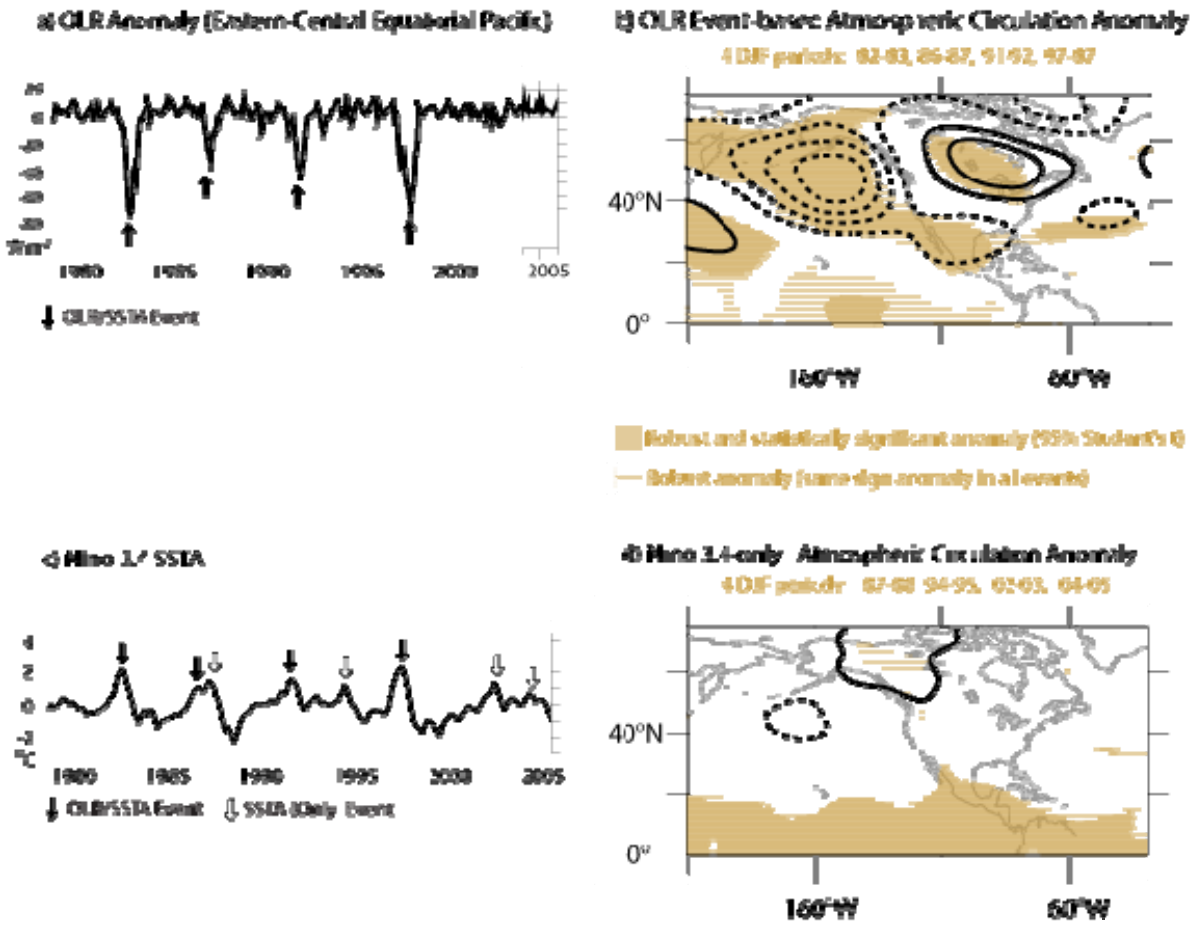


Figure 3. a) OLR-based warm-ENSO index showing four large events (marked by solid arrows) in the satellite era (post-1979). b) Composite-average 500mb geopotential height anomaly (z500) from the four December through February periods distinguished by the OLR-ENSO-index in panel (a). Contour interval is 20m. z500 and weather anomaly patterns are closely linked over the U.S. c) The commonly-used Nino 3.4 index showing warm anomalies both at the times of the OLR-ENSO-events and during years that are not distinct based on the OLR perspective. d) Composite average z500 anomalies during the four December through January periods that are distinguished as "El Nino" based on Nino 3.4, but are not distinct from background variability based on OLR. Note that statistically significant anomalies are not seen over the U.S. in this case.

6. *Reproducing the structure of the seasonal cycle of sea surface temperature (SST) in ocean mixed layer models forced with contemporary surface flux estimates.*
   Directly evaluating the quality of current global air-sea heat and momentum flux estimates is challenging because of the sparseness of high quality direct air-sea flux measurements. The researchers explore the possibility of evaluating the current flux data sets in a different manner, by comparing their ability to reproduce (the well observed) basin-wide SST behavior when integrated in ocean models**.** The team focus on the seasonal cycle since it is

globally the dominant mode of sea surface temperature variability, and because IPCC models suggest that climate change will be evident first at higher latitudes, they focus particularly on model/flux behavior at high latitudes, where there is a fall-off with latitude in the range of the seasonal cycle of SST that is not seen in the seasonal range of net surface heat flux and has not been adequately explained. The team show that newly available ocean mixed layer depth estimates, made possible by the Argo observing system, can be used to closely predict the observed zonal mean SST seasonal range structure in the ice-free latitudes of the Southern Ocean based on some currently available surface heat flux estimates, but not others. These results point out the characteristics of the fluxes that are compatible with the ocean models and observed SST behavior. Analysis shows that both the deepening with latitude, and temporal behavior of the ocean mixed layer, as resolved by recent ARGO measurements in the higher southern latitudes, are key to understanding the observed structure of the annual cycle of SST, but when configured to predict the ocean mixed layer depths by directly integrating the surface fluxes, the models used in this study were unable to adequately reproduce the observed SST behavior, showing that they have more to learn about the ways ocean dynamics and surface fluxes control the annual range of surface temperature at high latitudes. Accurate observations of SST and ocean mixed layer depth, and improved estimates of air-sea heat flux components are important contributions from the ocean observing system. This work has been presented at national meetings (2010 Ocean Sciences Meeting, 25 Feb 2010, Portland, OR) and appeared in refereed literature (see Chiodi and Harrison, 2010b).

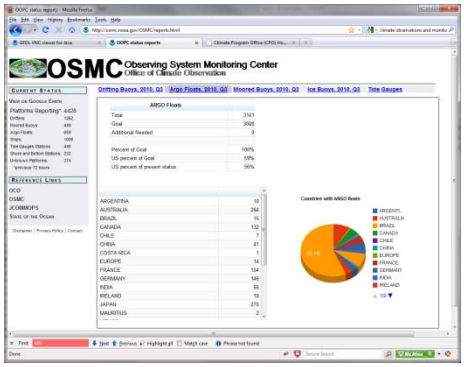
7. *A. Regional interdecadal trend variability in ocean temperature data.*
   Accurately quantifying interdecadal ocean variability is an important first step toward reliably determining trends over the historical record. The group has explored the effects that some bias corrections have on estimates of interdecadal temperature variability in different oceanic regions. Recent research indicates that, based on comparison with instruments that measure depth (pressure) and temperature concurrently, their reliance in previous decades on expendable bathythermographs (XBTs) for temperature information produces a decadally-varying temperature bias. Results have shown that new XBT bias corrections significantly reduce the level of interdecadal variability in globally-averaged ocean temperature. The team has shown that bias-corrected regional temperature data still contains strong interdecadal variability, and that the bias corrections are smaller than the interdecadal signal on regional scales (see Carson and Harrison, 2010, for more information). This work shows the extreme importance of long-time accurate observations of the ocean in order to get a reliable picture of long-term trends. Trends over even a 20year period can be strongly aliased by interdecadal variability. This work has appeared in refereed literature (see Carson and Harrison, 2010)

8. The NOAA PI has also played a key supportive role in the design of the next-decade Ocean Observing System for Climate through activities that include organizing the OceanObs2009 Conference and co-authoring several associated “White” and plenary papers (see Appendix 10 Publications).

9. *Observing System Monitoring Center (OSMC) at NOAA Office of Climate Observations.* The OSMC *(www.osmc.noaa.gov)* has continued to expand its role as a monitoring tool over the past year. As Candyce Clark, from the OCO, said "The OSMC is the national and international face for our work in building and maintaining the global ocean observing system for climate." As the international presence of the OSMC grows; the scientists are working to foster a closer relationship with their international partner JCOMMOPS. This partnership will allow for more precise status monitoring of the global ocean observing network. Through the Live Access Server software, the OSMC has the ability to fully monitor and track what observations are being recorded in the global ocean observing network. In addition to the many summary maps it can show including Argo profiles, ship and drifter tracks, as well as ship and drifter trajectories and time series data, the team has added the ability to accurately track XBT drops from VOS ships. The team continues to explore the use of popular Google tools, including Google Earth and Google Earth animations as well as Google Maps, Google gadgets and the newly released Google Charts.

It is widely understood that one of the great challenges in earth science data integration that must be addressed during the coming decade is the integration of observations and products. The OSMC is fast becoming a platform not only for climate observations monitoring, but also for climate product integration. In addition to the group's current integration with data products such as the SST bias errors computed by Dick Reynolds at NCDC and the Equivalent Buoy Density (EBD) products, they have also begin integrating additional sources of data as an attempt to compensate for shortcomings of the GTS data stream. They are now utilizing tide gauge monitoring data from the Intergovernmental Oceanographic Commission's (IOC) sea level monitoring facility at the Flanders Marine Institute in Belgium, as well as metadata from the Southern Ocean Carbon Atlas (SOCAT) project.

A major addition to the OSMC that is currently under development is the tracking and reporting of observing system metrics for reports to, among others, the Ocean Observations Panel for Climate (OOPC) by NOAA's Climate Observations and Monitoring Program. These metrics are derived from the observations stored in the OSMC database and a prototype of the display of these metrics has been deployed on the OSMC website (see figure on right).



Prototype of OSMC metric reporting

10. *Global Earth Observation Integrated Data Environment (GEO-IDE) Unified Access Framework (UAF).*
The Unified Access Framework project, under the guidance of GEO-IDE, is a project being led by the Observing System Research Studies group aimed at tackling the insufficient integration of NOAA data resources. The reality of poorly integrated data resources is a reflection of decision making strategies and traditions of the past that have tended to fragment data management, rather than to unify it. Predictably these traditions have hindered the development of integrated data management. The UAF project seeks to overcome these difficulties by developing a gridded dataset integration framework that leverages several de facto standards including netCDF, the Climate and Forecast (CF) metadata conventions, the OPeNDAP protocol for web transport of data subsets, THREDDS XML catalogs which provide a distributed topology connecting data suppliers and an OGC compatibility layer that provides access to the grids through WMS and WCS.

The initial focus has been to develop a NOAA-wide THREDDS catalog of CF-compliant datasets (e.g. model outputs, satellite products, HF radar observations, etc.) and to enable access to that data through the aforementioned web services (DAP, WMS, WCS). A parallel activity to harvest, repair, and extend metadata for the datasets will improve users' ability to discover and make use of these gridded datasets. The official UAF THREDDS catalog is on-line and publicly available (*http://ferret.pmel.noaa.gov/geoide/*) and is currently being used to drive many known user applications, such as the Live Access Server, Matlab, IDV, ERDDAP, Ferret, Google Earth, etc.

In the coming year, the UAF group will be focusing on expanding the data holdings for gridded data, as well as extending support for observational data (such as from the OceanSITES program) in the framework. In addition, the team is exploring several methods by which to improve the end user's ability to easily discover and access the massive data holdings.

11. *Live Access Server (LAS) interfaces for carbon dioxide datasets.*
The Live Access Server (LAS) group continues to play a central role in the data management of the Surface Ocean Carbon Atlas (SOCAT) project. A new interface for logging first order quality control on individual records, in addition to the cruise level second order flagging, was implemented by the LAS group in response to requests made by the community. Scientists from a dozen countries have now logged first and second order quality control much of the dataset, and problems with hundreds of cruise data files have been identified and repaired.

The project aims have a complete set of quality rating flags for over 2100 cruises by March 2011, when the dataset and LAS system will be released to the public

12. *The Curator Data Portal at the Geophysical Fluid Dynamics Laboratory (GFDL).*
The Curator Data Portal at GFDL *(http://data1.gfdl.noaa.gov:8380/lasV7/)* is a Live Access Server (LAS) that was installed to assist GFDL scientists and the general public in gaining access to the results of model runs done for the IPCC AR4 effort. Working with GFDL, the team has developed tools to read configuration information out of their massive database of

model runs, configure aggregations of the resulting data using the THREDDS data server to ease data access, and integrate those datasets into LAS for easy browsing and analyzing Work continues on integrating complex, yet common, GFDL data analysis tools, which are used almost daily by GFDL scientists analyzing their complex model outputs, into the Live Access Server. Once integrated, these tools will be readily available to any LAS user or, alternatively, as an LAS "web service". As in the past, GFDL scientists and developers work closely with the LAS team to enhance LAS user experience, increase performance, and identify analysis tools that should be integrated with LAS. In addition, the researchers recently performed upgrades to the GFDL public THREDDS servers to make them both more secure and to make available newly added THREDDS services that allow on-the-fly creation of metadata in order to enhance user discovery.

13. *Python version of the popular data visualization tool Ferret.*
    The popular data analysis and visualization tool Ferret, developed by group members at PMEL, is undergoing a dramatic change and evolution, bringing it into the future of data visualization applications. By creating a python version of ferret, known as PyFerret, the widely used ferret application will begin to utilize a whole host of well supported libraries to make using ferret easier and more productive. Included in the python version of ferret will be much improved graphic creation, easily created "external functions", which will seamlessly integrate ferret computations, as well as the massive improvement of performance which comes with the ability to run as a parallel processing application.

Awards Given To JISAO Employees

Mark Carson received a Ph.D. in Physical Oceanography from the University of Washington in August 2010 for Observing System Research Studies related work. Mark is currently in a Post-Doctoral position in Germany.

Protection and Restorations of Marine Resources

Coastal Observation and Seabird Survey Team (COASST)

PI
UW - Julia K. Parrish

Other Personnel
UW - Jane Dolliver, Anne Woods, Charles Wright

Themes
Protection and Restorations of Marine Resources
Marine Ecosystems
Ocean and Coastal Observations

Task III

NOAA Primary Contact
Kim Rivera, NMFS Alaska Region

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

Description
COASST is citizen-science program in which trained volunteers collect monthly, or more frequent, data on beached marine birds at standard sites throughout the North Pacific (Humboldt, CA to Shishmaref, AK). With 580 volunteers at over 300 sites distributed comprehensively throughout its range, and over 26,000 carcasses of over 130 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
Primary Objective: Maintain and expand beached bird data collection on beaches in the North Pacific.
In addition, COASST will provide annually: analyzed data on deposition, persistence, and scavenging by location and month; reports on threatened and endangered species; estimates of mortality from bycatch and other anthropogenic sources; special reports on mass mortalities; and copies of all scientific publications.

Accomplishments
1. Maintained monthly volunteer coverage on over 300 COASST sites throughout the North Pacific.
2. Conducted five training and refresher sessions to train new volunteers and refresh skills of current volunteers.

3. Provided data to all state and federal agencies and other interested groups or individuals via the COASST website or, in the case of specific requests, by contacting us directly.
4. Analyzed existing data for fishery mortality trends, and trends in beaching rates of species known to be bycatch in North Pacific fisheries.

Ami Wright (right) and seasonal assistant prepare for a COASST survey near Seward, Alaska.

COASST program coordinator Jane Dolliver and UW student Stefanie Porter examine a Brown Pelican near Long Beach, Washington. Photo by E. Wagner

UW students on a COASST field trip tag a Sooty Shearwater near Ocean Shores, Washington. Photo by P. Chilton

UW students on a COASST field trip process a Black- legged Kittiwake near Ocean Shores, Washington. Photo by P. Chilton.

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

PI
UW - Russell P. Herwig

Other Personnel
NOAA - Alan Mearns

Task II

NOAA Primary Contact
Dr. Alan Mearns, Emergency Response Division (ERD), National Ocean Service, Office of Response and Restoration (OR&R)

NOAA Goal

1. Protect, Restore & Manage the Use of Coastal & Ocean Resources Through Ecosystem-based Management

Description
This project began December 1, 2010, nearly 8 months following the beginning of the release of Louisiana crude oil into the Gulf of Mexico from the *Deepwater Horizon* (also referred to as the BP spill, Gulf of Mexico spill, or the Macondo blowout.) The blowout began on April 20, 2010. ERD provides scientific support for oil and chemical spill response and damage assessment. Their headquarters is on 7600 Sand Point Way NE in Seattle, WA. NOAA's ERD team quickly responded in full force, working with other federal agencies (U.S. Coast Guard, U.S. U.S. EPA, U.S. DOI [Department of Interior], U.S. NPS [National Park Service], and Bureau of Ocean Energy Management, Regulation and Enforcement [BOEMRE]), Gulf state governments, and contractors. Dispersants were used and injected into the oil streaming from the broken wellhead. Within several months oil floating on the Gulf surface was not visible, but a fraction remained at 1200 to 1300 m depth as well as along shorelines in four states. In addition to weathering (evaporation, dissolution, microbial transformations), dispersants, surface water skimming, burning and shoreline clean up were used or are removing significant amounts of oil from the surface and shoreline. A portion of remaining oil may be binding to sediments. Response and assessment scientists are working to locate and measure the remaining oil and estimate its fate.

Microbial transformation and metabolism is a major fate for the degradation and removal of the petroleum components. Under aerobic (with oxygen) conditions and appropriate levels of nutrients, much of the carbon and hydrogen present in petroleum hydrocarbons will be metabolized to harmless water and carbon dioxide. Microbial transformations not only occur in surface marine waters, but throughout the water column, Gulf sediments, intertidal water and sediment, and salt marshes. The rates of oil removal, types of microorganisms responsible for degrading the different oil fractions, and ultimate fates among the different environments are different.

Objectives

The objectives for the University of Washington during JISAO Year 1, starting December 1, 2010 (date of the project start) and into JISAO Year 2 are:

1. Reviewing biophysical degradation and fate of petroleum hydrocarbons associated with the *Deepwater Horizon* oil spill reports and manuscripts being prepared to describe the fate of oil.
2. Reviewing the literature to find information that describes the rates of biodegradation and biophysical processing of the constituents of petroleum hydrocarbons in the marine environment in various habitats including cold deep water, upper ocean mixed layer, and nearshore/onshore habitats. The degradation rates will be provided to NOAA modelers so biodegradation information can be incorporated into NOAA models.
3. Providing written text and comment about biodegradation and biophysical processing of oil that can be used in short documents that are distributed to the public.
4. Reviewing literature to find information that describes the rates of biodegradation of dispersants that are used to disperse petroleum hydrocarbons in the marine environment.
5. Provide expertise in environmental microbiology that will be useful for other scientists and technical personnel employed by NOAA's OR&R.

Accomplishments

Major accomplishments for the first three months of the project include:

Providing assistance in writing and reviewing Oil Fate and Current Conditions for the Operational Science Advisory team II (OSAT II) Report. Feedback and interpretations were provided for microbiology and biodegradation literature and topics written for the OSAT II report, particularly in support of the NPS representative.

Assembling EndNote (Thomson Reuters) databases for the following subjects' oil spill related topics: Dispersants, Dispersant Biodegradation, Hydrocarbon Biodegradation, Oil Spills, and Oil Bioturbation. The literature search was conducted by selecting key words and performing a search on the University Of Washington Libraries Web Of Science (ISI Web of Knowledge). Successful searches yielded citations to publication that included author names, article title, journal title, year of publication, abstract, key words and other information. Web of Science searches were saved by downloading their contents into an EndNote Library. Some of the saved Libraries are very large such as with 900 references in Oil Spills. The scientists are in the process now of reviewing literature that was saved. Complete copies of the more important or seminal papers will be made and saved as pdf files.

Linking Sublethal Copper Neurotoxicity to Population Abundance in Coho Salmon

PI
UW- David Beauchamp

Other Personnel
UW - Jenifer McIntyre
NOAA - David Baldwin, Nathaniel Scholz

Themes
Environmental Chemistry
Protection and Restorations of Marine Resources

Task II

NOAA Primary Contact
David Baldwin, Northwest Fishery Science Center,

NOAA Goal
5. Mission support

Description
The goal of this project was to characterize and integrate sublethal impacts of copper exposure on salmonids at the levels of olfactory neurophysiology, individual behavior, and population dynamics. This work focused on coho salmon, as this species favors small streams that are often the receiving waters for non-point source runoff. The bioavailability of copper depends on water chemistry conditions. In the first stage of this work, experiments were necessary to test how variable water chemistry affects copper availability to the olfactory system of coho salmon in order to determine if local salmon populations will be at risk of olfactory neurotoxicity from exposure to elevated copper concentrations. Subsequent work focused on experiments to assess olfactory-mediated effects of non-point source copper pollution on important life history stages of coho salmon. Survival of juvenile coho was tested in natural arenas with real predators, expanding on previous research that showed reduced anti-predator response in juvenile coho after realistic copper exposures. This research primarily involved behavioral observations of predator-prey interactions. The final work integrated sublethal impacts of copper on important olfactory-based behaviors into life cycle models for coho salmon in order to begin assessing potential population-level impacts.

Objectives
Since July 2010, the project objectives were to submit the predation manuscript for internal review at NOAA, make any necessary revisions, and submit to a peer-reviewed journal. Additional objectives were to construct a population model integrating sublethal copper effects on antipredation behavior, and for Jenifer to complete, defend, and submit her dissertation to the University of Washington.

Accomplishments
Jenifer constructed a population model in MATLAB integrating the survival consequences of lost antipredation behavior as a function of sublethal copper exposure in urban stormwater pulses. She successfully completed, defended, and submitted her dissertation. The predation manuscript remains ready to submit for internal review, however the occurrence of the Deepwater Horizon oil spill has significantly delayed key NOAA personnel from being able to attend to this and many other manuscript revisions. The manuscript waits in the revision queue which is again moving slowly forward.

Highlights are drawn from the model built to project population-level consequences of sublethal copper exposure in juvenile coho salmon. At the concentrations and exposure durations modeled, the primary expected effect on juvenile coho salmon was reduced sensory detection of predation risk based on empirical study of this response supported by earlier JISAO support.

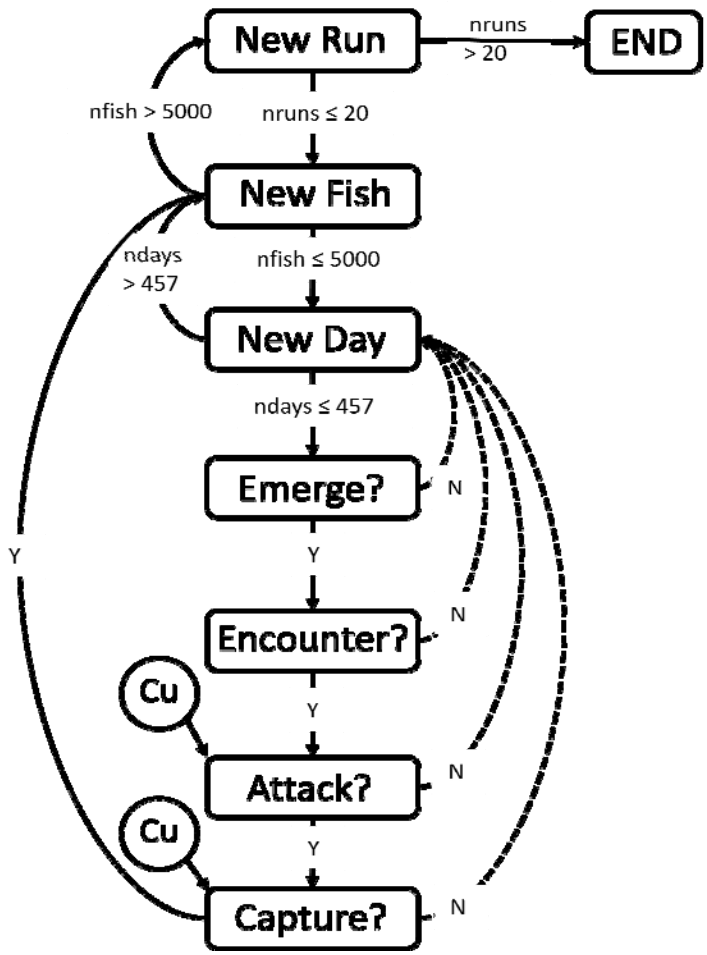


Figure 1. Schematic of the predation IBM (individual-based model) used to predict juvenile coho salmon survival for the population matrix model. Modeled impacts of dissolved copper were on the probability of attack given encounter with predators and the probability of capture given attack by predators.

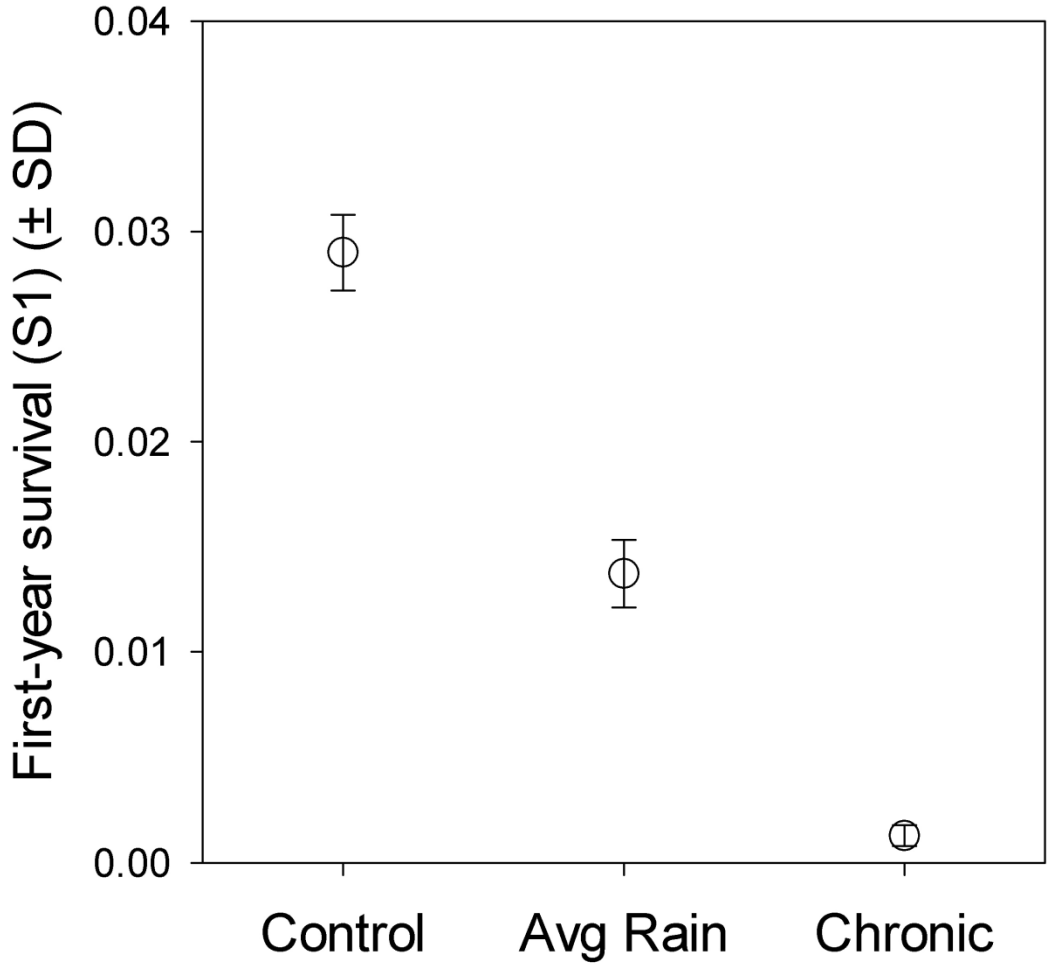


Figure 2. Model projection of average first year survival from emergence for juvenile coho salmon in a typical Puget Sound lowland stream. Model scenarios contrast a 'Chronic', 'Avg. Rain', and 'Control' scenarios. In the 'Chronic' scenario, juvenile coho were exposed daily to the Washington State chronic copper criterion for a typical Puget Sound basin stream (4.3 ppb). For the 'Avg. Rain' scenario, exposure was 4.3 ppb dissolved copper only during rain events with > 0.5" precipitation/day. In the control condition it was assumed that no copper entered the stream. Modeled effects arose from the reduced ability of juvenile coho to detect predators and avoid predation during copper exposure.

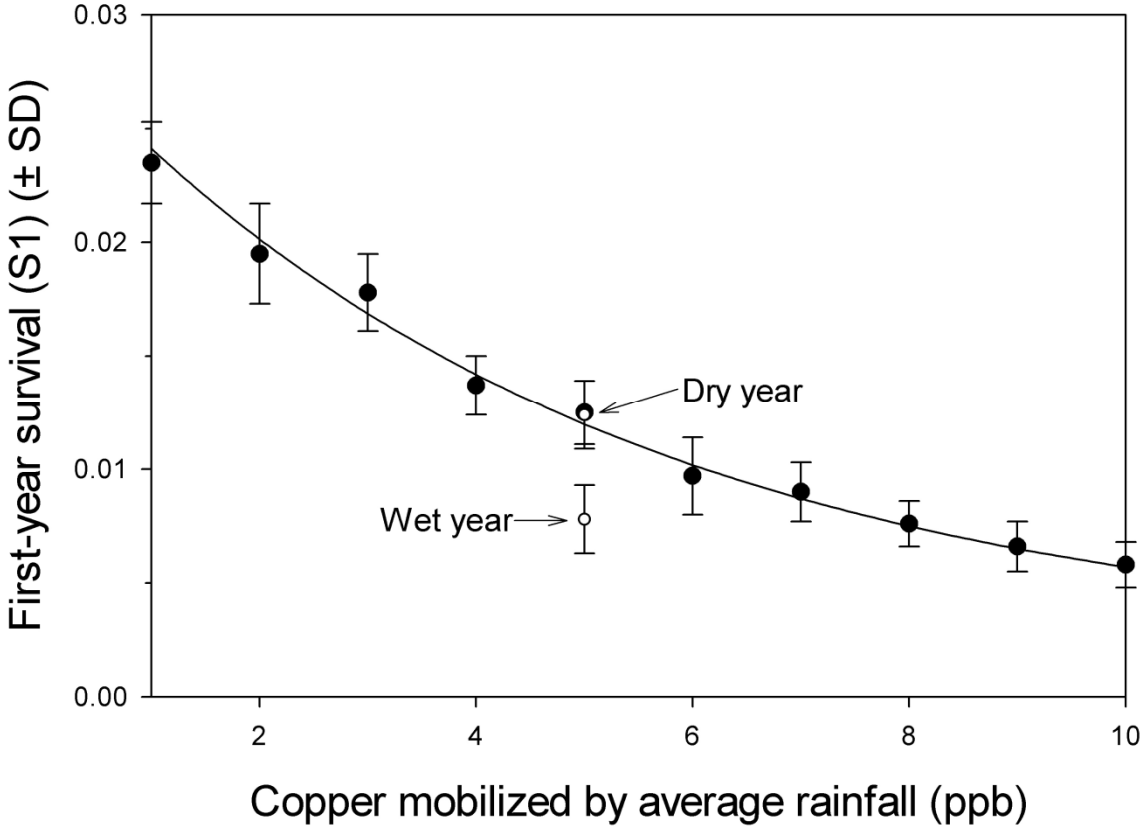


Figure 3. Model projection of average first year survival from emergence for juvenile coho salmon in a typical Puget Sound lowland stream exposed to various concentrations of dissolved, bioavailable copper on days with > 0.5 inches precipitation/day. In the control condition it was assumed that no copper entered the stream. Modeled effects arose from the reduced ability of juvenile coho to detect predators and avoid predation during copper exposure. At 5 ppb copper, further model scenarios simulated increased or decreased overall exposure associated with the driest and wettest years in 100 years of simulated annual precipitation patterns.

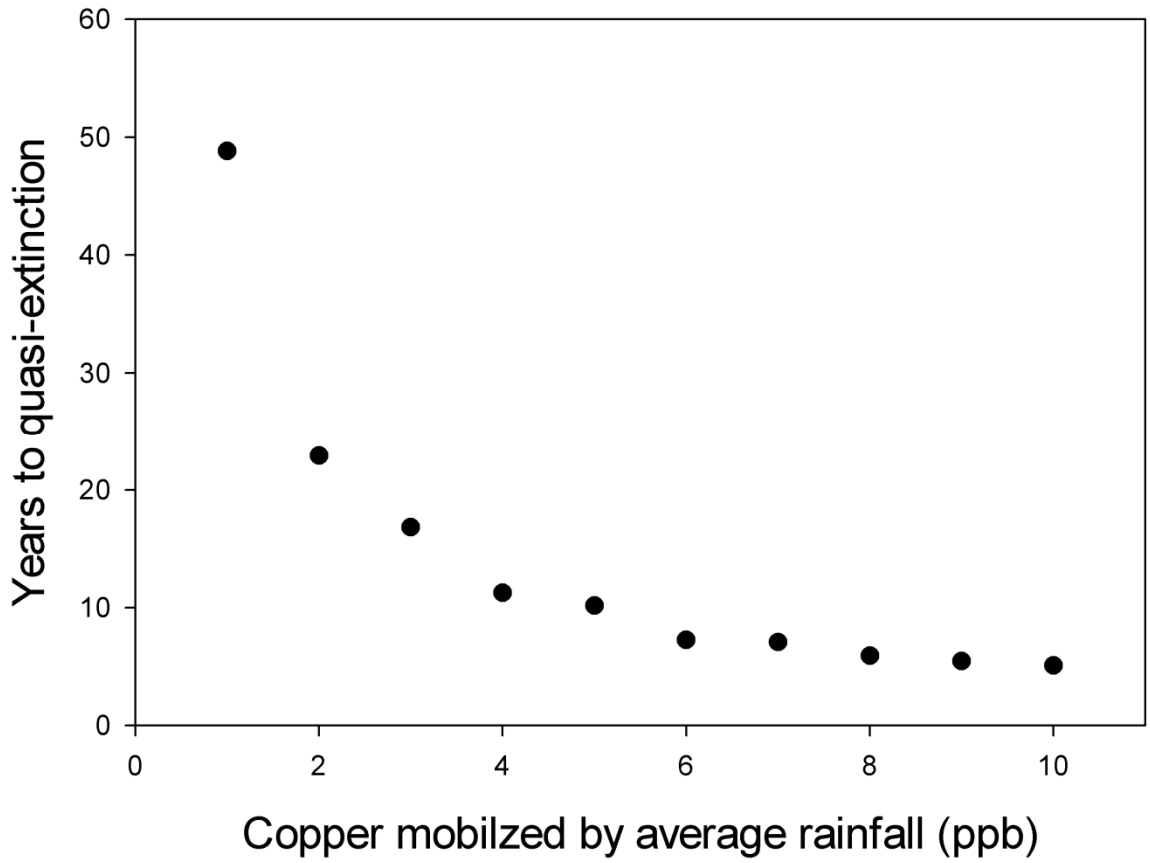


Figure 4. Combining stage-specific survival rates in a matrix population model generated a population growth rate, which was projected forward in time for various exposure scenarios. The above figure shows time to quasi-extinction (5% spawner abundance remaining) for a theoretical small Puget Sound lowlands population of coho salmon exposed to bioavailable dissolved copper mobilized by average rainfall (>0.5 inches precipitation/day). The models suggest that low levels of bioavailable copper may contribute to reduced resiliency of coho salmon in urbanizing basins of Puget Sound.

Sea Floor Processes

NOAA-VENTS Hydrothermal Research Group

PIs
UW - David A. Butterfield, Joseph A. Resing

Other Personnel
UW - Kevin K. Roe, Nathaniel J. Buck, Hoang-My Christensen, Andrew Opatkiewicz, Marvin D. Lilley, John Baross, Eric Olson, James Murray, Lia Slemons, Pamela Barrett
NOAA - Stephen Hammond, Ed Baker, Robert Embley, William Lavelle, John Lupton, Sharon Walker

Task II

NOAA Primary Contact
PMEL

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

Description
Exploration of the oceans is a NOAA priority, and has led the NOAA-PMEL Hydrothermal Research Group to discover unique volcanic features and ecosystems on the ocean floor that have importance for global ocean processes. Of recent interest is the first ever discovery of submarine volcanoes with persistent ongoing eruptions, affording a spectacular first look at deep ocean volcanic processes. Erupting volcanoes and the hydrothermally active volcanoes around them emit large quantities of acid and carbon dioxide, creating conditions of local acidification. The study of biological communities in these acidified environments has provided an understanding of the physiological effects of high CO_2 and low pH on marine life. During two research cruises in the past year the researchers re-visited these volcanoes to gain a better perspective on their oceanic impacts and continued to work on their existing data and samples to better inform the public of our findings. Additionally, detailed studies of volcanic and hydrothermal processes at Axial Seamount and Endeavour long-term seafloor observatory sites in the NE Pacific continue to provide a deeper understanding of the complex links between volcanic activity, hydrothermal chemistry, and microbial ecology.

The NOAA-VENTS Program serves the primary NOAA strategic goal to "protect, restore and manage the use of coastal and ocean resources through an ecosystem approach to management." To meet the needs of the strategic plan, the Vents program addresses ecosystem goals for the Office of Oceanic and Atmospheric Research as a part of the NOAA cross-cutting Ecosystem Research Program (ERP). The ERP is responsible for the systematic exploration of the ocean environment where new resources are discovered or developed and new regions are explored. Continued exploration and discovery in new areas will expand the boundaries of the scientific community's understanding of the Earth system. JISAO scientists Joseph Resing and David Butterfield are actively engaged in research that discovers and characterizes novel hydrothermal ecosystems and their impact on the ocean environment. Submarine volcanoes and their

hydrothermal vents affect marine ecosystems from the deep sea to the surface ocean. They present uniquely valuable natural laboratories to study the potential impact of ocean acidification and carbon dioxide sequestration in the deep ocean. 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. Finally, these submarine volcanoes are responsible for the creation of economically significant ore deposits that International Mining companies seek to exploit.

Objectives

1. Goal 1: To explore the ocean to locate and characterize neovolcanic areas, their associated hydrothermal ecosystems, and their impact on the oceans.
2. Goal 2: To understand the effects of ocean acidification on ecosystems around hydrothermal environments.

Accomplishments

Goal 1. Accomplishments in Exploration.

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

http://laueruptions.blogspot.com/

Mariana Arc. The Mariana Arc is among the most volcanically active island arcs in the western Pacific and the only one within waters of U.S. jurisdiction. In 2008, part of the Mariana Arc was made into a Marine National Monument, and the team's past and future discoveries have documented the resources present there.
The researchers' results show that the hydrothermal chemistry of the submarine volcanoes on the Mariana 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. Work on the relevant water and microbial samples has been completed and over the time period covered by this report, two manuscripts were submitted. Butterfield et al. discuss details and larger impact of sulfur chemistry at the NW Rota eruptive vent, and Huber et al. discuss the isolated communities of Epsilon-Proteobacteria found in diffuse fluids of the Mariana arc.

Lau Basin. The Lau basin has been examined by NOAA and JISAO scientists on five different cruises between 2004 and 2010. Resing was the chief scientist and led the effort on two of these cruises. Like the Marianas, the Lau basin contains many novel hydrothermal systems and geological settings. Of particular interest is the "Mata" series of volcanoes whose morphology is similar to that of the erupting W. Mata Volcano. Six of the seven Matas are hydrothermally active making the density of hydrothermal activity amongst the highest anywhere in the world. During the time period covering this report, the group submitted a paper on the active eruption at West Mata volcano and are preparing another on the eruptive activity at the NE Lau Spreading

center. In addition, they have used this time to plan for their next ocean exploration cruise to this region.

Indonesia. The NOAA Office of Ocean Exploration and Research has committed to a 5-year program of international collaboration with Indonesia to explore Indonesian waters and develop scientific ties with an important developing country. The first field exploration for this project took place in June and July, 2010, using the NOAA ship *Okeanos Explorer* to conduct high-resolution multibeam bathymetric mapping, CTD hydrocasts, and ROV operations. Using "telepresence", more than 20 scientists participated in the exploration at Exploration Command Centers in Jakarta and Seattle, and at ad hoc sites in Victoria, B.C., Newport, OR, Woods Hole, Hawaii, and other locations. Butterfield served as chief scientist during leg 1 exploration of the Mariana arc, and as science watch leader at the Seattle ECC for leg 2. Buck was the lead scientist on board *Okeanos Explorer* for leg 1. Ed Baker was science watch leader in Seattle for leg 3, with Resing and Buck standing watches. Butterfield presented results of the exploration at the Fall Meeting of the American Geophysical Union in December 2010, where he also participated in a press conference and spoke to the Indonesian ambassador and NOAA administrator Dr. Jane Lubchenko about the expedition. Planning for the next stage of the project is ongoing.

Axial Seamount and the NEMO Observatory. The scientists are in the 13th year of continuous monitoring at Axial Seamount with the NeMO observatory, aiming to study a full volcanic cycle from one eruption to the next. Dave Butterfield was co-chief scientist (with Bill Chadwick) on a 2010 research cruise on board *T.G. Thompson* with Jason 2 ROV operating at Axial Seamount, Juan de Fuca ridge. The project was funded by NSF for collaborative research into chemistry and microbial activity of the sub-seafloor habitat. The work involved a new method for *in-situ* preservation of RNA in filtered microbial material from hydrothermal vents and another year in the long time-series at the NeMO Axial Seamount observatory.
Axial Seamount will soon be the site of the Ocean Observatories Initiative Regional Scale Node (OOI-RSN, formerly NEPTUNE) which will provide real-time cabled communication and power between Axial Seamount and land, with streaming data from multiple sensors and instruments providing an unprecedented view of dynamic processes on a submarine volcano. Butterfield has connected an interactive water sampler to the Main Endeavour node of the NEPTUNE Canada network (*www.neptunecanada.org*) and is working with OOI-RSN to provide a vent fluid sampler and preserved DNA sampler. Data from these instruments will be publicly available through OOI. Butterfield is working (with Bill Chadwick and others) to organize a workshop to coordinate and optimize science community involvement in the OOI-RSN at Axial Seamount.

Goal 1 Summary.
In order to properly understand the volcanic-hydrothermal cycle and its effect on the ocean, it is critical to collect the volcanic and hydrothermal products of eruptions as soon after the eruption as possible. The closer the groups' studies come to the time of the eruption the better their understanding the evolution of hydrothermal venting and biological succession. Their work in the Mariana Arc (e.g., NW Rota), suggests that there must be a transition in hydrothermal systems from those dominated by magmatic fluids rich in SO_2 and CO_2, to systems dominated by the interaction between hot rock and seawater. The ability of microbes and macro-fauna to colonize these new sites may depend on the evolutionary state of these systems. A system rich in

sulfurous acid is likely to host a small number of adapted species. As the system becomes less magmatic, the biologic assemblage is likely to shift to one closer to that observed at longer-lived systems in the same oceanographic region. As submarine mining of sulfide mineral deposits in the western Pacific is poised to begin, the environmental impacts of this economic activity are unknown. It is possible that the impact of eruptive activity and chemical output of active submarine volcanoes may provide some advance indication of the potential impacts of mining submarine deposits.

Goal 2.

The long-term increase in atmospheric carbon dioxide and the consequent increased CO_2 content and lowered ocean pH raise serious concerns about the future habitability of the oceans for many species with critical ecological importance to our planet. There is a huge uncertainty in how ocean acidification will affect marine life. Can animals adapt to higher CO_2 and lower pH? Which species will survive and which will perish? Volcanic ecosystems provide natural laboratories to study these critical issues. Previous work has investigated mussels living in high-CO_2, low-pH areas affected by volcanic/hydrothermal fluids (Tunnicliffe et al., 2009). More recently, the group's work on NW Rota and W Mata has shown that hydrothermal shrimp avoid the most acidic, low-pH vents and congregate around vents with pH 5 or higher. These initial observations point to the need to understand the physiological adaptation mechanisms that allow hydrothermal fauna to thrive in low-pH, high- CO_2 environments.

Likewise, the intersection of coral reefs with volcanic hydrothermal systems provides a potential look into a future, more acidic ocean. Altered oceanic carbonate chemistry caused by a global increase in atmospheric carbon dioxide will lower seawater pH and impact coral ecosystems. Sites with CO_2-rich submarine volcanic emissions and coral reefs will allow us to understand this process. Maug caldera in the Northern Mariana arc is one such site where the scientists have completed initial site surveys, but have not yet obtained the funding for additional focused research.

The researchers are working on experimental approaches to help understand ocean acidification and its effect on biological processes, including coral calcification. Two RAS instruments were deployed in February 2010 in Kaneohe Bay, Hawaii, by graduate student Katie Shamberger to collect time-series samples within a coral reef environment in order to calculate variation in calcification rate. Katie has recently submitted a manuscript with her findings on coral calcification rates in Kaneohe Bay. In sum, the team's exploration work has discovered volcanic ecosystems that are important natural laboratories relevant to ocean acidification and diverse ecological issues.

A proposal has been submitted to study the eruption of Monawai submarine volcano. One of the impacts that the group can examine is the decrease in pH of surface waters from the dissolution volcanic CO_2 and SO_2 into the surface ocean. These acids will produce a local impact that mimics the anticipated effects of global ocean acidification. Enrichments in pCO_2 (acidification) may significantly impact the pelagic microbial ecosystem structure, but the full impacts of ocean acidification are yet unknown and untested in a natural setting. The scientists do not propose to

look directly at the biological aspects, but instead seek to document this setting and its effects on the surface ocean chemistry in the region.

Outreach and Service

Media
The scientists continue to provide high definition video form the West Mata eruption to museums and documentary film makers. Over the time period covering this report, they provided film for the National Geographic "Naked Science" Series produced by Scandinature Films, and for a BBC documentary entitled Naked Earth. Finally they provided footage to the Danfoss Universe Museum in Nordborg, Denmark for their "Blue Cube" exhibit .
David Butterfield participated in the Press Conference on Indonesian Exploration conducted by NOAA's Ocean Exploration program as a part of the INDEX cruise series.

Students and Interns
During the summer of 2010 JISAO intern Cole Perkinson was mentored by Joseph Resing. Two UW undergraduate student research assistants (Seth Shuler and Sara Drescher) were hired by David Butterfield to help on the 2010 Axial Seamount research cruise.

David Butterfield is on the graduate committees of Rika Anderson (biological oceanography), Alden Denny and Monica Kerr-Riess (geological oceanography).

Joseph Resing is on the Graduate Committees of Lia Slemons and Pamela Barrett (Chemical Oceanography)

Graduate students Ellie Bors and Samantha Zelin participated in Legs 2 and 3 of the Indonesian exploration from the ECC in Seattle and were mentored by David Butterfield, Ed Baker, and Joseph Resing.

David Butterfield has recruited NOAA-Hollings Scholar Alec Herr for Summer 2011 to work on NEPTUNE-Canada data analysis.

Professional
To further their understanding of Arc and Back-Arc hydrothermal and eruptive settings, Joseph Resing and David Butterfield (with Chadwick from Oregon State University, Rubin from the University of Hawaii, and Shank from Woodshole Oceanographic Institution) are co-editing a special theme section of Geochemistry, Geophysics, and Geosystems entitled "Assessing Magmatic, Neovolcanic, Hydrothermal, and Biological Processes along Intra-Oceanic Arcs and Back-Arcs."

David Butterfield and Joseph Resing serve on the ad-hoc committee for planning the multi-year collaboration between Indonesia and NOAA Ocean Exploration and Research.

Tsunami Observations and Modeling

Tsunami Research

PI
NOAA - Vasily Titov

Other Personnel
UW - Diego Arcas, Nicolas Arcos, Christopher Chamberlin, Donald Denbo, Edison Gica, Nazila Merati, Christopher Moore, Jean Newman, John Osborne, Clinton Pells, Dylan Righi, Michael Spillane, Liujuan Tang, Elena Tolkova, Michael Traum, Burak Uslu, Lindsey Wright, Yong Wei
NOAA - E. Bernard, Eugene Burger, Marie Eble, Nancy Soreide

Task II

NOAA Primary Contact
Pacific Marine Environmental Laboratory

NOAA Goals
3. Serve Society's Need for Weather and Water Information
4. Support the Nation's Commerce with Information for Safe, Efficient & Environmentally Sound Transportation

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, which have the potential for devastating impact, 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 and Atlantic Ocean, which detect and report in real time the passage of a tsunami wave. The instruments, called DART®s (developed at PMEL) are deployed and serviced by the National Data Buoy Center. Array studies, conducted at NCTR, assist in the choice of the optimal locations for the DART® buoys and assessment of the impact of instrument outages.

Other aspects of NOAA's tsunami-related activities include the U.S. National Tsunami Hazard

Mitigation Program (NTHMP), a Federal/State collaborative partnership of NOAA, USGS, FEMA, NSF and the Emergency Management and Geotechnical agencies of U.S. coastal states. Modeling efforts at NCTR facilitate risk assessment for exposed communities and existing or planned infrastructure. Public education, both within the U.S. and internationally, training and capacity building for scientific and emergency planning and response, and the development of partnerships, are vital to combating the tsunami threat. NCTR seeks to achieve these goals through presentations and workshops worldwide. In particular modeling and forecast tools are customized to facilitate this mission and establish warning services for global coastal communities.

Objectives

1. To develop and implement the main components of NOAA's operational tsunami forecast system "SIFT" (**S**hort-term **I**nundation **F**orecast for **T**sunamis) 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. During 2010-2011, NCTR has completed the installation of SIFT 3.0.5 at the Tsunami Warning Centers (TWCs) in Hawaii and Alaska. This version is an update of the previous version (SIFT 3.0.1) and improves the usability of SIFT by decreasing the number of windows of which the operator needs to keep track and includes an error analysis of the inversion results. NCTR is also finishing the development of SIFT 3.1.0 which features a newly designed user interface that streamlines the process of source inversion by allowing the operator to visualize and keep track of different inversion solutions without the need to submit each solution as a new event. SIFT 3.1 acts as a console with which the operator can prioritize and launch fast-executing numerical models for the communities most at risk to serve the needs of forecasters and emergency responders.
2. NCTR continues to provide analyses for tsunami hazard assessment projects for the State of Washington. Inundation modeling for the city of Everett from three seismic scenarios for Washington State's tsunami inundation mapping program has been completed, and a study of the tsunami threat to American Samoa conducted in collaboration with NOAA's National Ocean Service will be completed before the end of the current fiscal year. The second part of a two-year project with the Nuclear Regulatory Commission (NRC) will notify NRC officials of a tsunami event and will provide forecast parameters at the locations of threatened nuclear power plants via an internet distribution system (TsunamiCast).

3. During the period 2010-2011 NCTR has developed a Federal Emergency Management Agency (FEMA) and Department of Homeland Security (DHS) certified Tsunami Awareness course for the National Disaster Preparedness Training Center (NDPTC), at the University of Hawaii. This course works towards NOAA's mission of supporting disaster preparedness, response, and recovery activities. NCTR has also, continued the implementation and development of a Tsunami Train-the-Trainer for Washington Military Department's Emergency Management Division (WA EMD). The training program produces qualified Tsunami Public Education Instructors in the State of Washington. Additionally, work with the International Tsunami Information Center (ITIC) has begun to develop a "TsunamiTeacher" educational tool which will reach the general public via wbe-based learning tools including videos.
4. In order to provide tsunami forecasting capabilities to various audiences, a project to develop Web-based access to a SIFT-like server (T-Web) is well underway. Development on the intermediary server tiers are underway with the emphasis on the tier that will translate data from the operational SIFT software to a web consumable format. With all the client prototyping completed, progress on the development of the web client is steady.
5. NCTR is continuing the development of the high-resolution tsunami inundation models called Forecast Models (FMs) Ms (formerly known as **S**tand-by **I**nundation **M**odels, SIMs) as part of the Forecast System. The Implementation Plan calls for development of the Forecast Models for 75 coastal communities at risk in the U.S. by FY12. To date 54 FMs have been developed; 11 more are in progress to be delivered during the current fiscal year.
6. A method to automate the tsunami source inversion process so that input from the warning center operator can be minimized is under investigation, if successful it will allow to completely automate the forecasting process, facilitating the use of the Weather Service Supercomputer Center to produce forecast results. In addition combined use of real time sea-level data and GPS measurements to generate a single inversion is being investigated.
7. Three medium size events (Sumatra (April, 6) Mw=7.7, Mentawai (October, 25) Mw=7.7 and Bonin (December, 21) Mw= 7.4) have occurred during the current reporting period providing useful unplanned tests of the SIFT system, both locally at NCTR and at the TWCs. These unplanned events have validated some of the features of the SIFT forecasting software and exposed other areas where improvement is necessary, in order to attain a higher degree of automation and minimize user input.
8. Training workshops, using the Community Modeling Interface for Tsunami (ComMIT) were conducted in Citeko, Indonesia under the auspices of UNESCO and the Agency for the Assessment and Aplication of Technology (BPPT) to further tsunami detection, forecasting, and warning capabilities in Indonesia, bringing the total number of ComMIT workshops taught overseas to nine, with two more scheduled to take place in Mozambique and Tanzania before March 2011.

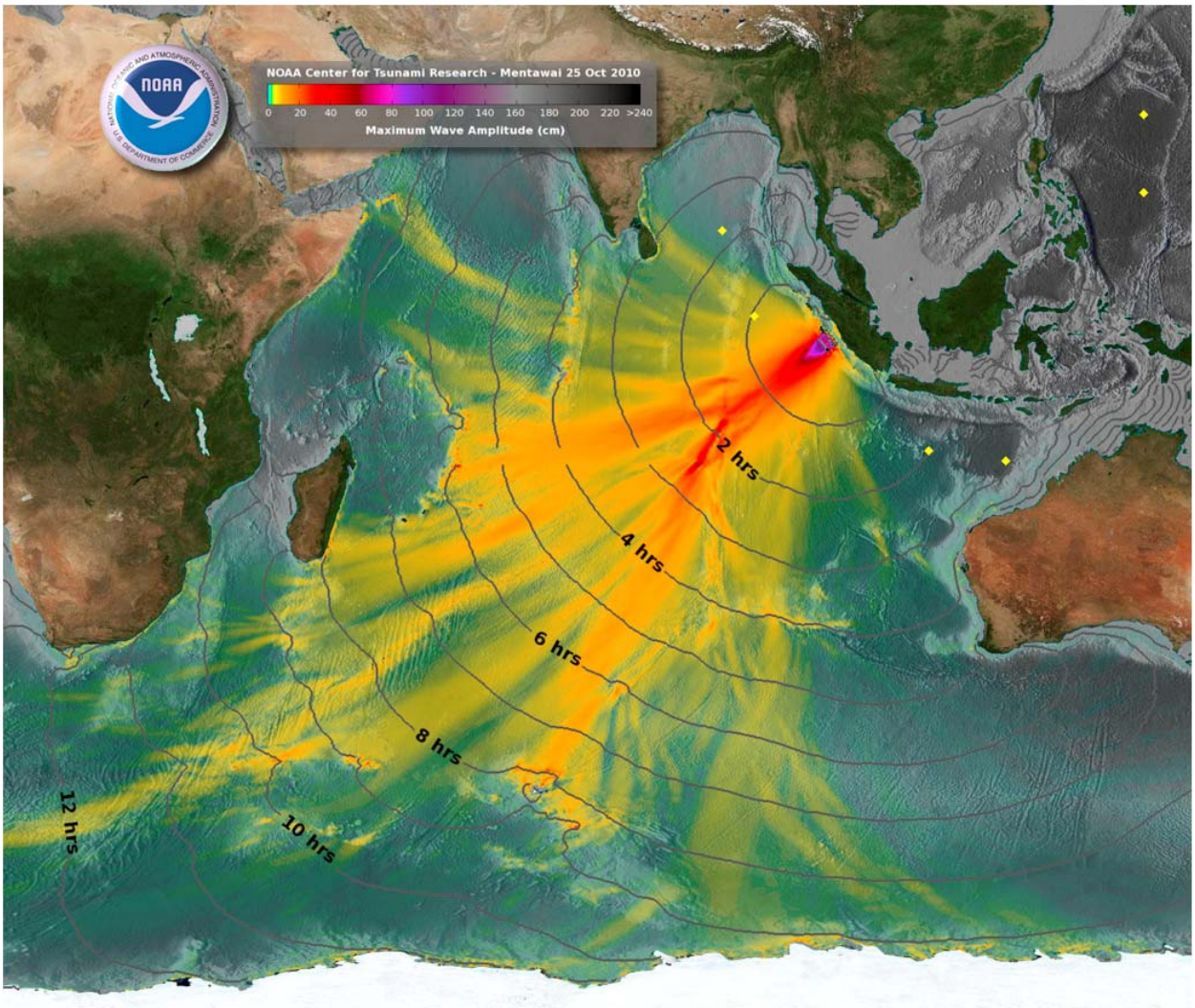


Figure1. Energy propagation pattern of the 25 October 2010 tsunami calculated with MOST forecast model. Filled colors show maximum computed tsunami amplitude in cm during 24 hours of wave propagation. Black contours show computed tsunami arrival time.

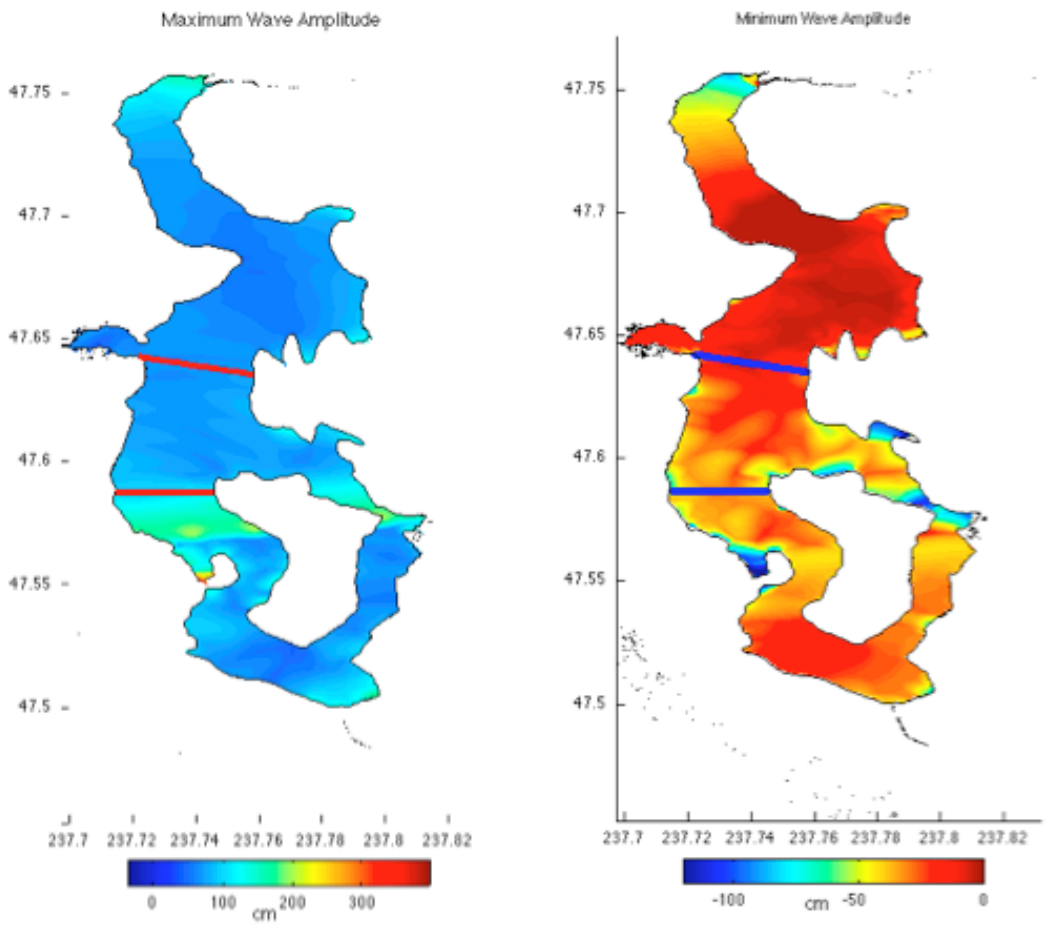


Figure 2. Distribution of the maximum (left panel) and minimum (right panel) wave elevation throughout Lake Washington from a hypothetical tsunami generated by the Seattle Fault. Color represents the maximum (left) and minimum (right) elevation reached by the water surface at any point in the lake during the length of the simulation. The red/blue lines indicate the approximate location of the SR-520 and I-90 bridges.

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

PI
UW - Donald B. Percival

Task III

NOAA Primary Contact
Vasily Titov, PMEL

NOAA Goal
3. Serve Society's Need for Weather and Water Information

Description
NOAA has deployed a series of DART buoys (primarily in the Pacific Ocean) for the purpose of directly measuring the start of a tsunami event, for the purpose of using these measurements to predict the impact of a tsunami along U.S. coastal communities. Tsunamis that these buoys are designed to measure are generated by earthquakes and landslides along known fault lines. While very large tsunami-generating events will lead to an immediate evacuation order, 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 up on the uncertainty in the estimated tsunami source amplitudes. Intermediate measures of interest are CIs for these source amplitudes.

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

Accomplishments
The scientists completed a paper that documents the inversion algorithm currently in NOAA's Short-term Forecast for Tsunamis (SIFT) tool. The paper was accepted for publication in 'Natural Hazards' and is now available on-line via the Web site for this journal. The researchers are currently working on a companion paper that compares three detiding methods for use within SIFT. Removal of tides from the data collected at the DART buoys is necessary because the inversion algorithm assumes the absence of tidal components.
The three methods are based on a harmonic analysis (the so-called Foreman method), on Kalman filtering/smoothing and on empirical orthogonal functions. The study involves introducing artificial tsunamis into actual records of tidal fluctuations recorded by DART buoys at

representative locations. The artificial tsunamis are taken from a database of unit source models for tsunamis.
Use of artificial tsunamis allows the scientists to assess how each of the three detiding procedures works because the true tsunami is known.

Appendices

Appendix 1

JISAO Senior Fellows and Council Members*

University of Washington

*Ackerman, Thomas, Professor, Atmospheric Sciences, Director, JISAO
Armstrong, David, Professor and Director, Aquatic and Fishery Sciences
Battisti, David S., Professor, Atmospheric Sciences
Bretherton, Christopher, Professor, Atmospheric Sciences/Applied Mathematics, Director, Program on Climate Change
Charlson, Robert J., Professor Emeritus, Atmospheric Sciences
Covert, David S., Research Professor, Atmospheric Sciences
Emerson, Steven R., Professor, Oceanography
Eriksen, Charles C., Professor, Oceanography
Fleagle, Robert G., Professor Emeritus, Atmospheric Sciences
Friedman, Carolyn, Associate Professor, Aquatic & Fishery Sciences
Fu, Qiang, Professor, Atmospheric Sciences
Gammon, Richard H., Professor, Oceanography and Chemistry
* Hartmann, Dennis L., Professor, Atmospheric Sciences
Hilborn, Ray, Professor, Aquatic & Fishery Science
Horne, John, Associate Professor, Aquatic & Fishery Science
Jaeglé, Lyatt, Associate Professor, Atmospheric Sciences
Jaffe, Dan, Professor, Interdisciplinary Arts & Sciences, Adjunct Professor, Atmospheric Sciences
Lettenmaier, Dennis P., Professor, Civil and Environmental Engineering
Mantua, Nathan, Associate Professor, Aquatic and Fishery Sciences and Co-Director Center for Science in the Earth System and Climate Impacts Group
McDuff, Russell, Director and Professor, Oceanography
* Miles, Edward L., Professor, Marine Affairs, Climate Impacts Group
Murray, James W., Professor, Oceanography
* Punt, Andre E., Associate Professor, Aquatic and Fishery Sciences
Quay, Paul D., Professor, Oceanography
Rhines, Peter B., Professor, Oceanography and Atmospheric Sciences
Ruesink, Jennifer, Associate Professor, Biology
Thompson, LuAnne, Associate Professor, Oceanography, Interim Director
Untersteiner, Norbert, Professor Emeritus, Atmospheric Sciences
Wallace, John M., Professor, Atmospheric Sciences

NOAA Pacific Marine Environmental Laboratory

Baker, Edward T., Supervisory Oceanographer, Ocean Environment Research Division, Affiliate Professor, Oceanography
Bates, Timothy S., Research Chemist, Ocean Climate Research Division, Affiliate Associate Professor, Oceanography
Bullister, John, Oceanographer, Ocean Climate Research Division, Affiliate Associate Professor, Oceanography
Cronin, Meghan, Oceanographer, Ocean Climate Research Division, Affiliate Associate Professor, Oceanography

* Feely, Richard A., Supervisory Oceanographer, Ocean Climate Research Division, Affiliate Professor, Oceanography

Harrison, D. E., Oceanographer, Ocean Climate Research Division, Affiliate Professor, Oceanography

* 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, Oceanographer, Ocean Climate Research Division, Affiliate Assistant Professor, Oceanography

Stabeno, Phyllis, Supervisory Oceanographer, Ocean Climate Research Division

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

***2010-2011 Council Members**

Appendix 2

Task III Principal Investigators and Projects

Principal Investigator	Academic Unit	Title of Project	Award
Armstrong, David	SAFS	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	**$140,000**
Baker, Joel	UW Tacoma	Organize and Host 2010 Marine Debris Microplastics Workshop	**$55,812**
Beauchamp, David	SAFS	Fitness Consequences of Sublethal Copper on Olfactory-Mediated Behaviors in Coho Salmon	**$9,140**
DeCosmo, Janice	URP	Northwest Fisheries Science Center and University of Washington Undergraduate Intern Program	**$78,272**
Doherty, Sarah	JISAO	IGAC Core Project Office - NOAA	**$90,179**
Doyle, Miriam	JISAO	Links Between the Early Life History Dynamics of Fish And Climate and Ocean Conditions in the Gulf of Alaska and Southeast Bering Sea	**$73,095**
Hilborn, Ray	SAFS	Fish Productivity and Fishing Impacts Compared Across a Range of Marine Ecosystems	**$81,820**
Horne, John	SAFS	Fisheries Acoustics Research	**$74,998**
Horne, John	SAFS	Forecasting Walleye Pollock Recruitment in a Bayesian Framework	**$88,412**
Lettenmaier, Dennis	CEE	Development Of An Experimental National Hydrologic Prediction System	**$72,000**
Mantua, Nathan	JISAO	Center for Science in the Earth System, Climate Dynamics/Experimental Prediction/ARC & RISA Transition	**$850,000**
Mass, Cliff	Atm Sci	Ensemble-Based Regional Data Assimilation	**$28,994**

Miller, Bruce	SAFS	Marine Biological Interactions in the North Pacific – Fish Interactions Task	**$336,092**
Parrish, Julia	SAFS	Coastal Observation and Seabird Survey Team (COASST)	**$7,491**
Percival, Don	APL	DART Data Inversion: Source Selection, Detiding and Inundation Forecast Uncertainty Assessment	**$50,000**
Punt, Andre	SAFS	Evaluating the Performance of a Spatially-Structured Fish Population Assessment Model	**$92,430**
Punt, Andre	SAFS	Improving Assessment Methods: Developing and Evaluating Alternative Estimators of Survey	**$85,793**
Punt, Andre	SAFS	West Coast Groundfish Stock Assessment	**$156,699**
Rigor, Ignatius	APL	International Arctic Buoy Programme (IABP) – Monitoring the Eurasian Basin of the Arctic Ocean	**$50,000**
Riser, Steve	OCE	The Argo Project: Global Ocean Observations for Understanding and Prediction of Climate Variability	**$2,700,268**
Stafford, Kate	APL	Bowhead Whale Feeding in the Western Beaufort Sea: Passive Acoustic Survey Component	**$64,062**
Steinemann, Anne	CEE	California NIDIS Pilot	**$99,372**
Torgersen, Christian	SFR	Floodplain Diversity and Spawning Area Productivity in the Yakima River, Part III: Multiscale Habitat Associations	**$86,583**
Wasser, Sam	Biology	Non-Invasive Physiological Monitoring of Southern Resident Killer Whales	**$32,779**

Appendix 3

Projects by Task

Task	Principal Investigator	Title of the Project	Amount
I	Ackerman, Thomas	Joint Institute for the Study of the Atmosphere and Ocean	**$200,100**
I/II	Ackerman, Thomas	Joint Institute for the Study of the Atmosphere and Ocean: Tasks I & II	**$10,546,895**
II	Herwig, Russell	Biological Removal of Petroleum Hydrocarbons in Marine and Aquatic Ecosystems to Determine the Fate of Deepwater Horizon Oil	**$37,503**
II	Horne, John	Spatial Analysis of a Near-Surface Acoustic Backscatter Layer in the Eastern Bering Sea	**$18,924**
II	Miller, Marc	Long Form Community Profile Development	**$4,500**
II	Punt, Andre	An Evaluation of Management Strategies for Implementation of Annual Catch Limits for Alaska Groundfish	**$144,999**
II	Salathe,Eric	ECOHAB – Modeling Favorable Habitat Areas for Alexandrium Catenella in Puget Sound and Evaluating the Effects of Climate Change	**$88,020**
II	Pietsch, Theodore	Annotated Checklist Of Bottom-Trawled Macroinvertebrates of Alaska, With an Evaluation of Identifications in the Alaska Fisheries Science Center Bottom-Trawl Survey Database	**$200,421**
III	Armstrong, David	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	**$140,000**
III	Baker, Joel	Organize and Host 2010 Marine Debris Microplastics Workshop	**$55,812**
III	Beauchamp, David	Fitness Consequences of Sublethal Copper on Olfactory-Mediated Behaviors in Coho Salmon	**$9,140**
III	DeCosmo, Janice	Northwest Fisheries Science Center and University of Washington Undergraduate Intern Program	**$78,272**

III	Doherty, Sarah	IGAC Core Project Office - NOAA	**$90,179**
III	Doyle, Miriam	Links Between the Early Life History Dynamics of Fish And Climate and Ocean Conditions in the Gulf of Alaska and Southeast Bering Sea	**$73,095**
III	Hilborn, Ray	Fish Productivity and Fishing Impacts Compared Across a Range of Marine Ecosystems	**$81,820**
III	Horne, John	Fisheries Acoustics Research	**$74,998**
III	Horne, John	Forecasting Walleye Pollock Recruitment in a Bayesian Framework	**$88,412**
III	Lettenmaier, Dennis	Development of an Experimental National Hydrologic Prediction System	**$72,000**
III	Mantua, Nathan	Center for Science in the Earth System, Climate Dynamics/Experimental Prediction/ARC & RISA Transition	**$850,000**
III	Mass, Cliff	Ensemble-Based Regional Data Assimilation	**$28,994**
III	Miller, Bruce	Marine Biological Interactions in the North Pacific – Fish Interactions Task	**$336,092**
III	Parrish, Julia	Coastal Observation and Seabird Survey Team (COASST)	$**7,491**
III	Percival, Don	DART Data Inversion: Source Selection, Detiding and Inundation Forecast Uncertainty Assessment	**$50,000**
III	Punt, Andre	Evaluating the Performance of a Spatially-Structured Fish Population Assessment Model	**$92,430**
III	Punt, Andre	Improving Assessment Methods: Developing and Evaluating Alternative Estimators of Survey	**$85,793**
III	Punt, Andre	West Coast Groundfish Stock Assessment	**$156,699**

III	Rigor, Ignatius	International Arctic Buoy Programme (IABP) – Monitoring the Eurasian Basin of the Arctic Ocean	**$50,000**
III	Riser, Stephen	The Argo Project: Global Ocean Observations for Understanding and Prediction of Climate Variability	**$2,750,268**
III	Stafford, Kate	Bowhead Whale Feeding in the Western Beaufort Sea: Passive Acoustic Survey Component	**$64,062**
III	Steinemann, Anne	California NIDIS Pilot	**$99,372**
III	Torgersen, Christian	Floodplain Diversity and Spawning Area Productivity in the Yakima River, Part III: Multiscale Habitat Associations	**$86,583**
III	Wasser, Sam	Non-Invasive Physiological Monitoring of Southern Resident Killer Whales	**$32,779**

Appendix 4

Personnel Count

Category	Number	B.S.	M.S.	Ph.D.
Faculty	2			2
Research Scientist	65	15	19	31
Visiting Scientist	0			
Postdoctoral Fellow**	11			10
Research Support Staff	5	5		
Administrative	0			
Total (> or = 50%)	83	20	19	43
Undergraduate Students	4			
Graduate Students	20			
Employees receiving less than 50% NOAA support	52			
Estimated # of FTEs	119			
Obtained NOAA employment within the last year	1			

**an additional PostDoc received less than 50% support

Appendix 5

Graduate Students

Student Name	Academic Department	Degree	Degree Supervisor
Ayres, Katherine Leah	Department of Biology	Ph.D.	Samuel Wasser
Dilmen, Derya	Earth And Space Sciences	M.S.	Vasily Titov
Fagan-Shamberger, Kathryn	School of Oceanography	Ph.D.	Richard Feely
Ferriss, Bridget E.	School of Aquatic and Fishery Sciences	Ph.D.	Tim Essington
Gray, Alison R.	School of Oceanography	Ph.D.	Cliff Mass
Haskell, Daniel	Civil and Environmental Engineering	M.S.	Joel Baker
Hennon, Tyler Douglas	School of Oceanography	M.S.	Stephen Riser, Matthew Alford
Hoelting, Kristin	School of Marine Affairs	M.S.	Marc Miller
Klett, Ryan S	School of Forest Resources	M.S.	Christian Torgersen
Madaus, Luke E	Department of Atmospheric Sciences	M.S.	Cliff Mass, Greg Hakim
Mcintyre, Jenifer	School of Aquatic and Fishery Sciences	Ph.D.	David Beauchamp
Ono, Kotaro	School of Aquatic and Fishery Sciences	Ph.D.	Ray Hilborn
Pelland, Noel	School of Oceanography	M.S.	Charles Eriksen
Rosenberg, Eric A.	Civil and Environmental Engineering	Ph.D.	Dennis Lettenmaier, Anne Steinemann
Rutter, Jeffery D	Quantitative Ecology & Resource Mgmt	Ph.D.	Andre Punt
Stachura, Megan M.	School of Aquatic and Fishery Sciences	M.S.	Nathan Mantua, Ray Hilborn
Vano, Julie A	Civil and Environmental Engineering	Ph.D.	Dennis Lettenmaier
Wenegrat, Jacob O	School of Oceanography	M.S.	Mike McPhaden
Whitehouse, George A.	School of Aquatic and Fishery Sciences	M.S.	Tim Essington
Wu, Motoki D	School of Aquatic and Fishery Sciences	M.S.	Andre Punt

Appendix 6

Postdoctoral Research Associates

Drumm, David T.
Holsman, Kirstin
Johnstone, James A
Kleiss, Jessica Marie
Lique, Camille
Mishra, Vimal
Muehlbauer, Andreas
Munoz-Arriola, Francis **
Siedlecki, Samantha A
Taylor, Ian G
Woillez, Mathieu
Zhou, Hongqiang

**Received less than 50% support from JISAO

Appendix 7

JISAO Awards Honors 2010-2011

2010

Jeremy Cram received the best student presentation award at the 2010 Water Center Annual Review of Research.

Richard Feely, JISAO Senior Fellow and project leader of the PMEL Carbon group, was honored with the Heinz Environmental Award at a ceremony in Washington D.C. on November 15, 2010. The 16th Heinz Awards focused on Global Change. Dr. Feely received this prestigious award for his seminal research on the changing ocean chemistry and its impact on marine ecosystems and for ultimately shifting public policy to address this growing issue.

Muyin Wang and **James Overland** published paper, (Wang and Overland, 2009, GRL) has been selected as PMEL Outstanding scientific paper for 2010.

Dave Peterson named Senior Scientist by the US Forest Service in October 2010

Julie Vano awarded American Water Resources Association Washington Chapter 2010 Student Fellowship. December 2010

Rob Norheim received the USDA Forest Service Certificate of Merit. Fall 2010

2011

Muyin Wang invited by Dr. Arthur Lee, Fellow of Chevron Corporation, to give a webinar to the Chevron Climate Energy Environment Webinar Series on February 22, "The changing of Arctic Climate and the global implications."

Thomas Ackerman, Director JISAO has been elected a Fellow of the American Geophysical Union. Only one in a thousand members is elected to Fellowship each year.

JISAO regularly presents awards to employees for recognition of excellent work and for years of service to the University.

Appendix 8

Publications count 2010-2011

	JISAO Lead Author
Peer-reviewed	66
Non-peer reviewed	1
Total	**67**
	NOAA Lead Author
Peer-reviewed	16
Non-peer reviewed	0
Total	**16**
	Other Lead Author
Peer-reviewed	83
Non-peer reviewed	11
Total	**94**
Peer-reviewed	**165**
Non-peer reviewed	**12**
Total	**177**

Appendix 9

Publications July 1, 2010-March 31, 2011

Not Previously Reported

1. Kwok, R., G. F. Cunningham, M. Wensnahan, I. Rigor, H. J. Zwally, and D. Yi , 2009, Thinning and volume loss of the Arctic Ocean sea ice cover: 2003-2008, J. Geophys. Res., 114(C7), C07005.

Published

2. Alkire, M. B., K. K. Falkner, J. Morison, R. W. Collier, C. K. Guay, R. A. Desiderio, I. G. Rigor, and M. McPhee , 2010, Sensor-based profiles of the NO parameter in the central Arctic and southern Canada Basin: New insights regarding the cold halocline, Deep Sea Research Part I: Oceanographic Research Papers, 57(11), 1432-1443.
3. Atwater, B., U. ten Brink, M. Buckley, R. Halley, B. Jaffe, A. López-Venegas, E. Reinhardt, M. Tuttle, S. Watt, and Y. Wei , 2010, Geomorphic and stratigraphic evidence for an unusual tsunami or storm a few centuries ago at Anegada, British Virgin Islands, Natural Hazards, 1-34.
4. Atwood, E., J. T. Duffy-Anderson, J. K. Horne, and C. Ladd , 2010, Influence of mesoscale eddies on ichthyoplankton assemblages in the Gulf of Alaska, Fisheries Oceanography, 19(6), 493-507.
5. Barberopoulou, A., M. Legg, B. Uslu, and C. Synolakis , 2010, Reassessing the tsunami risk in major ports and harbors of California I: San Diego, Natural Hazards, 1-18.
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May 3, 2011

In response to your message, here is the missing information for our report for NOAA Primary Contacts:

--Page 17 - TAO - David Legler, Climate Program Office

--Page 51 - Marine Carbon Program: Joel Levy, Climate Program Office

--Page 54 - Chlorofluorocarbon Tracer Program: Ken Mooney, Global Carbon Cycle Program, OAR

--Page 109 - Forecasting Walleye Pollock Recruitment: Kenric Osgood, NMFS Science & Technology

--Page 111 - Marine Biological Interactions: Roger Griffis, NMFS Science & Technology

--Page 113 - PMEL Ocean Climate Stations: Diane Stanitsky, Office of Climate Observations

--Page 140 - NOAA-VENTS: Alexander E. MacDonald, Assistant Administrator for Laboratories and Cooperative Institutes

--Page 146 - Tsunami Research: Jenifer Rhoades, Tsunami Program Manager, NWS/OCWWS/ORD/RMB

I believe the publications issue was cleared up, but if you need anything else, please let me know.

Thank you,
Mary C. Smith
JISAO Assistant Director