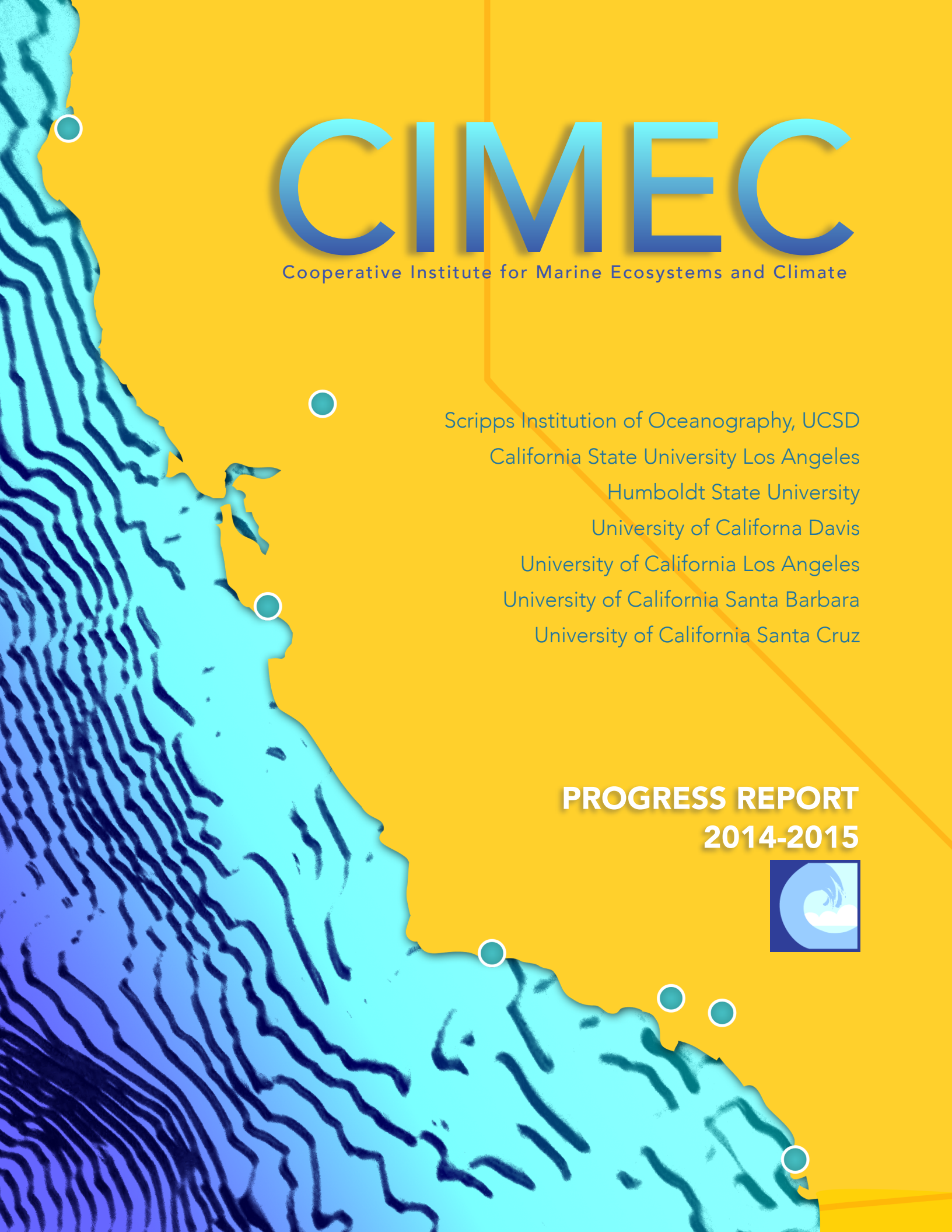

CIMEC

Cooperative Institute for Marine Ecosystems and Climate

Scripps Institution of Oceanography, UCSD
California State University Los Angeles
Humboldt State University
University of Californa Davis
University of California Los Angeles
University of California Santa Barbara
University of California Santa Cruz

PROGRESS REPORT
2014-2015

CIMEC

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Cooperative Institute for Marine Ecosystems and Climate

Progress Report

2014 - 2015

Prepared for

NOAA NA10OAR4320156

HUMBOLDT STATE UNIVERSITY

UCSB

UC San Diego

Ca Stat e LA

UCDAVIS

UCLA

SCRIPPS INSTITUTION OF OCEANOGRAPHY
UC San Diego

UC SANTA CRUZ

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12 June 2015

The Cooperative Institute of Marine Ecosystems and Climate will end its first five years on June 30, 2015. CIMEC begins its second five-year award on July 1, 2015. During its first five years, CIMEC has served NOAA and the Nation through observing and research by scientists at its constituent academic institutions. CIMEC's reach extends from the atmosphere to the deep ocean. CIMEC's products are used for near-term forecasts of the ocean and atmosphere and for the assessment and prediction of long- term change. CIMEC plays a critical role in sustaining marine fisheries and ecosystems. CIMEC contributes importantly to training the next generations of scientists. CIMEC's growth in its first five years is testimony to its increasing value and contribution to NOAA's mission.

CIMEC continues to be active in a wide variety of areas of concern to NOAA. Fisheries research and training occurs at the UCSC, UCSD and HSU, including The Center for Stock Assessment Research at UCSC, the Center for Advancement of Population Methodology at UCSD, and faculty at HSU. Research on fish ecology in support of NOAA's fisheries mission thrives at UCSC. The California Cooperative Oceanic Fisheries Investigations (CalCOFI) remains the longest ship-based physical/biological ocean time-series program. Passive acoustics are being used to sense marine mammals and anthropogenic noise. The Global Drifter Program provides observations critical for weather and hurricane forecasting. Surface drifters are particularly important for Southern Ocean observing. The Argo Project characterizes the state of the upper ocean. Deep Argo floats are being deployed. The Consortium on the Ocean's Role in Climate observes the ocean boundary currents. Two moorings in the California Current provide real-time observations of ocean physics, chemistry, and biology. Genomics and ocean acidification are increasingly observed in CalCOFI and at moorings. Atmospheric rivers have been the focus of a large field campaign. Atmospheric CO_2 and O_2 are measured globally. Collectively, these measurements and Argo significantly improve our understanding of the global carbon cycle and human influence on it. CIMEC plays a key role in NOAA's response to Hurricane Sandy through improved observing and prediction of El Niño, hurricanes and extreme rainfall events.

I will step down as Director of CIMEC at the end of this award period. On July 1, 2015, Dr. Bruce Cornuelle, a Research Oceanographer at Scripps, will become CIMEC Director. Bruce's interests range from modeling and state estimation of oceans to their coastal and Equatorial circulation. CIMEC will be in highly capable hands.

I appreciate the expert administrative support proved by Rose Keuler and Anne Footer.

It has been a privilege to serve as Director of CIMEC for the past five years. The PIs make CIMEC. NOAA's investment in the programs yields a high return for the Nation.

David M. Checkley, Jr.
CIMEC Director

8880 Biological Grade, La Jolla, CA 92037
(858) 534-1795 / (858) 822-0665 (Fax)

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INTRODUCTION

The Cooperative Institute for Marine Ecosystems and Climate (CIMEC) research and program activities for the year (2014-2015) of the **National Oceanic and Atmospheric Administration** (NOAA) grant **NA10OAR4320156** are outlined in this report. CIMEC is affiliated with the **Scripps Institution of Oceanography** (SIO), and is a multi-disciplinary Institution for ocean, climate, earth and environmental research as part of the University of California, San Diego (UC San Diego) campus and greater University of California (UC) system. Included in this report are the individual projects, activities and accomplishments of CIMEC researchers and partners at SIO, UC and Cal State, as well as other collaborating organizations associated with CIMEC.

CIMEC's purpose is to facilitate and enhance research cooperation between NOAA entities and SIO, in particular, and the University of California (UC) and California State Universities (Cal State), in general, pertinent to the mission of NOAA.

During the April 1, 2014 to March 31, 2015 period, the NOAA research entities listed below were engaged with SIO as part of CIMEC in marine, atmospheric and climate research, education and outreach efforts, data collection, and collaborative activities:

- Assessment and Monitoring Division (AMD)
- Climate Program Office (CPO)
- Earth System Research Laboratory (ESRL)
- Integrated Ocean Observing System (IOOS)
- Marine Ecosystems Division (MED)
- National Data Buoy Center (NDBC)
- National Integrated Drought Information System (NIDIS)
- National Marine Fisheries Service (NMFS)
- National Ocean Service (NOS)
- Ocean Assessment Program (OAP)
- Office of Habitat Conservation (OHC)
- Office of Oceanic and Atmospheric Research (OAR)
- Pacific Island Fisheries Science Center (PIFSC)
- Pacific Marine Environmental Laboratory (PMEL)
- Southeast Fisheries Science Center (SEFSC)
- Southwest Fisheries Science Center (SWFSC)

ORGANIZATION

Mission Statement

The mission of CIMEC is, in collaboration with NOAA, to develop and consolidate leading researching and educational programs across its member institutions in support of NOAA's mission "to understand and predict changes in the Earth's environment and conserve and manage coastal and marine resources to meet our Nation's economic, social and environmental needs."

Vision Statement

CIMEC shares the fundamental mission and goals of NOAA research and strives to achieve several objectives based on the unique resources and character of the Scripps Institution of Oceanography (SIO) and the other partner institutions in California: (1) to foster collaborative research between NOAA and UC/Cal State scientists; (2) to facilitate participation of UC/Cal State and other academic scientists in NOAA programs; and (3) to use the educational strength of CIMEC both to train students for productive work in environmental activities and to educate the citizenry about the intellectual excitement and importance of studying and managing our environment.

CIMEC builds upon SIO's experience from nearly twenty years of management of the Joint Institute for Marine Observations, and works closely with NOAA line offices, goal teams and laboratories to assist in transitioning research and development into NOAA data products and services. NOAA leadership and researchers will be strongly represented on CIMEC's Executive Board and Council of Fellows. An annual meeting will be held to communicate progress on CIMEC's projects and to seek input on research directions and priorities from NOAA leadership and scientists and stakeholder groups. CIMEC institutions will work to ensure that wherever possible NOAA's needs are represented in their educational programs, from undergraduate to postdoctoral levels. The education and outreach program will also address ocean-literacy needs at the K-12 levels and in the broader community.

CIMEC Leadership

DIRECTOR:
David Checkley is a professor at Scripps Institution of Oceanography, University of California, San Diego. His research interests are in the areas of long-term change in pelagic zooplankton and fish, including climate-biota interactions; role of zooplankton in the marine nitrogen cycle; effects of weather and air-sea interactions on plankton and fishes; ecology of marine zooplankton and fish; the biological pump, including the role of particles and plankton; ocean acidification; and instrument development. He holds a B.S. from the University of Washington and both an M.S. and Ph.D. from SIO.

DEPUTY DIRECTOR:
Dean Roemmich is a professor at Scripps Institution of Oceanography, University of California, San Diego. His research interests are the role of the oceans in climate and climate variability, general circulation of the oceans, and the California Current system. He holds a B.S. from the Swarthmore University and a Ph.D. from the Massachusetts Institute of Technology—Woods Hole Oceanographic Institution.

CIMEC Organizational Chart

CIMEC Employee Summary

Personnel Supported by NOAA/CIMEC Funding April 1, 2014 – March 31, 2015				
Category	**Total**	**B.S. / B.A.**	**M.S.**	**Ph.D.**
Assistant Professor	1	0	0	1
Researcher	2	0	0	2
Project Scientist	6	0	1	5
Museum Scientist	1	0	1	0
Postdoctoral Fellow	8	0	0	8
Research Specialist	5	0	0	5
Programmer Analyst	6	3	3	0
Staff Research Associate/Assistant	14	5	9	0
Laboratory Assistant	11	6	5	0
Marine Technician	2	2	0	0
Administrative Analyst	1	1	0	0
Total (≥ 50% support)	**56**	**16**	**19**	**21**

Undergraduate Students	22
Graduate Students	22

Employees less than 50% not including students	104

Personnel located at a NOAA Laboratory	41

Obtained NOAA employment (Within the last 12 months)	
FED, SWFSC	2 people
FED, NWFSC	4 people

Sub-Awards	
Postdoctoral Fellow	2
Graduate Student	2
Undergraduate Student	0

CIMEC Fellows Roster

Abell, Jeffrey - Humboldt State University
Allen, Andrew - Scripps Institution of Oceanography, UC San Diego
Appelgate, Bruce - Scripps Institution of Oceanography, UC San Diego
Baumann-Pickering, Simone - Scripps Institution of Oceanography, UC San Diego
Bock, Yehuda - Scripps Institution of Oceanography, UC San Diego
Cayan, Dan - Scripps Institution of Oceanography, UC San Diego
Centurioni, Luca - Scripps Institution of Oceanography, UC San Diego
Cornuelle, Bruce - Scripps Institution of Oceanography, UC San Diego
Dickson, Andrew - Scripps Institution of Oceanography, UC San Diego
Edwards, Chris - UC Santa Cruz
Goericke, Ralph - Scripps Institution of Oceanography, UC San Diego
Goldstein, Tracey - UC Davis
Hildebrand, John - Scripps Institution of Oceanography, UC San Diego
Jacobsen, Mark - Department of Economics, UC San Diego
Keeling, Ralph - Scripps Institution of Oceanography, UC San Diego
Koslow, J. Anthony - Scripps Institution of Oceanography, UC San Diego
Kriegman, David - UC San Diego
Mangel, Marc - UC Santa Cruz
Marinovic, Baldo - UC Santa Cruz
Miller, Arthur - Scripps Institution of Oceanography, UC San Diego
Mulligan, Timothy - Humboldt State University
Palkovacs, Eric - UC Santa Cruz
Ralp, Marty - Scripps Institution of Oceanography, UC San Diego
Ramanathan, Veerabhadran - Scripps Institution of Oceanography, UC San Diego
Roemmich, Dean - Scripps Institution of Oceanography, UC San Diego
Rudnick, Dan - Scripps Institution of Oceanography, UC San Diego
Semmens, Brice - Scripps Institution of Oceanography, UC San Diego
Send, Uwe - Scripps Institution of Oceanography, UC San Diego
Sirovic, Ana - Scripps Institution of Oceanography, UC San Diego
Sprintall, Janet - Scripps Institution of Oceanography, UC San Diego
Subramanian, Aneesh - Scripps Institution of Oceanography, UC San Diego
Sugihara, George - Scripps Institution of Oceanography, UC San Diego
Swift, James - Scripps Institution of Oceanography, UC San Diego
Terrill, Eric - Scripps Institution of Oceanography, UC San Diego
Thode, Aaron - Scripps Institution of Oceanography, UC San Diego
Tissot, Brian - Humboldt State University
Ward, Darren - Humboldt State University
Whitehead, Andrew - UC Davis
Xie, Shang-Ping - Scripps Institution of Oceanography, UC San Diego
Zilberman, Nathalie - Scripps Institution of Oceanography, UC San Diego

RESEARCH TASKS AND THEMES

Research Tasks

Under the Cooperative Institutes' cooperative agreement, five tasks are outlined by CIMEC and agreed upon by NOAA, allowing CIMEC to group and account for research more easily. The tasks are defined as follows:

Task 1. Administration
Task 1 funding is for administration of the Institute and includes support for the CIMEC Director's office and minimal support for the staff. It includes costs associated with annual scientific meetings that are deemed important for the CIMEC Director to attend, workshops sponsored by CIMEC, web-site development and maintenance, funding for the Joint Institute Director's and executive board and fellows meetings.

Task 2. Joint NOAA Laboratory/CIMEC Collaboration
Collaborative proposals have NOAA and participating California University partners working together jointly on research themes. These proposals are divided by theme and include all research associated with funding including the funding of salaries, benefits, travel as well as instrumentation and computer time.

Task 3. Individual Science Projects
Cooperative research proposals are specific to the CIMEC theme areas, but submitted by individual scientists of CIMEC. The distinction here is that there is a loosely bound tie between individuals working on similar themes or topics. It is also seen that this may be a mechanism for developing collaborative proposals in the future, as well as encouraging new areas of research to develop. These proposals are divided by theme and include all research associated funding including the funding of salaries, benefits, travel and instrumentation and computer time.

Task 4. Education and Outreach
In support of NOAA's Mission and Strategic Plan, CIMEC's Task 4 was developed to strengthen and coordinate an education and outreach component to compliment and convey CIMEC research into the academic and public realms.

Task 5. CIMEC Research Infrastructure Proposals
Because proposals relevant to CIMEC will use a variety of observation platforms in order to carry out the research objectives, an infrastructure task by theme area was defined, which includes proposals for platform and specialized research facilities.

Research Themes

Four thematic areas form the basis for research performed in partnership with NOAA. Each of these areas is relevant to the NOAA mission elements, particularly those of environmental assessment and prediction and environmental stewardship.

Theme A. Climate and Coastal Observations, Analysis and Prediction Research
The primary goals for this research theme are to understand the remote forcing functions that control fundamental ocean and atmosphere processes and to utilize this knowledge for prediction. For CIMEC the basis of interest is primarily the Pacific, although other areas may be studied as a model or to put the Pacific information in context (e.g., Indian, Arctic). These thrust areas include the following:

Oceanic roles in climate and global change
The oceans contain 96% of the Earth's free water. They are the source of 86% of all evaporation and the direct recipient of 78% of rainfall. The salinity of the ocean surface layer reflects the global pattern of evaporation minus precipitation, with salinity maxima in regions of excess evaporation and minima in regions of excess rainfall. The meridional transport of water vapor in the atmosphere is equal and opposite to the freshwater transport in the ocean. Long-term trends in salinity show the evaporative regions of the ocean becoming saltier and the high precipitation areas fresher indicating an acceleration of the global hydrological cycle. Slow freshening of the oceans as a whole is a yardstick for the melting of glaciers, ice sheets, and sea ice. Past research in the hydrological cycle has been focused on the land and atmosphere, while the large role of the oceans has been poorly observed. It is increasingly clear that the complete global hydrological system, including the oceans, must be addressed.

Last, and very importantly among (physical) global change issues, is sea level rise. The present observing system includes satellite and in situ observations of total sea level, plus satellite measurements of changes in ocean mass and in situ observations of the ocean's steric height. While the majority of future sea level rise may come from melting Antarctic and Greenland ice sheets, the steric component of sea level is nonetheless significant, and the increasing heat content of the high latitude oceans is a key factor in understanding and predicting melting and precipitation (ice deposition) rates.

CIMEC projects contribute to datasets in an effort to build the models to address these important issues.

Coastal oceans and climate
The scientific community is faced with challenging issues across our coastal waters:

- How do human activities impact the coastal ocean?
- How do coastal ecosystems respond to climate change?
- How does climate change and sea level rise present itself at local scales?
- What role does the coastal ocean play in the global biogeochemical cycles?
- What processes determine community structure in coastal ecosystems?
- How can we predict and mitigate coastal hazards that impact human populations?

CIMEC has a myriad of tools within its partner institutions, including the long-running CalCOFI program with its 60-year time series of the California Current, at its disposal to help investigate these questions and find the solutions to the problems some of these questions pose.

Theme B. Climate Research and Impacts
Observations and model simulations are crucial elements needed to guide decisions over the next several decades as global scale changes in climate, sea level and other environmental components such as aerosols and land surface changes continue to produce great impacts across the United States.

Regions affected by these changes include the region of the western mountainous states, in particular, California and the adjacent coastal zone. CIMEC research will study climate and its impact on society to serve the nation's needs for climatic information with programs conducting applied climate research to assist decision makers prepare for and adapt to climate changes, both natural and (potentially) anthropogenic.

Theme C. Marine Ecosystems

CIMEC will directly address NOAA's Ecosystem Mission Goal to "protect, restore, and manage the use of coastal and ocean resources through the ecosystem approach to management". Fisheries and protected species and their relation to the environment, including climate change, are broad areas of research and teaching within CIMEC, and will include participation from faculty, graduate students, postdocs, and NOAA colleagues.

Ecosystem characteristics of particular interest are marine population dynamics, biodiversity, and biogeochemistry. The means by which these will be investigated include observing, process studies, and modeling. Collectively, the results are used to assess and predict ecosystem productivity and health for decision makers. Fishing affects both the target species and their environment. Climate change will affect marine ecosystems through rising sea level, warming, ocean acidification, deoxygenation, and potential changes in productivity and circulation.

Primary regions of interest are the California Current Ecosystem (CCE), the Eastern Tropical Pacific (ETP), and the Southern Ocean (SO). Fisheries management research, such as the long-running 60-year time series of the California Current conducted under the CalCOFI program, provides policymakers and management officers with the information needed to manage the nation's marine resources.

Theme D. Ecosystem-Based Management

Fisheries management has undergone a paradigm shift in recent years from an exclusive focus on individual assessments of commercially exploited stocks to maximize sustainable yield (or comparable metric) to a precautionary, ecosystem-based approach. Ecosystem-based management (EBM) explicitly considers human impacts on key predator, prey and competitor species, on bycatch species and benthic habitat, as well as on directly targeted stocks. NOAA is mandated to manage US fisheries within an EBM framework and is implementing integrated ecosystem assessments (IEA) as a critical science-support tool.

The 60-year California Cooperative Oceanic Fisheries Investigations (CalCOFI) program is one of the longest running ocean observation programs in the world. A joint program of the Scripps Institution of Oceanography, the Southwest Fisheries Science Center (NMFS/NOAA), and the California Department of Fish and Game, CalCOFI is designed to provide data for stock assessment of key commercial species, as well as physical, chemical, and biological data on the state of the California Current ecosystem (CCE), including quantitative observations on ecologically critical species of krill, fish, seabirds and mammals. CalCOFI observations have provided the basis for much of our current understanding of the impact of climate variability (the El Niño, Pacific Decadal Oscillation, and the North Pacific Gyre Oscillation) on the CCE. In the future, CalCOFI will provide much of the observational 'backbone' for integrated ecosystem assessments (IEAs) and ecosystem-based management (EBM) of the CCE, as well as for modeling and understanding the impacts of long-term climate change.

<u>Integration of Marine Protection Areas (MPAs) and Conventional Fishery Management</u>

More than 15 percent of the coast of California will soon be in MPAs implemented under California's Marine Life Protection Act. Modeling of the effects of these for decision makers has been done by

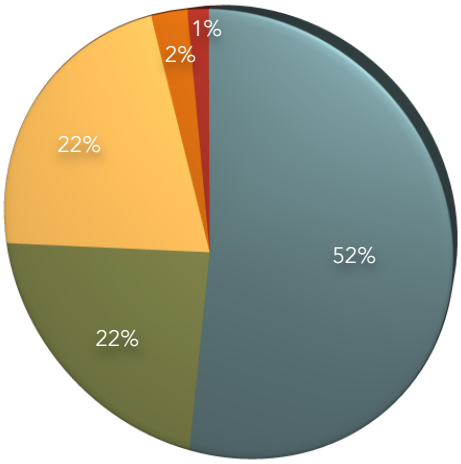
Partner labs, and will soon be started in a Sea Grant project to develop models to use in the evaluation of ongoing monitoring efforts.

The Center for Stock Assessment Research (CSTAR)

CSTAR was formed in 2001, as a collaboration between the NMFS laboratories in Santa Cruz and Pacific Grove, with the objective of undergraduate, graduate and post-doctoral research and training associated with the problems of assessing the numerical abundance, spatial distribution, size distribution and reproductive status of commercially important fish species and thereby increasing the pool of quantitatively trained biologists available to be hired by NMFS. The program of research and training at CSTAR is science done in the national interest and moves in the direction outlined by the National Research Council in its report "Recruiting Fishery Scientists."

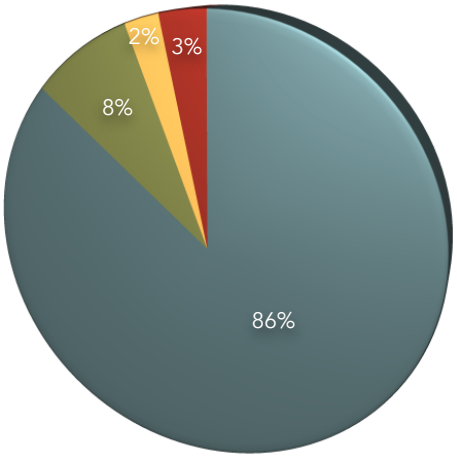
FUNDING SUMMARY

CIMEC Funding by Theme
$18,913,108

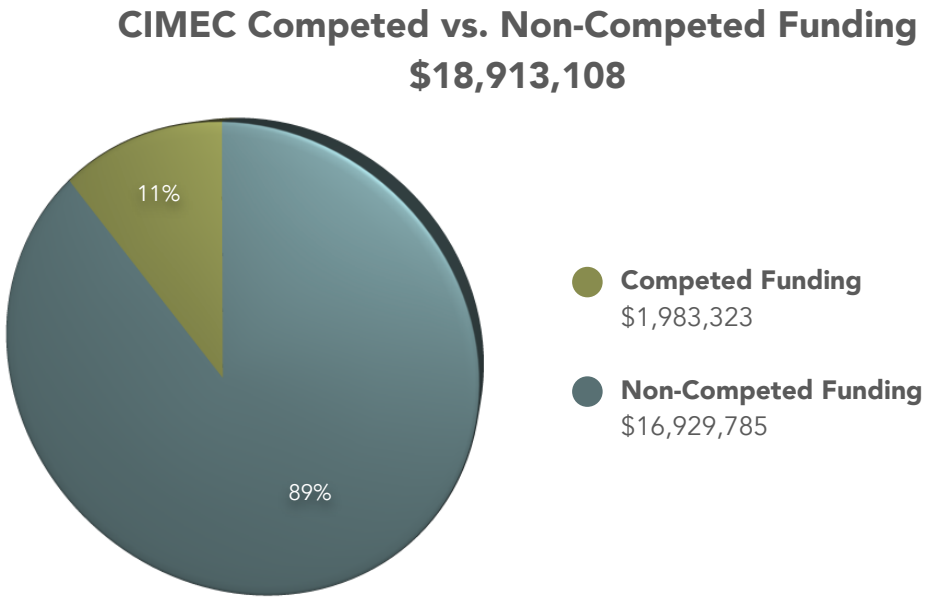


- **Theme A:** $9,770,038
  Climate and Coastal Observations, Analysis and Prediction Research
- **Theme B:** $4,226,201
  Climate Research and Impacts
- **Theme C:** $4,179,326
  Marine Ecosystems
- **Theme D:** $470,089
  Ecosystem-Based Management
- **Task 1:** $267,454
  Administration

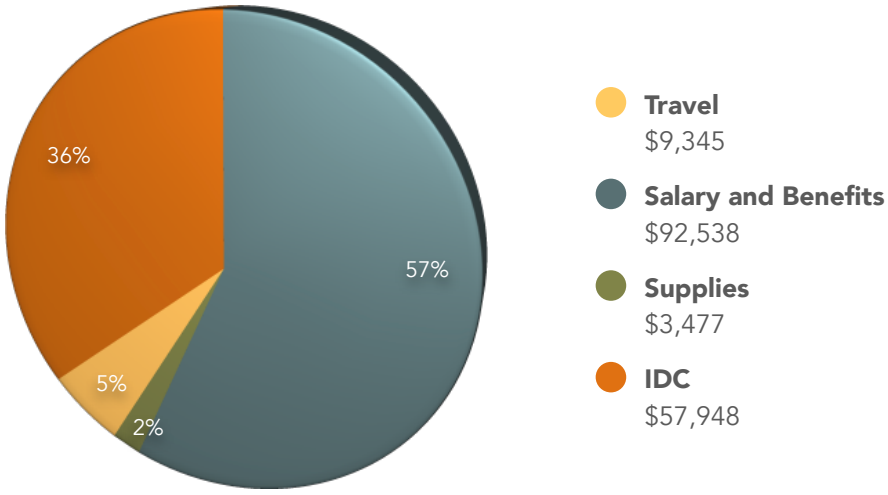
CIMEC Funding by Task
$18,913,108



- **Task 1**: $467,454
  Administration
- **Task 2**: $16,340,220
  Joint NOAA Lab/CIMEC Collaboration
- **Task 3**: $1,485,547
  Individual Science Projects
- **Task 5**: $619,887
  CIMEC Research Infrastructure Proposals

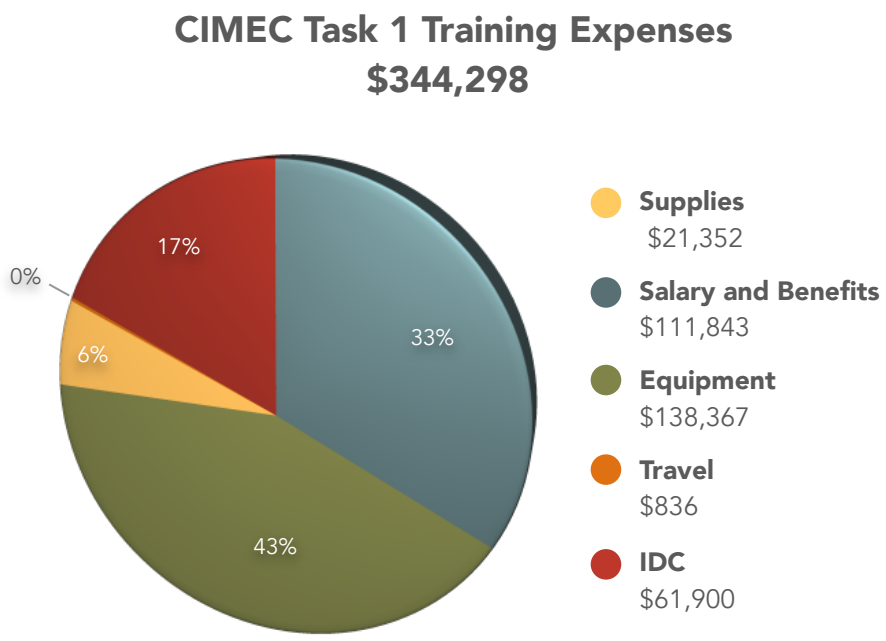

CIMEC Competed vs. Non-Competed Funding
$18,913,108
11%
89%
Competed Funding
$1,983,323
Non-Competed Funding
$16,929,785

CIMEC Task 1 Administration Expenses
$163,309



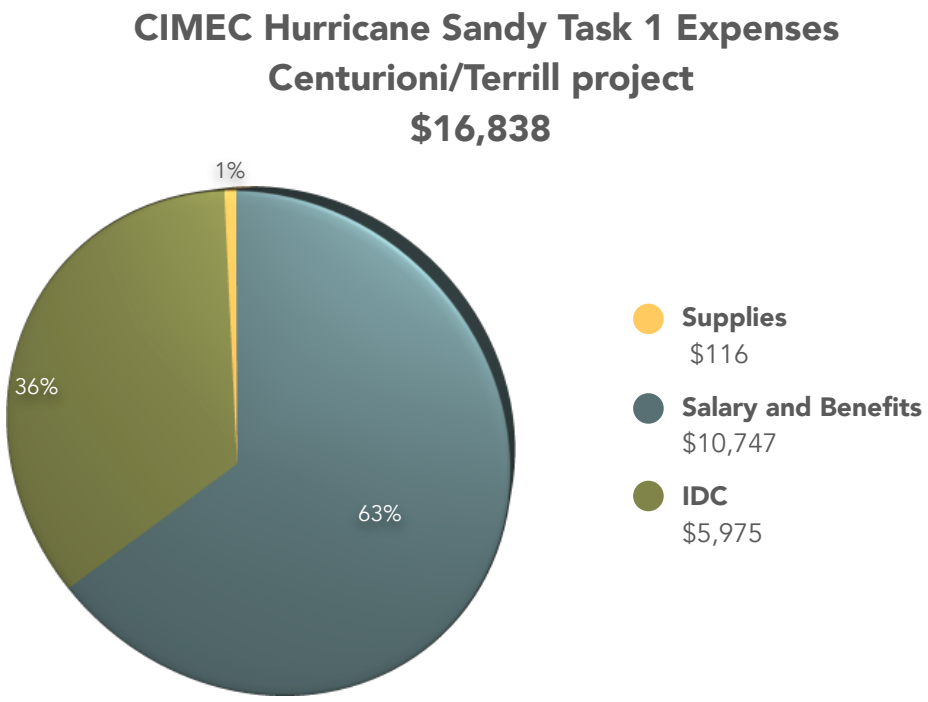
CIMEC Task 1 Administration Expenses April 1, 2014 – March 31, 2015		
Category	**Awarded**	**Expensed**
Salary and Benefits	$66,270	$92,538
Supplies	$4,863	$3,477
Travel	$3,000	$9,345
IDC	$40,773	$57,948
Total	**$114,906**	**$163,309**

Salary and Benefit expenditures are comprised of support for the CIMEC Director and Administrative staff. Supply expenditures comprise NGN costs (network support), project specific supply costs and meeting costs. Travel expenses were for costs associated with the CIMEC Formal Review, which was held in February 2014, but Partner Institute expenses did not post until April and June 2014. The CIMEC Director attended the CI Annual Meeting Held in Silver Spring, MD in March 2015.



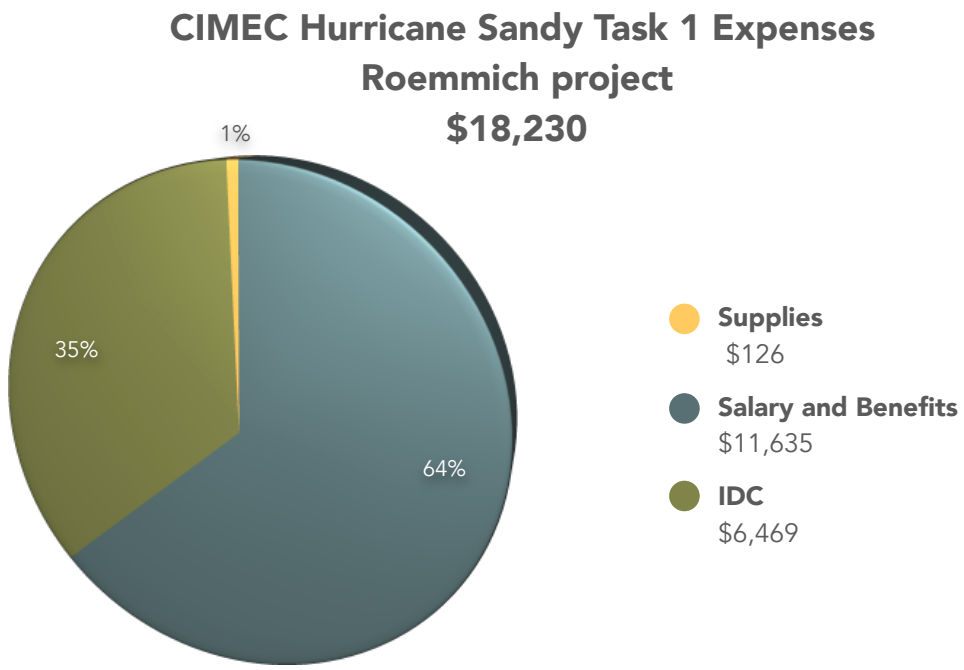
CIMEC Task 1 Training Expenses April 1, 2014 – March 31, 2015		
Category	**Awarded**	**Expensed**
Salary and Benefits	$87,572	$111,843
Equipment	$74,720	$148,367
Supplies	$1,250	$21,352
Travel	-	$836
IDC	$36,458	$61,900
Total	**$200,000**	**$344,298**

Task 1 "Training of the Next Generation of Marine Population Dynamics Scientists" is a continuing project.



CIMEC Hurricane Sandy Task 1 Expenses Centurioni/Terrill April 1, 2014 – March 31, 2015		
Category	**Awarded**	**Expensed**
Salary and Benefits	$11,000	$10,747
Supplies	$78	$116
IDC	$6,092	$5,975
Total	**$17,170**	**$16,838**

Hurricane Sandy Task 1 is related to the Luca Centurioni and Eric Terrill project.



CIMEC Hurricane Sandy Task 1 Expenses Roemmich project April 1, 2014 – March 31, 2015		
Category	**Awarded**	**Expensed**
Salary and Benefits	$16,643	$11,635
Supplies	$132	$126
IDC	$9,225	$6,469
Total	**$26,000**	**$18,230**

Hurricane Sandy Task 1 is related to the Dean Roemmich project.

RESEARCH HIGHLIGHTS

CIMEC research activities are categorized by the following themes:

A. Climate and Coastal Observations, Analysis and Prediction Research
B. Climate Research and Impacts
C. Marine Ecosystems
D. Ecosystem-Based Management

Research highlights, or Executive Summaries, of the most recent individual research projects are summarized below and are more fully developed in the body of this report.

Theme A: Climate and Coastal Observations, Analysis and Prediction Research

Collaborative Scientific and Technical Support to the NOAA Earth System Research Laboratory

Yehuda Bock, Scripps Institution of Oceanography, UC San Diego
Peng Fang, Scripps Institution of Oceanography, UC San Diego

- Maintained high reliability orbit solutions in terms of two global sub-networks in parallel with an automatic failover system.
- Started using ''true-to-day' a priori site position for routine data processing to take advantage of self-consistent reference frame, in addition to using the most updated error models.
- Continued to improve the orbit quality control procedure to reduce the risk of contaminating the IPW estimates in the GPS/Met solutions.

California Cooperative Oceanic Fisheries Investigations (CalCOFI), and Ocean Observation Program for the Southern California Current

Dr. David M. Checkley, Jr., Scripps Institution of Oceanography, UC San Diego
Dr. Ralf Goericke, Scripps Institution of Oceanography, UC San Diego

- Observation of anomalous North pacific warming.
- Use a CalCOFI-derived temperature index in the management of the Pacific sardine fishery.
- Initiation of underway pH and pCO2 measurements.
- Initiation of directed sampling for the NOAA-CalCOFI Ocean Genomics (NCOG) program.
- Collaboration with Dr. Ken Buesseler (WHOI) to investigate if Fukushima accident effects are detectable off California.
- Release of surface drifters for the Global Drifter Program (OAR) and Apex profiling floats for US Navy.

Developing a data-assimilative modeling tool to estimate oxygen and pH over the California Current System shelf

Christopher A. Edwards, UC Santa Cruz

- Oxygen and carbonate chemistry dynamics have been successfully added to the nonlinear NEMURO biogeochemical model.
- Tangent linear and adjoint versions of oxygen dynamics required for 4DVar assimilation have been successfully implemented and tested.
- Tangent linear and adjoint versions of carbonate chemistry are underway.

An Atmospheric River Case Study on the Russian River and a Vision for Western US Observing Systems

Dr. F. Martin Ralph, Scripps Institution of Oceanography, UC San Diego

- The March 2012 and December 2012 case studies are examples in the difficulties in managing a reservoir for both flood control and water supply.
- The case studies showed the importance of atmospheric rivers to water supply in the Russian River.
- The case studies have also supported the development of a Forecast Informed Reservoir Operations steering committee.
- A journal article suggesting the importance and how to proceed with developing a western observing system for extreme precipitation.

CalWater and West-Coast Atmospheric River Research

Dr. F. Martin Ralph, Scripps Institution of Oceanography, UC San Diego

- AR Portal website fully functional in real-time
- AR Detection Tool (ARDT) locally functional in real-time
- Historical record of AR activity developed using ARDT and Reanalysis data
- CalWater2 dropsonde measurements processed and analyzed
- Several new AR forecast tools developed and added to AR Portal website

The Argo Program – Global Observations for Understanding and Prediction of Climate Variability

Dean Roemmich, Scripps Institution of Oceanography, UC San Diego
John Gilson, Scripps Institution of Oceanography, UC San Diego

- Two prototype Deep SOLO floats, capable of profiling to 6000 m depth, were successfully deployed by RV Tangaroa in June 2014 and have each completed 75 cycles to 5700 m depth.
- 1968 research publications since 1998 have used Argo data http://www.argo.ucsd.edu/Bibliography.html, including 349 during 2014.
- The Argo Program is obtaining over 11,000 Temperature/Salinity/Pressure profiles per month.
- The Argo Program has sustained its global coverage of more than 3000 active floats since 2007.

- N. Zilberman published an estimate of basin-wide absolute geostrophic velocity and meridional transport in the South Pacific Ocean at 32°S, using Argo profile and trajectory data, in the Journal of Geophysical Research.
- D. Roemmich estimated global ocean heat gain of 0.5 W/m^2 during the Argo era in a paper published in Nature Climate Change.

SIO High Resolution XBT/XCTD Transects

Janet Sprintall, Scripps Institution of Oceanography, UC San Diego
Dean Roemmich, Scripps Institution of Oceanography, UC San Diego
Bruce Cornuelle, Scripps Institution of Oceanography, UC San Diego

- A case study on combining High Resolution XBT, Argo, and satellite altimetry data for estimations of western boundary current mean and time-varying volume transport was carried out by N. Zilberman and colleagues in the East Australian Current.
- High Resolution XBT data provide the near-surface and subsurface temperatures structure and the geostrophic current, 0-800m, flowing across the sampled routes, on a quarterly basis and with spatial resolution as fine as 10-15 km in boundary current regions.
- Data from Scripps High Resolutions XBT transects have been used in 10 PhD dissertations.

HF Radar National Network Data Management Development

Dr. Eric Terrill, Scripps Institution of Oceanography, UC San Diego

- Configured two new servers (1) a new development server and (2) a new processing server for redundancy and new product processing.
- Configured nodes, systems designed to act as data repositories and vector processing for the participating Institutions: SIO, NDBC, and Rutgers University.
- Supported International radial acquisition and RTV processing within HFRNet for two regions: Canada and Mexico
- Supported International totals for two regions: Australia, and Spain
- Upgraded National HFR metric
- Maintained THREDDS server for near real-time RTV's
- New Codar sites were made available to all Nodes for RTV processing:
    - Newport Beach, CA (SCNB) University of Southern California http://cordc.ucsd.edu/projects/mapping/stats/?sta=SCNB
    - Core Banks, NC (CORE) University of North Carolina http://cordc.ucsd.edu/projects/mapping/stats/?sta=CORE
    - Long Point Wildlife Refuge, MA (LPWR) Woods Hole Oceanographic Institution http://cordc.ucsd.edu/projects/mapping/stats/?sta=LPWR
    - MVCO Meteorological Mast, MA (METS) Woods Hole Oceanographic Institution http://cordc.ucsd.edu/projects/mapping/stats/?sta=METS
    - Squibnocket Farms, MA (SQUB) Woods Hole Oceanographic Institution http://cordc.ucsd.edu/projects/mapping/stats/?sta=SQUB
    - Bradley Beach, NJ (BRAD) Rutgers University http://cordc.ucsd.edu/projects/mapping/stats/?sta=BRAD
- Decommissioned Sites
    - San Mateo Point, CA (SDSM) Scripps Institution of Oceanography

- Supported Domains and available data:
- USEGC – US East and Gulf Coast – 2008-03 through present
- USWC – US West Coast – 2008-03 through present
- GAK – Gulf of Alaska – 2009-05 through present (when available)
- PRVI – Puerto Rico and US Virgin Islands – 2010-01 through present

Develop Forecast Methods and an "AR Portal" for Atmospheric River Data and Tools

Dr. Daniel Cayan, Scripps Institution of Oceanography, UC San Diego

- AR Portal website fully functional in real time
- AR Detection Tool (ARDT) locally functional in real time
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Targeted In-Situ Tropical Cyclone Observations from Ocean Sensors

Luca Centurioni, Scripps Institution of Oceanography, UC San Diego
Eric Terrill, Scripps Institution of Oceanography, UC San Diego

- mADOS software simulations designed to determine buoyancy and hardware requirements on December, 2014
- mADOS sensor selection finalized and CAD hardware design and FEA simulations completed April, 2015
- mADOS hardware fabrication began May, 2015, and preliminary field data collection will begin July, 2015.
- First miniature wave buoy (MWB) article rotochute was fabricated by September 30, 2014.
- Successful drop tests were conducted off of SIO pier (30m) on January 31, 2015.
- The MWB electronics package has been designed and integrated into the A-size MWB package and a new antenna has been designed.
- MWB data set has been compared to CDIP Datawell Buoy (Scripps Nearshore #201) with good results as expected.

Bridging the gap in NOAA's extended and long range prediction systems through the development of new forecast products for weeks 3 and 4

Shang-Ping Xie, Scripps Institution of Oceanography, UC San Diego

- Ongoing development of first weeks 3-4 statistical tool for forecaster decision support well underway and on track for implementation in September 2015
- Five papers submitted, in press, or published, including a NOAA MAPP-supported *Nature* paper on temperature extremes in press
- Advances in understanding subseasonal ENSO variability and the dynamics of extratropical variability
- NOAA MAPP webinar on project delivered by Co-I Johnson in February 2015

Western Boundary Current Transport as a Climate Index

Nathalie Zilberman, Scripps Institution of Oceanography, UC San Diego
Dean Roemmich, Scripps Institution of Oceanography, UC San Diego
Sarah Gille, Scripps Institution of Oceanography, UC San Diego

- A method was developed for improving estimates of the volume transport in the EAC region.
- Preliminary estimates of the mean volume transport in the EAC System off Brisbane are 18.3 Sv southward for the EAC west of 155.6°E, with a recirculation of 4 Sv northward between 155.6°E and 158°E.
- EAC strengthening and weakening result from local wind-stress curl forcing.
- EAC transport variability at interannual time scales shows El Niño-Southern Oscillation (ENSO) signature.

Modernizing the tropical ocean/atmosphere observing system

Dean Roemmich, Scripps Institution of Oceanography, UC San Diego
Daniel Rudnick, Scripps Institution of Oceanography, UC San Diego
Bruce Cornuelle, Scripps Institution of Oceanography, UC San Diego
John Gilson, Scripps Institution of Oceanography, UC San Diego

- 38 out of the 41 equatorial Argo floats deployed by this project remain active, having completed 65-70 cycles each since deployment in early 2014.
- Repeated Spray glider transects of temperature, salinity, pressure, and chlorophyll fluorescence along 95°W from 2°S to 2°N were obtained throughout the year, including about 1400 dive cycles..
- Improved estimates of the spatial statistics of variability in the tropical Pacific, by F. Gasparin based on Argo data, have allowed more accurate mapping of tropical Pacific Ocean variability than was previously possible.
- Automation of the ocean state estimation, using all available observing systems, has continued with additional testing on assimilation window lengths and blending methods.
- A major eastward propagating event in the equatorial thermocline (7°C temperature anomalies) was observed in float and glider data in early 2015

A Nudging and Ensemble Forecasting Approach to Identify and Correct Tropical Pacific Bias-Producing Processes in CESM

Dr. Arthur J. Miller, Scripps Institution of Oceanography, UC San Diego
Dr. Aneesh Subramanian, Scripps Institution of Oceanography, UC San Diego

- First global climate model with couple data assimilation being analyzed for model biases
- Identified the reduction in double ITCZ bias in the CESM
- Recruited Ph.D. student Jonathan Eliashiv (SIO) to participate in this research

NOAA Ocean Acidification Program CalCOFI OA Monitoring and QA/QC Analytical Support

Dr. Andrew G. Dickson, Scripps Institution of Oceanography, UC San Diego

- We continue to submit our data from high-quality measurements of goal alkalinity and total dissolved inorganic carbon from CalCOFI samples to the CalCOFI database, and to Dr. Alin at NOAA/PMEL
- The workshop we held on the quality control of CO2 measurements was considerd a success by the various participants.

Integrated Boundary Current Observations in the Global Climate System

Uwe Send, Scripps Institution of Oceanography, UC San Diego
Russ Davis, Scripps Institution of Oceanography, UC San Diego
Daniel Rudnick, Scripps Institution of Oceanography, UC San Diego
Bruce Cornuelle, Scripps Institution of Oceanography, UC San Diego
Dean Roemmich, Scripps Institution of Oceanography, UC San Diego

- Continuous occupation of two CC sections with gliders and one SS section with gliders, with 100% data return
- Occupation of one cross-shore and one along-shore CC section with moorings/PIES, and one SS section
- Analyses of the 2014 warm anomaly off California in glider and mooring data
- Extended and improved transport time series through the SS in density layers
- Validation of SS transports with the endpoint moorings/PIES, skill of using PIES/moorings and PIES/altimetry
- Final product of merging of HR-XBT, ARGO, and altimetry for optimal estimates of EAC transport
- Short-term state estimates generating indices for the CC

Theme B: Climate Research and Impacts

Global Drifter Program

Luca Centurioni, Scripps Institution of Oceanography, UC San Diego

- GDP array completed with 1,424 drifter in the array at the time of writing
- SIO is now posting drifter data to the GTS
- Significant increase in the number of drifters in the Indian Ocean
- Coordinated GDP Activities Between Partners and Support of other science programs
- Enhanced the GDP Array with Matching Contributions
- Monitored and Advised the Drifter Manufacturers to Ensure Drifter are Built According to Specifications
- Updated and Maintain the Enhanced GDP dataset/GDP data distribution
- Maintained Statistics of Drifter Performances
- Reported GDP activities and research at several meetings and conferences
- Scientific Analysis of GDP data

Measurements of O_2/N_2 & Ar/N_2 ratio by the SIO O_2 program

Ralph Keeling, Scripps Institution of Oceanography, UC San Diego

- Measurements have continued which resolve global atmospheric trends in O2 and CO2 and can quantify global carbon sinks
- Data from program are increasingly relied on as benchmark for ocean biogeochemical model validation
- The data provide emergent constraints on natural ocean heat transport from southern to northern hemispheres.

Meridional Overturning Variability Experiment (MOVE)

Uwe Send, Scripps Institution of Oceanography, UC San Diego
Matthias Lankhorst, Scripps Institution of Oceanography, UC San Diego

- PIES recovered, new PIES deployed, additional data downloaded acoustically, over 14-1/2 years of data in hand now
- Increasing transport since 2008 confirmed, also by referencing to PIES and GRACE bottom pressure data

NOAA Support for the CLIVAR and Carbon Hydrographic Data Office at UC San Diego/SIO

Dr. James H. Swift, Scripps Institution of Oceanography, UC San Diego
Dr. T. Bruce Appelgate, Scripps Institution of Oceanography, UC San Diego

- Continued increase of US and non-US CTD profiles, both public and non-public, available for Argo reference data.
- Continued reconciliation of EXPOCODE expedition identifiers among US data centers.

- Establishment of the means for large data users (e.g., modelers) to directly download any/all data of interest, for example all-basin data, or all program (e.g. WOCE) data.
- On-going harmonization of disparate data centers and the data from various large-scale hydrographic surveys has led to a better "capture percentage" of all data (US-HYDRO, GO-SHIP, DIMES). Because the CCHDO carries out data curation for these programs, their data interoperability is improved as the metadata and discovery information. NOAA/NODC benefits because it obtains all curated data from the CCHDO.
- NOAA funded observations are captured by the CCHDO through the GO-SHIP, Argo and OceanSITES programs and are provided in a uniform format with consistent content. The CCHDO is an IODE Associated Data Unit (ADU), a class of IODE members created specifically to include organizations such as BCO-DMO, CDIAC and the CCHDO, on par with each member nation's NODC.
- The CCHDO's involvement in IODE, SOOS, Argo, OceanSITES, GO-SHIP, DIMES and related organizations leads to continued improvement in the areas of NOAA interest funded by the award.

Coping with Drought in California's Russian River Watershed

Dr. F. Martin Ralph, Scripps Institution of Oceanography

- Determined the impacts of drought on the diverse stakeholders within the Russian River Watershed.
- Determined 5-6 important drought indicators for the Russian River
- Determined that 3-7 year mega-drought would be most informative to stakeholders and will use the historical record to provide justification for the context of the mega-drought scenario.
- Preliminary research suggests that ARs are likely to become more intense in the future due to increase water vapor, though the frequency, duration and period without ARs are still to be analyzed.

Intraseasonal to Interannual Variability in the Intra-Americas Sea in Climate Models

Shang-Ping Xie, Scripps Institution of Oceanography

- We developed several successful process-oriented model diagnostics that can distinguish between models with good and poor intraseasonal variability, to inform model development.
- We have shown that the ENSO-forced Pacific–North American (PNA) teleconnection pattern is projected to move eastward and intensify under the climate warming, intensifying rainfall anomalies on the west coast of North America.
- We showed that basin-wide total TC counts/days are much more predictable than local TC occurrence, identifying a serious challenge to the prediction of U.S. landfall hurricanes.

Moored carbon, biogeochemical, and ecosystem observations in the Southern California Current

Uwe Send, Scripps Institution of Oceanography
Mark Ohman, Scripps Institution of Oceanography

- Recovery and re-deployment of two equivalent highly instrumented real-time moorings across the California Current ecosystem with physical, chemical, carbon, and ecosystem sensors
- Calculation of dynamic f-ratios showing changes between new and regenerated production
- Changes in water masses coordinated with changes in acoustic fish detections
- Impact of 2014 warm anomaly on aragonite saturation and potentially related changes in along-shelf flow

Theme C: Marine Ecosystems

Ocean Observing and Fisheries Oceanography Research off Northern California

Brian Tissot, Humboldt State University

- 12 successful ocean observing cruises along the Trinidad Head Line.
- Observations from coastal waters off Northern California contributed to State of the California Current Report (Leising et al, 2014) and a book chapter highlighting the value of zooplankton data from coastal transects for ocean observing systems (Bjorkstedt and Peterson, in press).
- Data have supported analyses of copepod community dynamics and energetic content in zooplankton communities in the northern California Current, resulting in presentations at the 2014 Eastern Pacific Ocean Conference (Cass, "Latitudinal and temporal variability in lipid and energy content of the northern Pacific euphausiids *Euphausia pacifica* and *Thysanoessa spinifera*" and Bjorkstedt and Peterson, "A comparison of mid-shelf copepod assemblages in the northern California Current: Coherence and variability in the context of local and regional forcing"), and the 2014 CalCOFI meeting (Bjorkstedt and Peterson, "Coherence, variability, and potential predictability of mid-shelf copepod assemblages in the northern California Current").

Collaborative Opportunity: Exploring 'omic Technologies to Support Ecosystem Understanding and Fisheries Assessments

Andrew Allen, Scripps Institution of Oceanography

- Design and implementation of MiSeq technologies
- Implementation of epmotion robotics platform
- Data generated for 16S and 18S DNA for 2014 samples (all four cruises)
- Preliminary analyses of data suggest large scale contrast between cyano dominated vs diatom dominated food webs

Evaluation of exposure to and infection with Phocine Distemper Virus to the eastern Distinct Population Segment of Steller sea lions (*Eumetopias jubatus*) and continued monitoring of the western Distinct Population Segment

Tracey Goldstein, UC Davis

- In addition to the 334 Steller sea lion serum samples tested for antibodies against Phocine Distemper virus to examine exposure in the previously untested eastern Distinct Population segment for comparison with results from animals in the western Distinct Population segment off Alaska and Russia during the last reporting period, 352 nasal swabs collected from animals in the central Aleutians (Bogoslof Island) and eastern Aleutians (Aggattu, Ulak and Ugamak Islands) in Alaska in 2011 and 2013; and the Commander Islands (Medney Island and Koslova Cape) and Sea of Okhotsk (Yamsky and Iony Islands) off Russia in 2004 (final results are pending); and six tissues from two animals that stranded and died in Southeast Alaska in 2013 and 2014 were tested during this reporting period.
- Although Nasal swab samples were only available for testing for some years, PCR results supported the serology data confirming that infection did occur first after 2002 and again more recently after 2009.
- PCR results showed that animals sampled throughout the Aleutian Islands and in the central Gulf of Alaska were positive for virus.
- Results to date thus indicate that exposure to Phocine Distemper virus is more widespread than previously thought in Steller sea lions and appears to be circulating in the populations across the eastern Pacific.

The Next Generation of CoralNet: Improving Automated Methods Benthic image Analysis and Optimizing for NMFS Benthic Imagery

David Kriegman, Scripps Institution of Oceanography

- Novel method based on Convolutional Neural Networks was applied to the benthic survey image annotation problem.
- These new methods improve the accuracy by 10%, and enable 78% of the annotation work to be done automatically.
- New operational modes of annotation have been implemented in CoralNet.
- The NOAA Coral Reef Ecosystem Division (CRED) has recently taken the first steps towards using CoralNet in their image annotation pipeline.

CSTAR - The Center for Stock Assessment Research

Marc Mangel, UC Santa Cruz

- NSF Post-doc Carl Boettiger continued development of Bayesian Nonparametric methods for the use in fisheries management and published a paper in Proc Roy Soc B on Gaussian Process Dynamic Programming for fisheries management. He will start as Assistant Professor at UCB in July 2015
- PhD student Ryan Driscoll joined CSTAR, after completing a MSc at SDSU. He has extensive field experience (10 cruises in the Antarctic with AMLR) and will develop models for the vertical distribution of krill species.
- PhD student Duran Fiack advanced to candidacy and continues his work exploring the effects of hydraulic fracturing on habitat for Central Valley and Coastal salmon species.
- Junior Specialist Nick Grunloh (MSc in Statistics and Applied Mathematics, UCSC, 2014) joined the CSTAR to work with the Groundfish Team. He is working on improving commercial catch estimates and quantifying uncertainty in commercial landing statistics using Bayesian hierarchical models.
- NSF Post-doc Holly Kindsvater continued her development of methods for data-poor stocks, particularly sharks and sex-changing species such as groupers.
- Post-doc Who-Seung Lee joined CSTAR (replacing Dr. Santiago Salinas, who moved to the University of the Pacific) to work on thermal transgenerational plasticity in fish.
- PhD student and NSF GRF Juan Lopez continued development of life history models for steelhead, including visiting the University of Amsterdam for three months (supported by a NSF GROW fellowship) to work with Prof Andre de Roos on structured population models and field work and modeling on the Carmel River, to understand the maintenance of anadromy.
- CSTAR Director Marc Mangel received a DSc honoris causa from the University of Guelph. . The citation reads "This degree is awarded in recognition of your significant academic contributions combining mathematics and statistics with theoretical ecology and evolutionary biology. You have profoundly influenced an entire generation of ecologists environmental scientists and applied mathematicians on how to solve important practical problems and make the world a better place". He offered a series of 10 lectures on quantitative fisheries science – aimed for MSc level people – at the FED in Jan-Mar 2015
- Post-doc Melissa Hedges Monk worked on both data poor ground fish and a first ever stock assessment for otters in Southeast Alaska; she transitioned to NOAA employment in August 2014.
- Post-doc Valerie Poynor continued to develop Bayesian Nonparametric methods for the analysis of time series data, including the development of fundamental methodology and applications to populations with sparse data.
- PhD student and NSF GRF Kate Richerson completed and had accepted in Marine Ecology Progress Series a major paper on the behavior of krill on oceanic drift trajectories and conducted an analysis of the acoustic data collected by US AMLR.
- Post-doc Santiago Salinas continued his work on thermal transgenerational plasticity in fish and moved to the University of the Pacific as Visiting Assistant Professor. On 1 July 2015, he will start at Kalamazoo College as tenure track faculty.
- Assistant Researcher Jarrod Santora continued his work on predator-prey relations in the California Current and the Antarctic, including two cruises in the southern ocean.
- CSTAR Alum and EU Marie Curie Outgoing Fellow Simone Vincenzi continued his work with the Molecular Ecology Team on genetic correlates of life history variation in marbled trout.

Collaborative Acoustic Studies in the Central and Western Pacific Ocean

Ana Širović, Scripps Institution of Oceanography
Simone Baumann-Pickering, Scripps Institution of Oceanography

- Eight years of data from three sites were analyzed for patterns in ocean ambient noise.
- Acoustic propagation models were developed for low frequency (baleen whale) sounds at two locations in the Northern Marianas Islands.
- Acoustic monitoring of 7 species of odontocetes and two unidentified signal types during one year of acoustic data, showing clear diel behavior for some species and possible seasonal trends.

Investigations in Fisheries Ecology

Dr. Eric Palkovacs, UC Santa Cruz

- Developed and began testing and documenting a general salmon cohort reconstruction model.
- Published a journal article evaluating a suite of alternative forecast methods for Sacramento River fall Chinook salmon.
- Published a journal article evaluating match-mismatch dynamics in salmon ocean entry timing.
- Published a report on the potential applications of genetic tagging techniques to coastwide salmon management.
- Published a report on a framework for modeling the life cycle for winter-run Chinook that will help evaluate the effects of water management operations on Chinook salmon in the Central Valley.
- Constructed an aquarium system to evaluate multiple levels of hypoxia and ocean acidification effects on juvenile rockfish.
- Developed statistically-based GIS tool to identify fishing 'hot spots' that was used by Pacific Fishery Management Council to consider spatial closures for rougheye rockfish.
- Published a journal article on the bioenergetics of adult fish migrations in the Sacramento River
- Published a manuscript on salmon growth modeled by Individual Based Model.
- Published a manuscript validating the use of regional oceanographic models for describing central California observations.
- Published a manuscript to provide guidance to ecosystem management and evaluating model complexity.

Freshwater Ecology Research Collaboration

Dr. Eric Palkovacs, UC Santa Cruz

- Published six papers in peer-reviewed journals
- Awarded $920,354 in extramural research funds to support research program
- Member of the Tidewater Goby ESA recovery team organized by US Fish and Wildlife Service
- Member of River Herring technical advisory committee organized by NMFS and the Atlantic States Marine Fisheries Commission
- Participated in South-Central and Southern California Steelhead Research and Monitoring Colloquium
- Gave invited seminars at McGill University and UC Berkeley
- Organized a special session at the Cal-Neva AFS meeting in Santa Cruz
- Primary advisor for 1 Postdoctoral Scholar, 3 PhD students, and 1 Master's student

- Mentored 10 undergraduate students in research projects
- Served on 4 graduate student comprehensive exam committees
- Developed and taught Freshwater Ecology and Freshwater Ecology Lab courses
- Executive Board Member for the Institute for the Ecological and Evolutionary Climate Impacts
- Member of the UCSC Institute for Marine Sciences advisory committee
- Member of the San Francisco Bay Bird Observatory Scientific Advisory Board
- Participated in the NSF Workshop, Identifying and prioritizing directions for long-term ecological research
- Served an NSF panel (DEB – Community and Ecosystem Ecology)

Freshwater Fish Ecology Research Collaboration

Darren Ward, Humboldt State University

- Graduate student Jennifer Rebenack published a paper in Transactions of the American Fisheries Society on life history diversity and monitoring coho salmon populations.
- Graduate student Justin Alvarez produced the first large-scale estimate of the abundance of non-native brown trout in the Upper Trinity River. He electrofished three passes over 40 miles of river while marking and collecting diet samples from over 500 brown trout.
- Molly Gorman was awarded a 2015 California Sea Grant award to continue her work on coho salmon in the Shasta and Klamath Rivers. She was interviewed about her project on ABC's Nightline.

Molecular mechanisms of response to persistent oil spill pollutants

Andrew Whitehead, UC Davis

- We performed exposures of hundreds of killifish embryos to a 5-dose range of whole oil and three fractions
- Developmental abnormalities were scored that provide preliminary data on relative toxicity of fractions
- Videos were collected that may reveal subtle impacts on heart rate
- Detailed chemical analysis is characterizing the chemical composition of our different oil fractions

NOAA/PMEL/EOI addition of days to Moyer Mariana Expedition: R/V *Roger Revelle* - November-December 2014

Bruce Appelgate, Scripps Institution of Oceanography

- Successful sampling of microbial mats in conjunction with associated fluid chemistry measurements in and around iron-dominated hydrothermal vent systems using the Jason ROV.
- Successfully compared several methods of quantifying CO2 output using multi-beam sonar, hydrophone mooring, and water column CTDs.
- Ship support was very good.

NOAA/SWFSC Winter 2015 CalCOFI Cruise Ship Time: R/V New Horizon Cruise Dates January 10 – February 08 2015

Bruce Appelgate, Scripps Institution of Oceanography

- CalCOFI 1501NH winter cruise on RV New Horizon; 15 Jan - 8 Feb 2015.
- 100 stations were successfully occupied; sta 60.90 & a few net tows were cancelled due to high winds & rough seas. SCCOOS stations 80.0 50.5 & 85.4 35.8 were skipped. Refer to station activities for specific station work performed.
- CTD notes: due to the inability of the CTD to power dual T, C, & O2 sensors after sta 64 (80.90), single T, C, & O2 data were collected on casts 65 -100. These include sta 80.100 and all stations north on Lines 77 - 60.
- After the departure of 8 scientists & volunteers in Monterey, the CTD-rosette was programmed to trip 12 bottles.
- Ship support was very good.

Measurements of North Atlantic Ambient Noise

John A. Hildebrand, Scripps Institution of Oceanography

- Deployed High-frequency Acoustic Recording Package south of Bermuda
- Obtained ambient noise data from June 2013 to March 2014
- Low frequency ambient noise levels at this site were comparable to those measured in 1966

Ocean observing and fisheries oceanography research of the coastal ocean off northern California

Dr. Jeffery Abell, Humboldt State University

- 12 successful ocean observing cruises along the Trinidad Head Line.
- Observations from coastal waters off Northern California contributed to State of the California Current Report (Leising et al, 2014) and a book chapter highlighting the value of zooplankton data from coastal transects for ocean observing systems (Bjorkstedt and Peterson, in press).
- Data have supported analyses of copepod community dynamics and energetic content in zooplankton communities in the northern California Current, resulting in presentations at the 2014 Eastern Pacific Ocean Conference (Cass, "Latitudinal and temporal variability in lipid and energy content of the northern Pacific euphausiids *Euphausia pacifica* and *Thysanoessa spinifera*" and Bjorkstedt and Peterson, "A comparison of mid-shelf copepod assemblages in the northern California Current: Coherence and variability in the context of local and regional forcing"), and the 2014 CalCOFI meeting (Bjorkstedt and Peterson, "Coherence, variability, and potential predictability of mid-shelf copepod assemblages in the northern California Current").

Theme D: Ecosystem-based Management

Frontiers of Marine Resources Course

Mark Jacobsen, UC San Diego (Department of Economics)

- Sponsored two additional visitors to the economics department, focusing on natural resources and marine policy
- Department-wide presentations and individual meetings with PhD students working on natural and marine resources

Center for the Advancement of Population Assessment Methodologies (CAPAM)

Brice Semmens, Scripps Institution of Oceanography

- Published 15 additional peer reviewed articles and 1 workshop series proceeding
- Four papers from the CAPAM selectivity workshop special issue are in the Fisheries Research journal's top 25 downloads (as of January 2015)
- Held the annual CAPAM workshop, with a focus on Growth: theory, estimation, at the SWFSC on the SIO campus. The workshop was attended by 100 scientists from around the world, and generated a special issue in the peer-reviewed journal Fisheries Research.
- CAPAM's research scientist Juan Valero continues to working with graduate students and post-docs from the University of Washington, Simon Fraser University and University of British Columbia in collaboration with scientists from the NWFSC in Seattle. The goal of this collaborative work is to provide education and mentoring opportunities for upper level graduate students interested in learning quantitative stock assessment methods.

Identifying Critical Habitat for Highly-Mobile Marine Vertebrates under the Endangered Species Act

Brice Semmens, Scripps Institution of Oceanography

- We have developed a spatially-explicit individual based model (IBM) to explore the effects of changes in prey availability at various locations on the energy balances of endangered Southern Resident Killer Whales (Orcinus orca).
- Postdoc Charlotte Boyd has published or submitted several peer-reviewed publications related to spatial prediction in fisheries, management of marine species of concern, and fisheries bycatch.

Using Combined Video/Acoustic Recordings of Marine Mammal/Fishing Gear Interactions to Evaluate Utility of Passive Acoustic Monitoring

Aaron Thode, Scripps Institution of Oceanography

- Twelve TadPro devices extended and redesigned with improved timer mechanism, in-field programming capability, and addition of accelerometer and calibrated ultrasonic hydrophone recording.

- In January 2015 Five TadPros were deployed on 14 sets of pelagic fishing gear off Hawaii over a three week period. Video, audio, and accelerometer data of two species' gear interaction obtained two false killer whale encounters.
- Preliminary acoustic analysis of Hawaii deployments has begun.
- Results of Hawaii field work presented to NOAA Take Reduction Team for False Killer Whale Bycatch
- Preparations for opportunistic Alaska fieldwork beginning.

Using Combined Video, Acoustic, and Accelerometer Measurements to Determine the Conceptual Viability of a "Smart" Hook

Aaron Thode, Scripps Institution of Oceanography
Victoria O'Connell, Scripps Institution of Oceanography
Janice Straley, Sitka Sound Science Center

- Twelve TadPro devices extended and redesigned with improved timer mechanism, in-field programming capability, and addition of accelerometer and calibrated ultrasonic hydrophone recording.
- In January 2015 Five TadPros were deployed on 14 sets of pelagic fishing gear off Hawaii over a three-week period.
- Video, audio, and accelerometer data of two species' gear interaction obtained: two false killer whale encounters, and two mahi-mahi encounters.
- Preliminary acoustic and accelerometer analysis of Hawaii deployments begun.

Training the Next Generation of Marine Population Dynamics Scientists

Brice Semmens, Scripps Institution of Oceanography

- Authored or co-authored 3 published peer-reviewed manuscripts, 3 peer-reviewed articles in review or in press, and 1 report
- Lab members presented at 19 conferences and meetings
- PI Semmens co-coordinated a special session at the International Marine Conservation Congress in Glasgow, Scotland, titled "End-to-end marine conservation: Case studies in successfully translating science into management action through communication and outreach"
- Lab members organized and implemented the CAPAM Growth Workshop
- PI Semmens coordinated the K-12 Grouper Moon education and outreach program
- Ongoing coordination of the California Acoustic Tracking Network (CATN) collaboration, a broad network of academic institutions, NOAA partners, and fisheries science non-profits.

RESEARCH PROJECTS

Theme A: Climate and Coastal Observations Analysis, and Prediction Research

Collaborative Scientific and Technical Support to the NOAA Earth System Research Laboratory

Yehuda Bock, Scripps Institution of Oceanography, UC San Diego
Peng Fang, Scripps Institution of Oceanography, UC San Diego

NOAA Technical Contact: Kirk Holub, ESRL
Links to NOAA Strategic Plan:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: 10, 56, 95, and 139

Research Objectives and Specific Plans to Achieve Them
To reliably estimate the absolute integrated precipitable water (IPW) at 30-minute temporal resolution with an accuracy of 1.5mm or better in near real time using data collected from continuous GPS receivers covering the continental U.S. as a way of supplementing and improving numerical weather prediction models, i.e., short-term weather forecasting. At NOAA's Earth Systems Research Laboratory, a ground-based GPS meteorology system, capable of simultaneously processing sub-networks, has been implemented, with continued scientific input, oversight, and refinement from the Scripps Orbit and Permanent Array Center (SOPAC). The major effort has been focused on various sophisticated quality control elements of an automated data processing system, generating precise GPS orbits and Earth orientation parameters at SOPAC, using a 24-hour sliding window in an hourly update cycle.

The precision of the orbits is approximately 3 cm within the observed session and below 7 cm in the 12-hour predicted segment. The Co-PI (Peng Fang) will ensure to take full advantage of the major processing software package, GAMIT/GLOBK version10.50 by keeping up with the improved error modeling updates for our routine operation. The Co-PI will continue to interact closely with our sponsor at NOAA (Kirk Holub), and our international contacts to enhance their systems for GPS Meteorology, providing scientific and technical consultations.

Research Accomplishments
High quality orbits are now delivered hourly with better than 98.6% (5 interruptions over a 365 day period, most of them due to internal or external Internet or centralized archive system related problems) reliability with a precision of about 3 cm, and a predictive capability of 7 cm. In combination with the effort jointly with JPL/NASA, true-to-day site position generation has been implemented to ensure the use of accurate a priori position information, which may otherwise suffer errors due to geophysical or anthropogenic processes, for data reduction. An automated text message alert generation mechanism was implemented in order to promptly bring attention to the operator so that the system issues could be handled as quickly as possible after system failure. A few improved error-modeling schemes have been incorporated into the data processing system. Upon ESRL's request, many special solutions for the

Northern America region as well as places of global interest were generate for updating or expanding current data collecting networks operated by ESRL.

Experimental high sampling tropospheric delay estimation using real-time high rate GNSS data is in progress. This research has directly contributed to the atmospheric sounding research in general as well as to operational weather forecasting by NOAA in the U.S. Techniques developed for this system can support other applications in geodynamics and surveying/navigation.

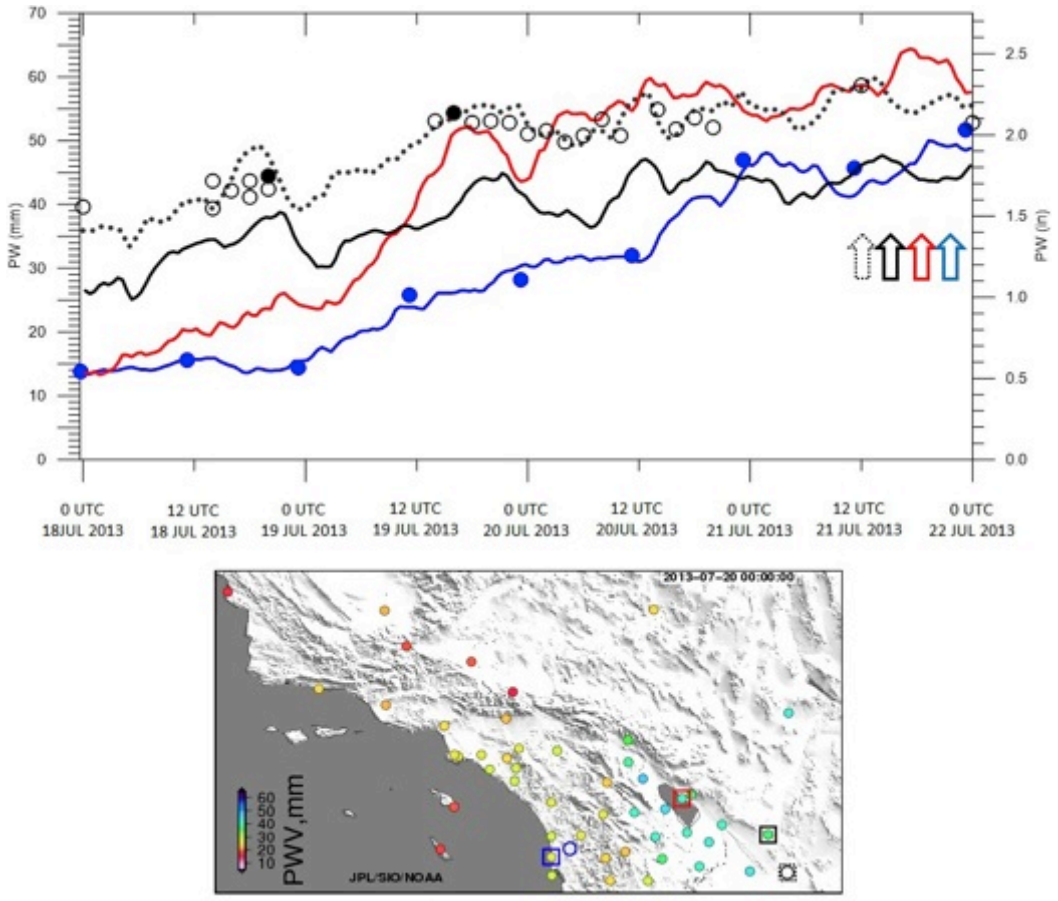

Figure 1: PW measurements during the evolution of the July 2013 monsoon event. Circles represent PW in cm for radiosondes at San Diego (blue) and Yuma, AZ (black). At the U.S. Army Yuma Proving Ground (YPG), radiosondes are launched irregularly in support of the local mission, and many observations only become available to the NWS and WMO retrospectively and with a variable delay. Solid black circles indicate those that were available to forecasters in AWIPS leading up to the flash flood watch and warning. Open circles are additional Yuma soundings provided for retrospective insight into the event. Solid traces show GPS PW measurements at San Diego (blue), Durmid, CA (red), and Glamis, CA about 60 km from Yuma. Dotted black trace is PW from a GPS station in Yuma that was not available to the forecasters at the time of this study, but was post-processed to compare with PW measured by the Yuma radiosondes during the passage of the inverted trough. Arrows indicate the times of passage of the wave at the identified GPS/Met sites. Map locates GPS stations with squares at San Diego (blue), Durmid (red), Glamis (black), and Yuma (dotted black) and radiosondes with circles at San Diego (blue) and Yuma (black). PW in mm at the GPS stations is shown, according to the color scale, at 1700 PDT 19 July (0000 UTC 20 July).

California Cooperative Oceanic Fisheries Investigations (CalCOFI), an Ocean Observation Program for the Southern California Current

Dr. David M. Checkley, Jr., Scripps Institution of Oceanography, UC San Diego
Dr. Ralf Goericke , Scripps Institution of Oceanography, UC San Diego

NOAA Technical Contact: R. Hewitt, SWFSC
Links to NOAA Strategic Plan:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: 7, 28, 58, 90, and 119

Research Objectives and Specific Plans to Achieve Them
CalCOFI's primary objectives are 1) to continue its 66-year time series of comprehensive, high-quality physical, chemical and biological observations of the southern California Current System, with an emphasis on the living marine resources, and 2) to contribute through its data and analyses to a scientific understanding of the human impacts and influence of climate variability and climate change on the living resources of the California Current in support of an ecosystem approach to management.

Our specific plan to achieve these objectives is, in collaboration with NOAA's SWFSC, to conduct quarterly cruises in the CCS, analyze the resultant data and samples, make the data and results available to users, and present those results in the peer-reviewed literature and at meetings, including the annual CalCOFI Conference. We also work closely with ancillary programs, including the NSF-sponsored CCE-LTER study and marine mammal and seabird observers.

Research Accomplishments
Highlights of this year's CalCOFI program include successful completion of four quarterly cruises, observation of anomalous North Pacific warming, use a CalCOFI-derived temperature index in the management of the Pacific sardine fishery, initiation of directed genomics observations, initiation of underway pH and pCO2 measurements and continued publication in top scientific journals on a range of topics, including improved understanding of the regional physical oceanography, modeling of sardine spawning habitat, and prediction and understanding of climate impacts on all levels of the marine food web in the California Current including phytoplankton, zooplankton, krill, sardine and dominant fish assemblages, marine mamdmals and seabirds.

Figure 1: CalCOFI research technician Dave Faber holds onto the CTD rosette at productivity station 87.80 as a wave crashes onto the deck of R/V New Horizon on 12 April 2015.

Developing a data-assimilative modeling tool to estimate oxygen and pH over the California Current System shelf

Christopher A. Edwards, UC Santa Cruz

NOAA Technical Contact: F. Werner, NMFS
Links to NOAA Strategic Plan:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management
Amendment No.: 129

Research Objectives and Specific Plans to Achieve Them
This project advances the tools needed to produce coastal ocean state estimates of oxygen levels and ocean acidification based on a rigorous synthesis of model predictions with observations. The research objectives of this project are to add oxygen dynamics and carbonate chemistry to the data assimilative form of the NEMURO biogeochemical model used within the Regional Ocean Modeling System (ROMS). This effort requires the construction and evaluation of nonlinear, tangent linear and adjoint models that include the new biogeochemical dynamics. These models (particularly the adjoint model) are complex pieces of code that require extensive debugging for functioning within a data assimilative system. The approach is general, appropriate for any regional ocean environment, but we will test its potential within the California Current System.

Research Accomplishments
The UCSC Ocean Modeling Group has developed the capability to assimilate both physical and biogeochemical information (e.g., sea surface height, temperature, standing stocks of chlorophyll, and macronutrients) into a coupled physical and biogeochemical model of the California Current System. The system applies an advanced 4-Dimensional, Variational assimilation (4DVar) methodology and imposes a lognormal transformation to address skewed statistics and positive-definite requirement of biogeochemical variables.

We have augmented the nonlinear NEMURO biogeochemical model with a carbon sub-model by adding three compartments: dissolved inorganic carbon (DIC), alkalinity, and calcium carbonate (CaCO3). The equilibrium partial pressure of CO2 (pCO2) in surface seawater is computed following the numerical methods developed by the Ocean Carbon-Cycle Model Intercomparison Project. An oxygen cycling component has also been added to NEMURO.

The tangent and adjoint models for the oxygen component have been coded and thoroughly debugged. Results are shown in Figure 1 using model twin experiments within the California Current System. In this approach, a nonlinear model is run with full oxygen dynamics producing a simulated ocean state that represents truth (Fig 1a). Simulated observations are drawn from this output representing real observations, in this case of surface oxygen concentrations. A second model simulation is run with very different initial conditions, representing the prior state estimate (Fig 1 b). Clear discrepancies between the prior state and truth are evident visible and as quantified by the difference between fields shown in Fig 1d. Following assimilation, a posterior estimate is obtained (Fig 1c). The adjustment of the prior estimate to more closely match observations is clear visibly, and in the substantial reduction in the difference between model and truth (Fig 1e).

The tangent linear and adjoint code for the carbonate chemistry is not yet completed, but we anticipate its successful implementation within the next several months of the no-cost time-extension. At that time will also evaluate its functioning within a realistic California Current System case.

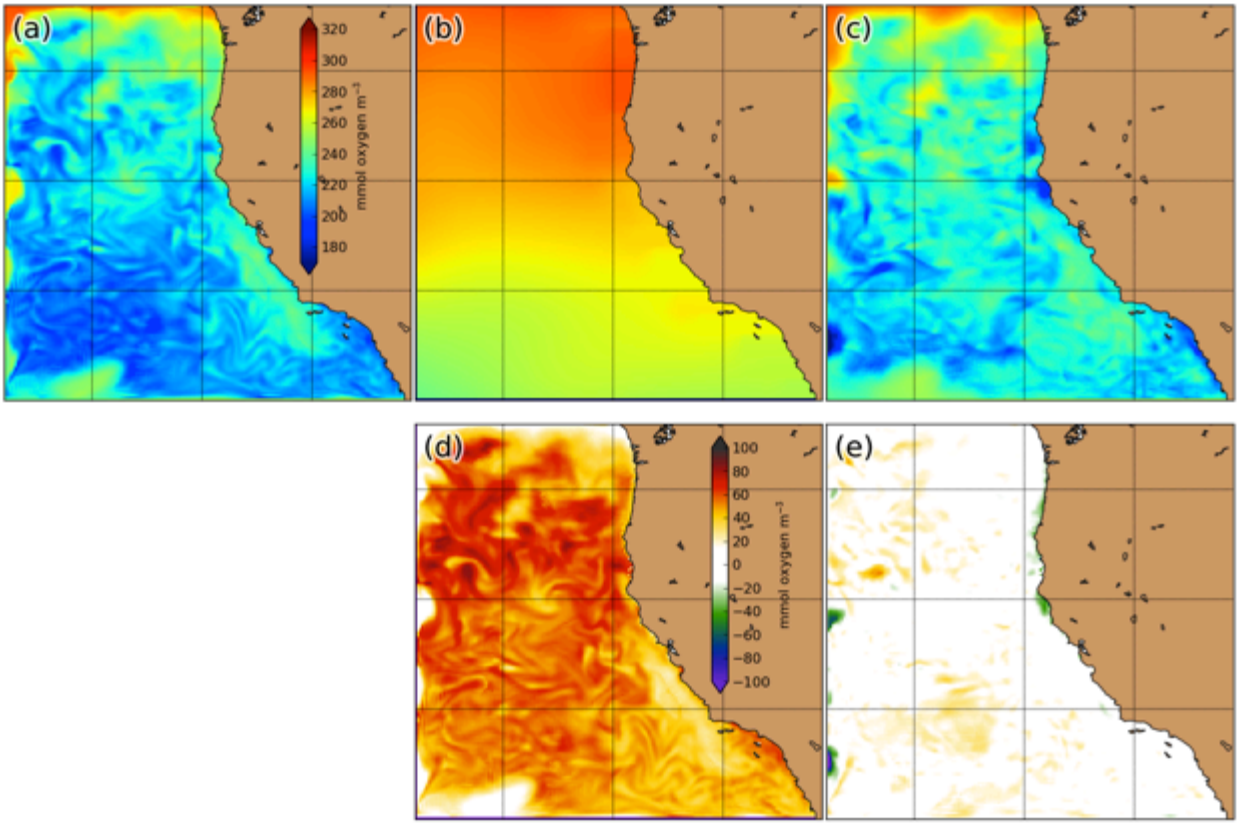

Figure 1: A model twin experiment testing potential assimilation of oxygen information. (a) Model-produced simulation of surface oxygen concentration, treated as truth from which simulated surface observations are drawn. (b) Prior estimate that clearly shows enormous discrepancies with respect to truth. (c) Posterior estimate showing greater agreement with observations following data assimilation. (d) Difference between prior estimate and truth. (e) Difference between posterior estimate and truth.

An Atmospheric River Case Study on the Russian River and a Vision for Western US Observing Systems

Dr. F. Martin Ralph, Scripps Institution of Oceanography, UC San Diego

NOAA Technical Contact: William Neff, Earth Science Research Laboratory, NOAA
Links to NOAA Strategic Plan:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Goal 3: Serve Society's Needs for Weather and Water Information
Amendment No.: 94

Research Objectives and Specific Plans to Achieve Them
The first of two objectives of the project was to document the role of landfalling atmospheric rivers in the Russian River, located in northern California, during March 2012, and its role in providing beneficial water supply. March 2012 was to be contrasted it with a 2007 events. This first objective has been accomplished through a detailed analysis of the March 2012 event showing that landfalling atmospheric river conditions are responsible for the precipitation leading to increased reservoir levels. The increase in reservoir storage was in coherence with the rule curve enabling the water to remain in the reservoir and serve as an important water supply throughout the summer and fall. The 2007 event was also analyzed, however, a December 2012 event has been contrasted with the March 2012 more frequently to illustrate the importance of timing of the arrival of atmospheric rivers and how the "rule curve" used for flood control impacts water supplies. The second objective was to present a vision of Western Observing System for presentation to western stakeholders. The second objective has been achieved through the publication of a peer-reviewed journal on western observations for extreme precipitation. This brought together many leading experts in the field to propose a way forward with for the development of an observation system to help mitigate the impacts from extreme precipitation. More information on the journal article is provided below.

Research Accomplishments
The March 2012 case study has been compared to 2007, but it a more meaningful comparison has been to the landfalling atmospheric river conditions in December of 2012. In contrast to the March 2012 event, during the December 2012 landfalling AR conditions produced large amounts of precipitation to fill the reservoir, but much of the water to be released because it exceeded the allotted storage for this time of year. During winter, the mandated storage level is reduced to ensure there is sufficient room for flood protection. Following this event there was no precipitation in the region for another 14 months illustrating the importance of the timing of precipitation. These two events have been used to highlight the difficulties in managing a reservoir for both flood control and water supply. Further, the two case studies have been used in the development of a Forecast Informed Reservoir Operations steering committee.

The journal article on a Western Observing System presents the need for observations that track, predict, and manage the occurrence and impacts of major storms. The vision for this observing system was informed by a range of user requirements, workshops, scientific advances, and technological demonstrations. The article recommends measuring rain, snow, snowmelt, flood, and their hydrometeorological precursor conditions, including radars to monitor winds aloft and precipitation, soil moisture sensors, stream gages. The proposed timeline for an observing system like this is 5-10 years, but the impact of better forecasting extreme events as a result of direct observations could save over $100 million a year.

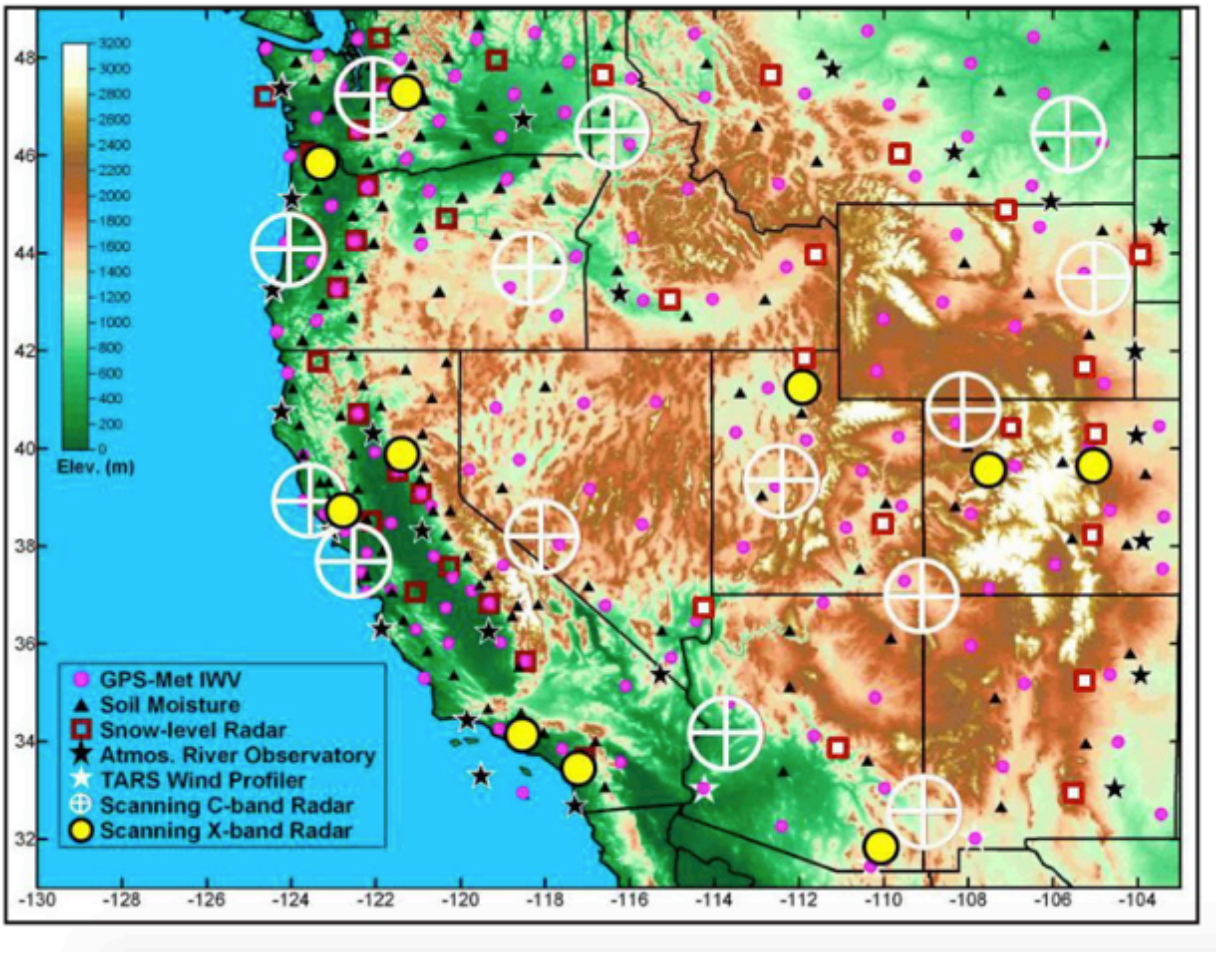

Figure 1: Schematic network of new sensors (land-based) to improve monitoring, prediction, and climate trend detection for hydrometeorological conditions that create extreme precipitation and flooding.

CalWater and West-Coast Atmospheric River Research

Dr. F. Martin Ralph, Scripps Institution of Oceanography, UC San Diego

NOAA Technical Contact: Shannon Louie, OAR CIPO
Links to NOAA Strategic Plan:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: 114

Research Objectives and Specific Plans to Achieve Them
Many people in the weather and hydrologic prediction communities, as well as engineering, emergency preparedness and response, water supply, flood control, agriculture and others, have been looking for information on atmospheric rivers (ARs). This project addresses many of these needs including, real-time information, short-term forecasts, medium range forecasts, seasonal outlooks, state-of-the-art, research findings, climate projections and others.

This project will develop and implement real-time tools for monitoring and prediction of atmospheric rivers, including lead times of hours to days, and will explore the potential for seasonal forecasts of AR frequency. These data and tools will be hosted on an "AR Portal" web site that will developed by the project and hosted at the Center for Western Weather and Water Extremes at Scripps Institution of Oceanography. These products will include several previously developed, as well as new ones, and will be made available to users from federal, state, local, private and other entities, as well as the public via this AR Portal.

Research Accomplishments
The new AR Portal web page at http://arportal.ucsd.edu is now fully functional in real time and open to the public. The website provides background and links to relevant data regarding ARs allowing users to examine current and forecasted conditions.

Several new forecast tools were developed and made accessible through our AR portal website. These tools were developed in part to support the planning and conduction of research flights during Cal Water 2 experiments that took place during the quarter. Included in these new products are 0-10 day forecasts of integrated water vapor (IWV), integrated vapor transport (IVT), precipitation rate, and time-integrated IVT. Figure 1 shows an example forecast for IVT based on GFS ensemble products.

Dropsonde measurements from the recently completed CalWater2 campaign were processed and analyzed. The AR statistics from these newly sampled ARs have been added to those from earlier field campaigns to provide a more complete catalog of observed AR conditions. A journal article is presently being prepared that we expect to submit for publication in the near future.

We have created locally functional real time and updated version of the Automated Atmospheric River Detection Tool (ARDT - originally developed by Dr. Gary Wick at NOAA ESRL PSD lab). A new historical record of AR activity dating back to 1948 was developed by applying the ARDT to NCEP Reanalysis data. Using this record of AR activity we have begun to study the interannual-decadal variability in land-falling ARs including relationships with ENSO and the PDO as well as the spatial/temporal variability of ARs and their associated precipitation patterns over California. Future work aims to improve understanding of the physical mechanisms that drive ARs in the Pacific with the goal of improving predictability of "drought-buster" storms over California. Figure 2 shows the interannual variability in AR activity over the California coast from 1949-2010.

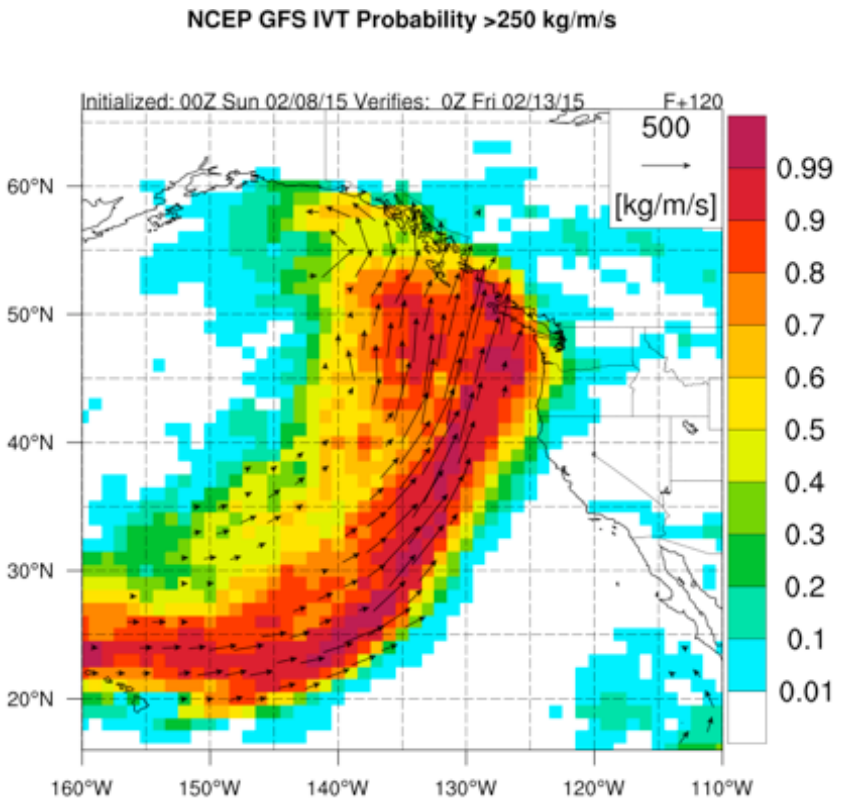

Figure 1: Plot showing the 120-hr forecast probability of Integrated Vapor Transport (IVT) exceeding 250 kg m^{-1} s^{-1} at 0Z February 13, 2015 based on the 20 members of the GFS Ensemble (shaded) and the IVT vectors from the control forecast.

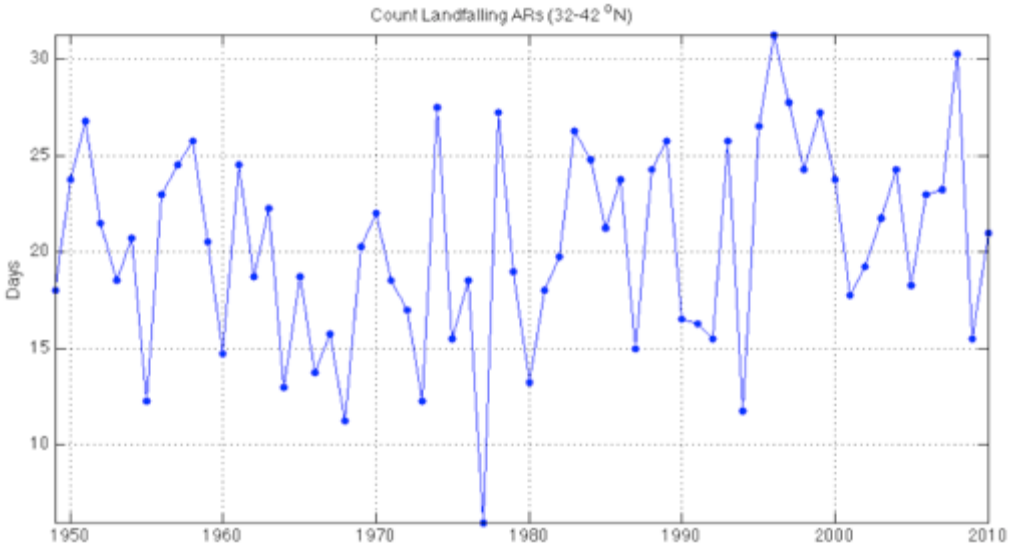

Figure 2: The number of days per water year in which an AR was detected to hit the California coast using the ARDT algorithm applied to NCEP Reanalysis.

The Argo Program – Global Observations for Understanding and Prediction of Climate Variability

Dean Roemmich, Scripps Institution of Oceanography, UC San Diego
John Gilson, Scripps Institution of Oceanography, UC San Diego

NOAA Technical Contact: Stephen Piotrowicz, CPO
Links to NOAA Strategic Plan:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Goal 3: Serve Society's Needs for Weather and Water Information
Amendment No.: 15, 42, 74, and 105

Research Objectives and Specific Plans to Achieve Them

Argo is an international collaboration providing a global array of profiling CTD floats for a broad range of operational and scientific applications (http://www.argo.ucsd.edu). The Argo array, now including about 3800 active floats, is providing unprecedented real-time views of the evolving physical state of the ocean. These measurements reveal the physical processes that balance the large-scale mass, heat, and freshwater budgets of the ocean on basin-to-global scale. Argo is a major initiative in oceanography, merging research and operational objectives to provide a uniquely valuable global dataset for climate science, ocean state estimation, seasonal-to-decadal forecasting, education and other applications. All Argo data are freely available in near-real time.

SIO plays a number of key roles within U.S. and international Argo. The U.S. provides over 50% of the international Argo array, including instrumentation development, float production and deployment, communications and data management, and scientific analyses to demonstrate the value of Argo data. SIO produces and deploys one-fourth of the U.S. floats, carries out float technology development, participates in delayed-mode quality control, coordinates the U.S. Argo partnership, and provides leadership for international Argo through the Argo Steering Team.

Research Accomplishments

During the 12 months covered by this report (04/2014 – 03/2015), 98 SIO Argo floats were built, shipped, and deployed, and an additional 30 have been built and shipped. Deployments included 52 floats by RV Kaharoa in the S/W Pacific, 20 floats by RV Palmer in the Southern Ocean, 18 floats by RV Tangaroa in the Southern Ocean, and 8 floats by S/V Libby in the eastern tropical Pacific. In addition to these Argo-funded floats, our lab also built 2 Argo floats for the New Zealand Argo Program, and these were deployed in the Southern Ocean.

The total number of active Argo floats produced in our lab is now 513. For all active floats, profile and engineering data are regularly monitored to identify any technical problems with the instrument or sensor. Technology development continues to focus on further improvements in reliability and capability of profiling floats. Deployments of the new generation SOLO-II float have been successful, with a high percentage of floats deployed since 2011 remaining active. The SOLO-II design provides greater buoyancy adjustment, more robust operation, and increased lifetime relative to all existing Argo floats. During the present reporting period a new float CPU and new firmware were successfully incorporated in floats deployed this year.

During this reporting period the design and development of Deep SOLO floats, capable of about 150 cycles to full ocean depth (6000 m), was continued. Two prototype Deep SOLO floats were deployed in the Southwest Pacific in June 2014 in water depth of about 5700m. Both floats are active after completing 75 cycles, and it is planned to recover them in September 2015 after 110 cycles.

Scientific quality control of all SIO Argo profile data has been carried out by J. Gilson, S. Escher, and M. Scanderbeg according to protocols set by the international Argo Data Management Team. All eligible delayed-mode profiles (i.e. > 12 months old) have been reviewed. SIO Argo data are freely available from either of the two Argo Global Data Assembly Centers.

D. Roemmich has been Chairman of the international Argo Steering Team since its inception in 1998. The AST, which is responsible for coordinating the international Argo partnership, was hosted by Argo France at IFREMER in Brest France for its March 2015 meeting. The meeting report for AST-16 is available from http://www.argo.ucsd.edu/FrMeeting_reports.html. M. Scanderbeg provides support for a wide variety of AST functions, including Steering Team and Data Management Team meeting planning, reporting, and inter-sessional activities, and is responsible for designing and updating of the Argo web site, http://www.argo.ucsd.edu.

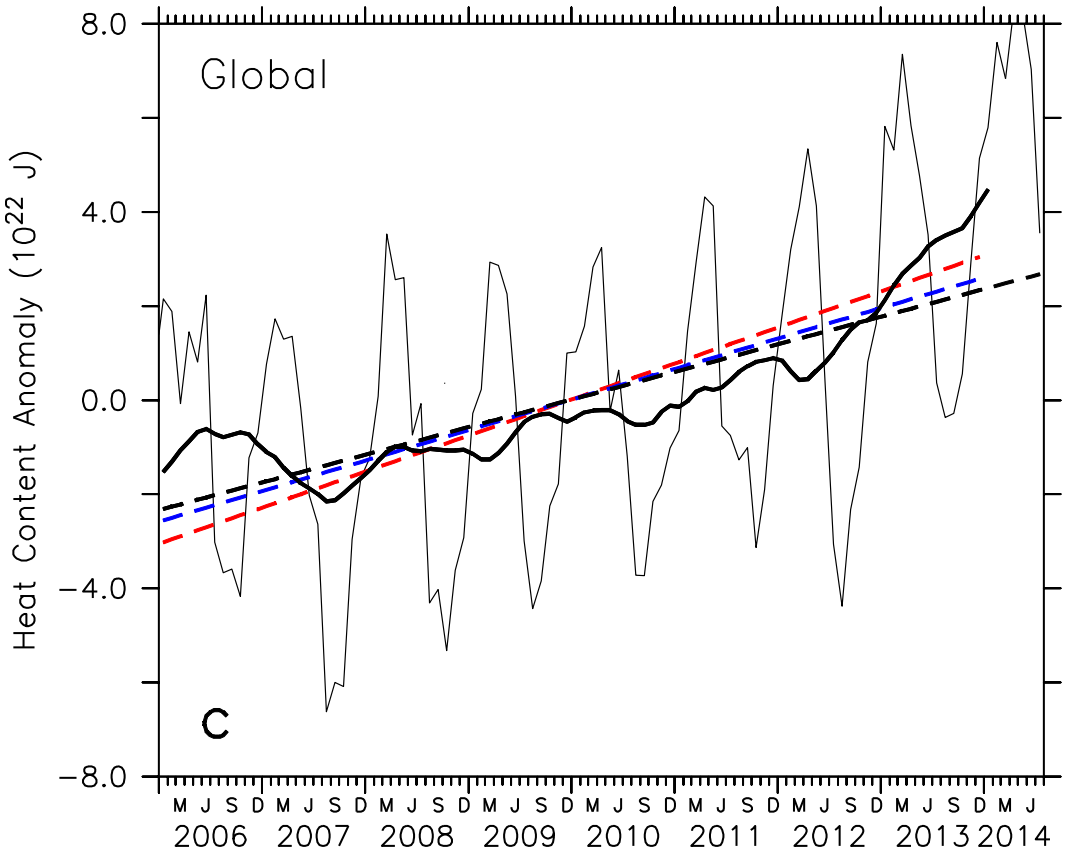

Figure 1: Global ocean heat content anomaly (10^{22} J) from Argo data, 2006 – 2014 (From: Roemmich et al., *Nature Climate Change*, 2015). The thin line shows monthly values; the thick line is for 12-month running means. Dashed lines show estimated trends from 3 different analyses of Argo data.

SIO High Resolution XBT/XCTD Transects

Janet Sprintall, Scripps Institution of Oceanography, UC San Diego
Dean Roemmich, Scripps Institution of Oceanography, UC San Diego
Bruce Cornuelle, Scripps Institution of Oceanography, UC San Diego

NOAA Technical Contact: C. Clark, CPO
Links to NOAA Strategic Plan:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Goal 3: Serve Society's Needs for Weather and Water Information
Amendment No.: 20, 47, 78, and 108

Research Objectives and Specific Plans to Achieve Them
The SIO High Resolution XBT Network is a set of basin-spanning shipping routes (http://www-hrx.ucsd.edu) along which eddy-resolving temperature transects are collected four times per year. The HRX Network was initiated in 1986 along a commercial shipping route between New Zealand, Fiji, and Hawaii. It was subsequently expanded during the 1990's to include basin-spanning temperature transects in all of the oceans. Major partners in the HRX network include Scripps (Pacific and Indian Ocean), NOAA/AOML (Atlantic), and CSIRO (SW Pacific, Indian). Typically, each transect is repeated on a quarterly basis to resolve variability in temperature, geostrophic circulation and transport on annual and longer periods. Scientific objectives of the HRX Network are:

- Measure the seasonal and interannual fluctuations in the transport of mass, heat, and freshwater across ocean-wide transects spanning the ocean's boundary currents and interior circulations.
- Determine the long-term mean, annual cycle and interannual fluctuations of temperature, geostrophic velocity and large-scale ocean circulation in the top 800 m of the ocean.
- Obtain long time-series of temperature profiles at precisely repeating locations in order to unambiguously separate temporal from spatial variability.
- Determine the space-time statistics of variability of the temperature and geostrophic shear fields.
- Provide appropriate *in situ* data (together with Argo profiling floats, tropical moorings, air-sea flux measurements, sea level etc.) for testing ocean and ocean-atmosphere models.
- Determine the synergy between HRX transects, satellite altimetry, Argo, and models of the general circulation. What are the minimal sampling requirements for *in situ* data?
- Identify permanent boundary currents and fronts, describe their persistence and recurrence and their relation to large-scale transports.
- Estimate the significance of baroclinic eddy heat fluxes.

Research Accomplishments
HRX transects, quarterly in most cases, have been maintained along routes that include:
PX37/40 (North Pacific – Los Angeles to Hawaii to Yokohama)
PX38 (North Pacific – Hawaii to Alaska)
PX05 (Western Pacific – Brisbane to Yokohama)
PX44 (Western Pacific – Taiwan to Naha to Guam)
PX06/31 (Central Pacific – Auckland to Fiji to San Francisco)
PX30 (South Pacific – Brisbane to Fiji, joint with CSIRO Australia)
IX21 (South Indian –Durban to Mauritius)
Logistical assistance or XBT probes are provided collaboratively for:
PX34 (South Pacific – Wellington to Sydney, CSIRO Australia)

IX28 (Southern Ocean – Hobart to Antarctica, CSIRO Australia)
AX22 (Southern Ocean - Drake Passage)

During each cruise, XBT temperature profiles (0-800 m) were collected at spatial intervals from 10 km near ocean boundaries and the equator, to 50 km in interior regions – resolving boundary currents and interior eddies for calculation of ocean-wide integrals of geostrophic transport. A web site for the project, with downloadable data, is maintained at http://www-hrx.ucsd.edu . HRX data are transmitted on the GTS immediately after collection for real-time applications. Due to the rapidly evolving nature of the present-day commercial shipping industry, a strong focus of the work has been to maintain sampling along routes as ships and shipping companies change.

Scientific analysis of the HRX dataset is progressing both on a stand-alone basis and in the context of ocean data assimilation (ODA) modeling. The HRX Network is observing the volume transport and variability of all the world's subtropical western boundary currents: with a total of 10 repeating transects across the Gulf Stream, Kuroshio, Agulhas, Brazil Current, and East Australian Current. Other boundary current sampling includes the California Current and the Antarctic Circumpolar Current. Absolute geostrophic transports for the upper 800 m are estimated using Argo profile and trajectory data in conjunction with HRX transects.

HF Radar National Network Data Management Development

Dr. Eric Terrill, Scripps Institution of Oceanography, UC San Diego

NOAA Technical Contact: J. Harlan, NOS
Links to NOAA Strategic Plan:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Goal 3: Serve Society's Needs for Weather and Water Information
Goal 4: Support the Nation's Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation
Goal 5: Provide Critical Support for NOAA's Mission
Amendment No.: 2, 23, 39, 89, 103, and 110

Research Objectives and Specific Plans to Achieve Them
Local, state, regional, and federal support for the Integrated Ocean Observing System (IOOS) have supported the installation, development, and operation of a network of surface current mapping systems for use by a broad range of end users. Central to the operational success of a large-scale network is a scalable data management, storage, access, and delivery system. The objectives for this project are to continue the research, development, and implementation of the data management system for ocean surface current information derived from HF radar with a focus on preparing the data for operational needs. The surface currents are made available for integration into systems such as the United States Coast Guard (USCG) Search and Rescue Optimal Planning System (SAROPS); NOAA Office of Response and Restoration (ORR) General NOAA Operational Modeling Environment (GNOME); and CA Regional Ocean Modeling System (ROMS).

The architecture of the HF-Radar Network lends itself well to a distributed real-time network and serves as a model for networking sensors on a national level. This proposal concentrates on development activities critical for network growth and sustainability. Programming staff will configure network hardware for node operators and translate the rowg website to a new platform. Programmers will

evaluate the existing processing code to optimize network growth and ensure total vector processing is maintained in near real-time. Additionally, evaluation of DOA metrics will continue. Archiving RTV's through THREDDS at NODC will be completed with a plan for next steps. As the national network continues to grow, support and maintenance requires increased time and dedication.

Research Accomplishments

CORDC research and implementation efforts met expectations during this reporting period. Throughout this reporting period, efforts focused on continued operations, maintenance, and expansion; improving national metrics; configuring and initializing two new servers (1) a new development server and (2) a new processing server for redundancy and additional product processing; redesign and launch of the rowg website; and RTV archiving through NODC. Programmers completed NODC submission information forms (SIF) for both near real-time vectors (RTV) and radial files. Additionally, CORDC supported global partnership by visualizing surface current measurements of Spain and Australia networks.

As the network of HF radar systems grows nationally, programmers continue to update and incorporate new data streams into the mapping system. A total of 6 new sites were added to the network during this period: 1 site on the west coast, and 5 sites on the east coast.

HF Radar radial metrics were collected from additional systems at Martha's vineyard by Woods Hole Oceanographic Institution (WHOI) researchers. Scripps and WHOI compared results of the distributions of these 6 radial metrics:

- Signal Power of the Response (Signal Power)
- Direction of Arrival Function Maximum (DOA)
- Direction of Arrival Function Width (DOA Width)
- Signal-to-Noise Ratio Antenna 1 (SNR1)
- Signal-to-Noise Ratio Antenna 2 (SNR2)
- Signal-to-Noise Ratio Antenna 3 (SNR3)

As stated from participating researchers "The method looks at the hourly distribution of radial metric values (e.g. Doppler Cell SNR from Antenna 3) to find the mean and standard deviation. As an example, radial velocity vectors that have a Doppler Cell SNR that is 2 standard deviations below the mean of that hour's distribution may be removed. All combinations of all six metrics listed above, with varying filter threshold values were examined. It was determined that Signal Power and Doppler Cell SNR from Antenna 3 were the metrics that improved data quality the most.

The effect of the filtering reduced the baseline variance in many cases, at the expense of minor reduction in coverage. Even if the operator doesn't want to remove inconsistent radials, each radial velocity could be flagged using the MUSIC metrics, and vectors with less that optimal metrics can at least be weighted less in the computation of system total vectors. \

The methodology was also tested on a second data set, taken from SeaSonde HF radar observations made in 2012 at the Martha's Vineyard Coastal Observatory (MVCO). Compared to in situ near-surface velocity observations made by an ADCP. Use of radial velocity metrics to screen the MUSIC results was found to both decrease the velocity variance of the mean radial velocity and decrease RMS differences between the HF radar and ADCP velocities. Use of the dynamic, two standard deviation cutoff for estimating outliers was compared to a similar estimate using static thresholds for each of the metrics, finding similar results."

CORDC programmers maintained a THREDDS server for hosting the near real-time vectors (RTV) and operationally support the following organizations:

- University of Connecticut Short Term Prediction System (STPS)
- Applied Science Associates (ASA) Environmental Data Server (EDS)
- U.S. Coast Guard Search and Rescue Optimal Planning System (SAROPS)
- Office of Response and Restoration (OR&R) Emergency Response Division (ERD) and Assessment and Restoration Division (ARD)
- Official NOAA forecasts for oil spill trajectories General NOAA Operational Modeling Environment (GNOME)
- Office of Spill Prevention and Response (OSPR), California Department of Fish and Wildlife

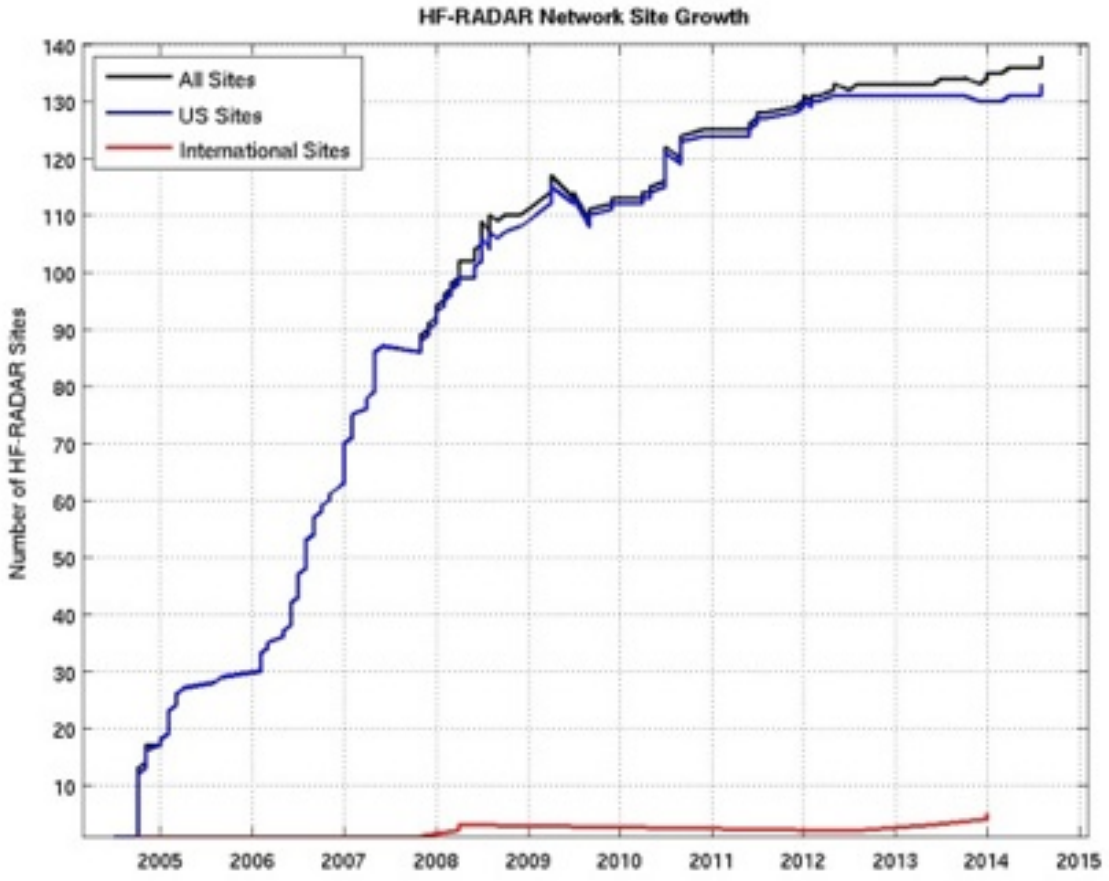

Figure 1: Growth of the HF Radar Network (HFRNET) expressed by the total number of radar stations reporting into the network.

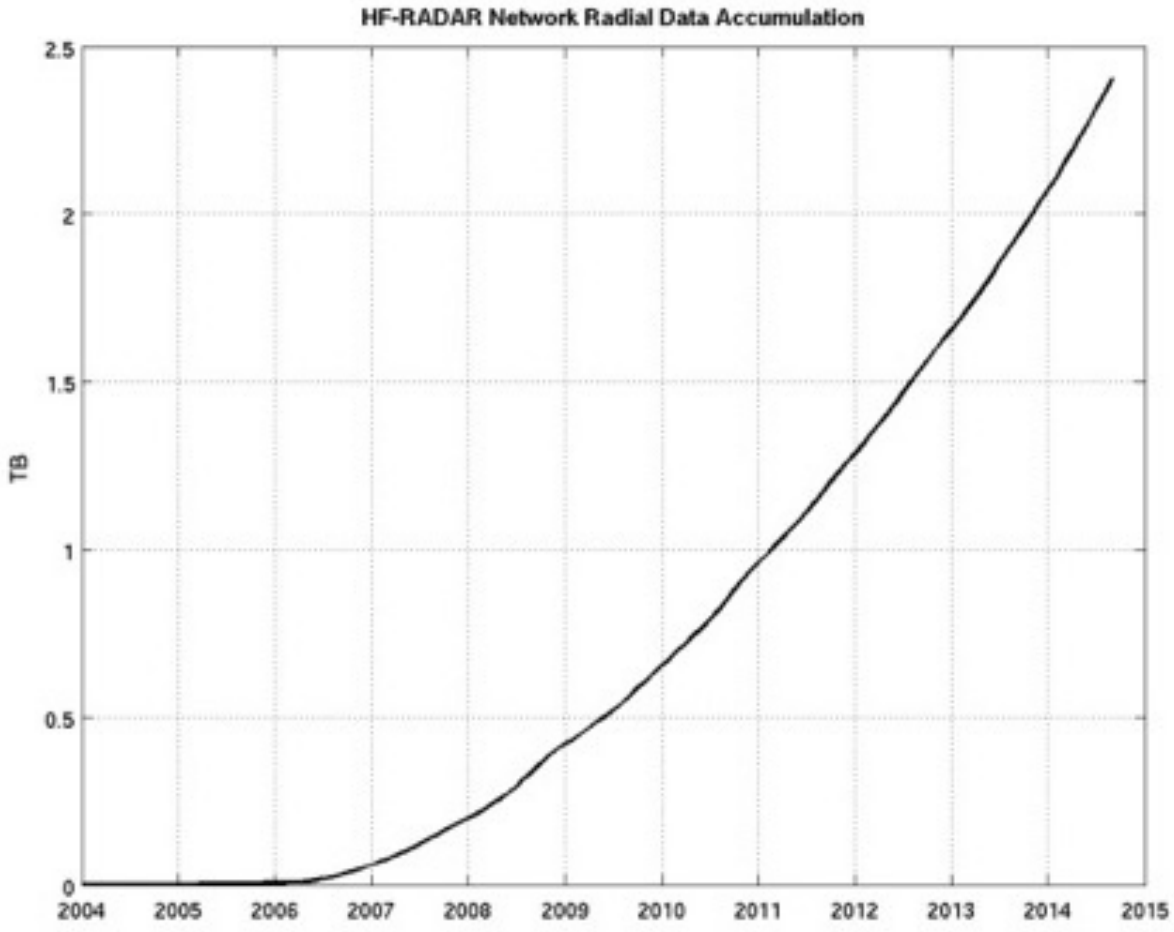

Figure 2: Growth of the HF Radar Network (HFRNET) expressed by the total number of terabytes of radial vector fields that are being stored on the data system in support of HFRNET.

Develop Forecast Methods and an "AR Portal" for Atmospheric River Data and Tools

Dr. Daniel Cayan, Scripps Institution of Oceanography, UC San Diego

NOAA Technical Contact: Shannon Louie, OAR CIPO
Links to NOAA Strategic Plan:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Goal 3: Serve Society's Needs for Weather and Water Information
Amendment No.: NA13OAR4830231 (competed)

Research Objectives and Specific Plans to Achieve Them
Many people in the weather and hydrologic prediction communities, as well as engineering, emergency preparedness and response, water supply, flood control, agriculture and others, have been looking for information on atmospheric rivers (ARs). This project addresses many of these needs including, real-time information, short-term forecasts, medium range forecasts, seasonal outlooks, state-of-the-art, research findings, climate projections and others.

This project will develop and implement real-time tools for monitoring and prediction of atmospheric rivers, including lead times of hours to days, and will explore the potential for seasonal forecasts of AR frequency. These data and tools will be hosted on an "AR Portal" web site that will developed by the project and hosted at the Center for Western Weather and Water Extremes at Scripps Institution of Oceanography. These products will include several previously developed, as well as new ones, and will be made available to users from federal, state, local, private and other entities, as well as the public via this AR Portal.

Research Accomplishments
The new AR Portal web page at http://arportal.ucsd.edu is now fully functional in real-time and open to the public. The website provides background and links to relevant data regarding ARs allowing users to examine current and forecasted conditions.

Several new forecast tools were developed and made accessible through our AR portal website. These tools were developed in part to support the planning and conduction of research flights during Cal Water 2 experiments that took place during the quarter. Included in these new products are 0-10 day forecasts of integrated water vapor (IWV), integrated vapor transport (IVT), precipitation rate, and time-integrated IVT. Figure 1 shows an example forecast for IVT based on GFS ensemble products.

Dropsonde measurements from the recently completed CalWater2 campaign were processed and analyzed. The AR statistics from these newly sampled ARs have been added to those from earlier field campaigns to provide a more complete catalog of observed AR conditions. A journal article is presently being prepared that we expect to submit for publication in the near future.

We have created locally functional real time and updated version of the Automated Atmospheric River Detection Tool (ARDT - originally developed by Dr. Gary Wick at NOAA ESRL PSD lab). A new historical record of AR activity dating back to 1948 was developed by applying the ARDT to NCEP Reanalysis data. Using this record of AR activity we have begun to study the interannual-decadal variability in land-falling ARs including relationships with ENSO and the PDO as well as the spatial/temporal variability of ARs and their associated precipitation patterns over California. Future work aims to improve understanding of the physical mechanisms that drive ARs in the Pacific with the goal of improving predictability of "drought-buster" storms over California. Figure 2 shows the interannual variability in AR activity over the California coast from 1949-2010.

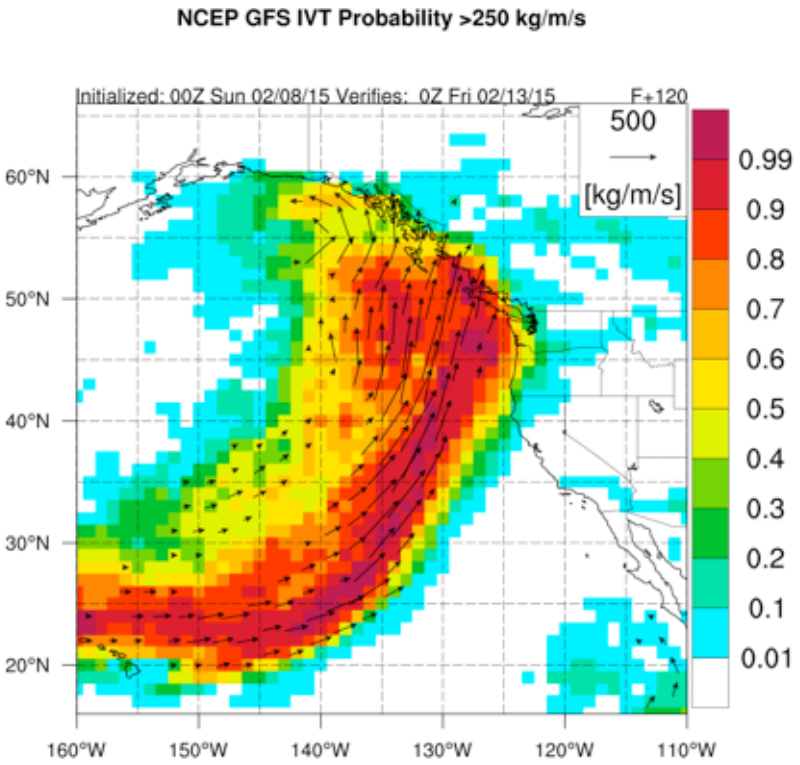

Figure 1: Plot showing the 120-hr forecast probability of Integrated Vapor Transport (IVT) exceeding 250 kg m^{-1} s^{-1} at 0Z February 13, 2015 based on the 20 members of the GFS Ensemble (shaded) and the IVT vectors from the control forecast.

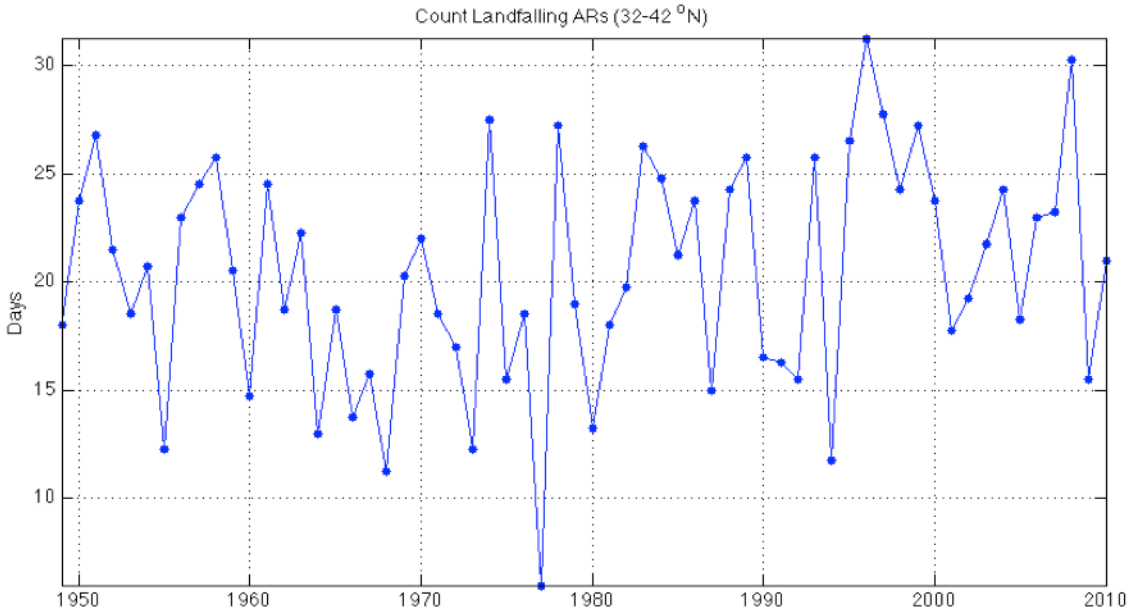

Figure 2: The number of days per water year in which an AR was detected to hit the California coast using the ARDT algorithm applied to NCEP Reanalysis.

Develop Forecast Methods and an "AR Portal" for Atmospheric River Data and Tools

Dr. Daniel Cayan, Scripps Institution of Oceanography

NOAA Technical Contact: Shannon Louie, ESRL
Links to NOAA Strategic Plan:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: NA14OAR4830271 (Competed)

Research Objectives and Specific Plans to Achieve Them
Many people in the weather and hydrologic prediction communities, as well as engineering, emergency preparedness and response, water supply, flood control, agriculture and others, have been looking for information on atmospheric rivers (ARs). This project addresses many of these needs including, real-time information, short-term forecasts, medium range forecasts, seasonal outlooks, state-of-the-art, research findings, climate projections and others.

This project will develop and implement real-time tools for monitoring and prediction of atmospheric rivers, including lead times of hours to days, and will explore the potential for seasonal forecasts of AR frequency. These data and tools will be hosted on an "AR Portal" web site that will developed by the project and hosted at the Center for Western Weather and Water Extremes at Scripps Institution of Oceanography. These products will include several previously developed, as well as new ones, and will be made available to users from federal, state, local, private and other entities, as well as the public via this AR Portal.

Research Accomplishments
The new AR Portal web page at http://arportal.ucsd.edu is now fully functional in real-time and open to the public. The website provides background and links to relevant data regarding ARs allowing users to examine current and forecasted conditions.

Several new forecast tools were developed and made accessible through our AR portal website. These tools were developed in part to support the planning and conduction of research flights during Cal Water 2 experiments that took place during the quarter. Included in these new products are 0-10 day forecasts of integrated water vapor (IWV), integrated vapor transport (IVT), precipitation rate, and time-integrated IVT. Figure 1 shows an example forecast for IVT based on GFS ensemble products.

Dropsonde measurements from the recently completed CalWater2 campaign were processed and analyzed. The AR statistics from these newly sampled ARs have been added to those from earlier field campaigns to provide a more complete catalog of observed AR conditions. A journal article is presently being prepared that we expect to submit for publication in the near future.

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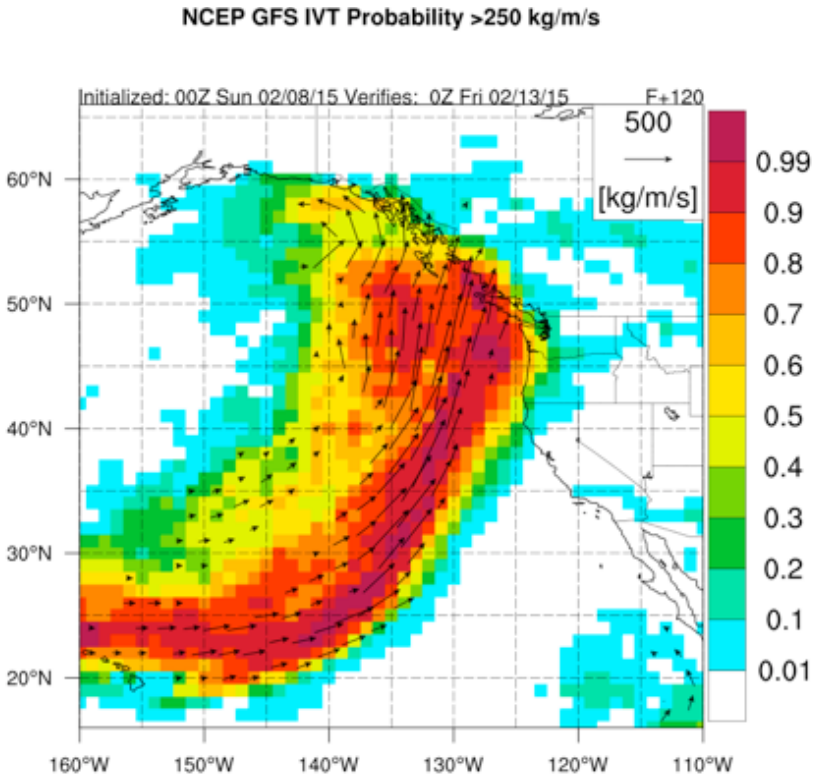

Figure 1: Plot showing the 120-hr forecast probability of Integrated Vapor Transport (IVT) exceeding 250 kg m^{-1} s^{-1} at 0Z February 13, 2015 based on the 20 members of the GFS Ensemble (shaded) and the IVT vectors from the control

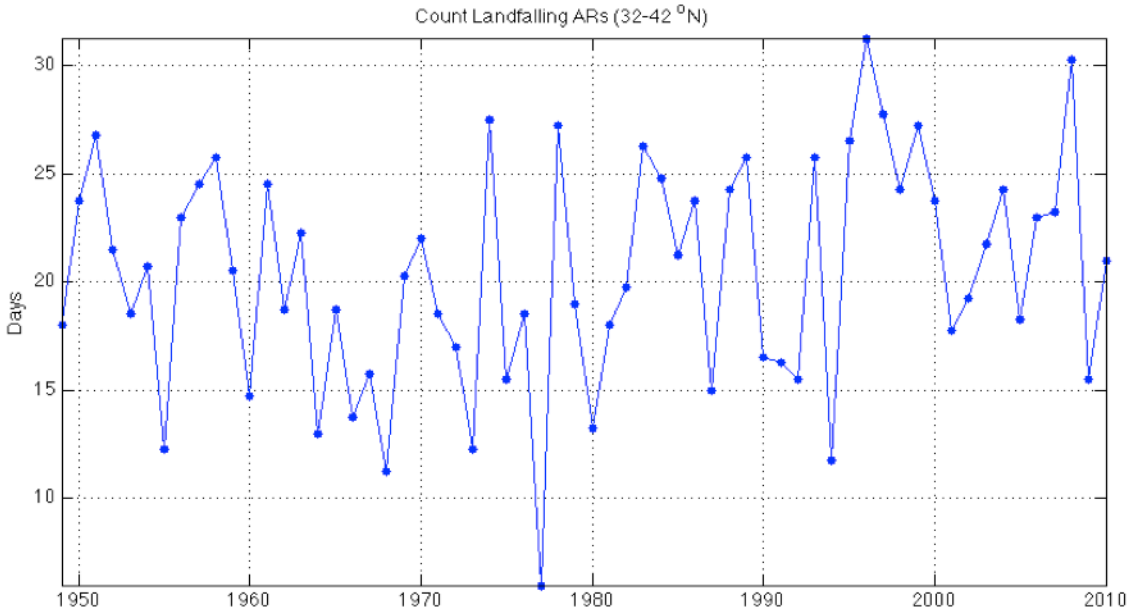

Figure 2: The number of days per water year in which an AR was detected to hit the California coast using the ARDT algorithm applied to NCEP Reanalysis.

Targeted In-Situ Tropical Cyclone Observations from Ocean Sensors

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Eric Terrill, Scripps Institution of Oceanography, UC San Diego

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Links to NOAA Strategic Plan:
Goal 3: Serve Society's Needs for Weather and Water Information
Goal 4: Support the Nation's Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation
Amendment No.: NA14OAR4830118 (Competed)

Research Objectives and Specific Plans to Achieve Them

To improve Tropical Cyclone (TC) forecasts, there is a clear need for 1) positioning ocean sensors directly across the path of the storm to provide accurate and relevant in-situ observations at the air-sea interface and in the ocean and 2) ensuring the data are delivered in real time to forecasters in a format readily available for assimilation (e.g. through the Global Telecommunication System-GTS). Targeting TCs with air-deployed ocean-sensors is an effective answer to the problem. Sensor technology has improved to the point of readiness to address this problem, but adapting the technology to the complexities of the logistics surrounding operational hurricane monitoring remains. Targeted observations using air-dropped instrumentation allows the observations at the air-sea interface to be made at the right place and time with the scales required to provide direct improvement of the forecast. We propose a modern generation of hurricane instruments for targeted, real-time, ocean-atmosphere data acquisition under TCs in support of HFIP, NHC, NCEP (waves) forecast and coupled-modeling efforts. Archived data will be publicly available to support scientific research on ocean/tropical cyclone interaction. We will modernize and pilot test a family of sensors to observe the upper-ocean and air-sea interface and the data route to make the observations available in real-time to the forecasters and the research community. We address the competition scope stating that floats, drifters and new sensors provide key observations for TC forecast and the need to demonstrate new and improved observing technologies. The lead PI of this proposal is also the PI of the NOAA funded Global Drifter Program, the data of which are fully accessible through the GTS from the Drifter Data Assembly Center located at AOML, Miami, Florida, and from several servers maintained by his group at the Scripps Institution of Oceanography.

Research Accomplishments

The miniature autonomous drifting ocean station (mADOS) is being designed and fabricated into an A-sized package ready for air deployment. During the first phase of the project, sensor selection was determined for feasibility with respect to ruggedness and form factor for the A-sized package. Following selection of the anemometer and barometric pressure sensors, development focus shifted to hardware packaging, parachute deployment and separation, and bladder inflation.

Computer-aided Design (CAD) models were generated and validated via Finite Element Analysis (FEA) to determine durability and necessary tolerances for the design. Orders have been placed with fabrication shops for the main buoy housing, barometer port and anemometer mount, electronics chassis, bladder firing system, and parachute deployment and release/separation system.

Following receipt of fabricated hardware, field testing will commence to determine necessary filtering algorithms to maintain sensor accuracy in a rough sea state, required reserve buoyancy for quality measurements and satellite performance, as well as determine feasibility of the parachute separation and bladder firing systems.

The miniature wave buoy (MWB) in an A-sized package is being designed and fabricated for initialization/assimilation in the operational models for improved storm assessment and forecast guidance. The first article rotochute assembly was designed in the first quarter to aerodynamic and weight specifications of A-size diameter housing with expected MWB electronics and batteries installed. Alternate arrangements/placements of MWB components and batteries are being analyzed for rotational stability during deployment. The first drop test off of SIO pier (30m) was conducted on January 31, 2015. Video analysis determined the number of rotations and angle of entry into the water. Dynamic simulation of prototype design is continuing, with an emphasis on rotational stability with an emphasis on placements of weight loading for impacts on flight stability.

Additionally, the MWB electronics package has been designed and integrated into the A-size MWB package and a new antenna has been designed. Antenna selection and exact placement depended on the results of prototype rotochute drop. Either (a) the entire A-size MWB package housing would rotate with the rotochute; or (b) the housing would not rotate at all and just the rotochute would rotate. From the drop test we have determined that the housing will not rotate at all, just the rotors will rotate. This way the antenna will be fixed to the electronics with a cable

The A-size package constraints have been analyzed and a new prototype housing is under design to house electronics and batteries. Engineers compared prototype A-sized MWB system with standard MWB and CDIP Datawell Buoy (Scripps Nearshore #201) with good results.

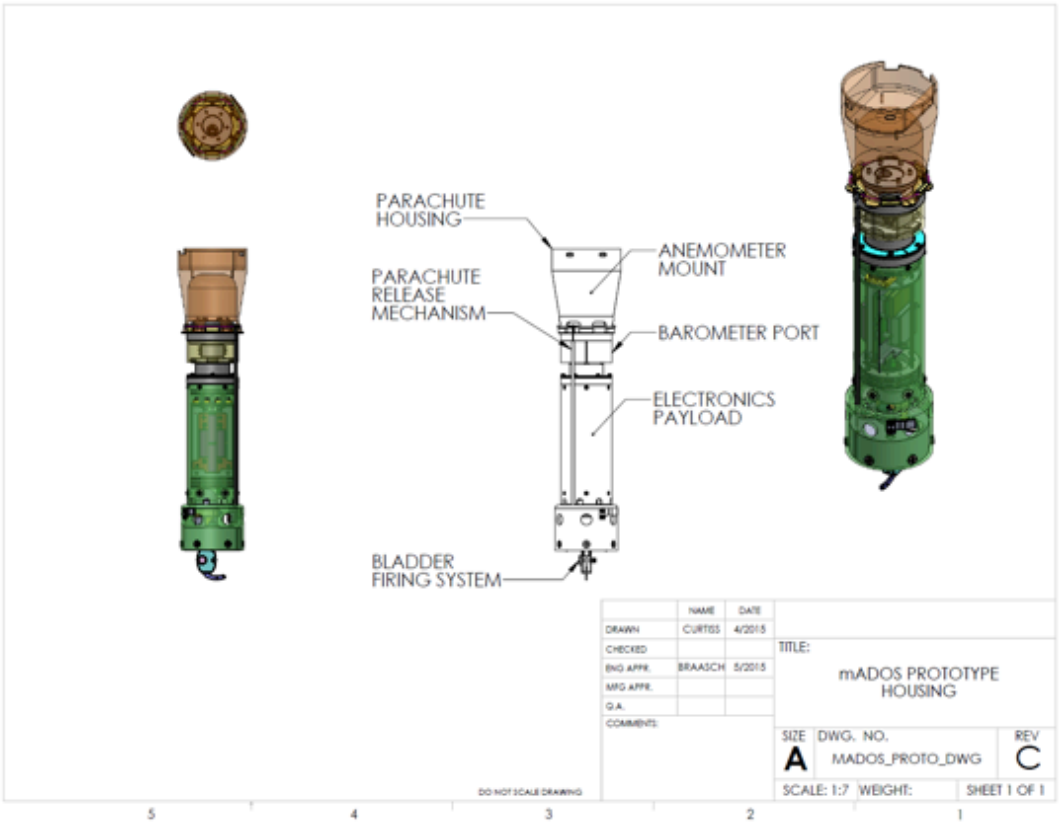

Figure 1: Technical drawing of main electronics housing for mADOS system with bladder and t-Chain not shown.

Figure 2: Rendering showing design of A-sized wave buoy. Rotochute blades are shown in the open position. Electronics and battery configuration are visible.

Bridging the gap in NOAA's extended and long range prediction systems through the development of new forecast products for weeks 3 and 4

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NOAA Technical Contact: Annarita Mariotti, OAR Climate Program Office
Links to NOAA Strategic Plan:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Goal 3: Serve Society's Needs for Weather and Water Information
Amendment No.: NA14OAR4310189 (Competed)

Research Objectives and Specific Plans to Achieve Them

This project proposes to develop new operational temperature and precipitation forecast products over North America for lead times of 3 and 4 weeks that would bridge the gap between NCEP/CPC's 8-14 day and monthly outlooks and complete a seamless prediction system that links NOAA's intraseasonal and seasonal forecast products. At the foundation of this proposal, recent work by the PIs demonstrates the feasibility of a simple statistical forecast model that combines information from the Madden-Julian Oscillation (MJO), El Niño-Southern Oscillation (ENSO), and linear temperature trend to generate skillful North American wintertime temperature forecasts in weeks 3 and 4. To build upon this effort, the purpose of this project is (1) to transition this statistical model into an operational week 3 and week 4 temperature and precipitation outlook for all seasons; (2) to determine the feasibility of providing information on extremes at these lead times; (3) to calibrate CFSv2 forecasts with the use of archived reforecasts to evaluate the performance of products for weeks 3 and 4 based on the CFSv2; and (4) to explore extending the model calibration approach to the North American Multi-Model Ensemble (NMME).

Research Accomplishments

Our progress since the start of the project (8/1/2014) has incorporated both advances in the research-to-operations objective and fundamental understanding of predictability for lead times of three to four weeks. We have successfully extended the MJO/ENSO phase model developed previously by the PIs to temperature for all three-month seasons beyond December-February with the standard temperature dataset used in CPC's operations. An example of the new forecast guidance is provided in Fig. 1. We anticipate that these efforts will result in the first probabilistic, statistical tool for forecaster decision support by the implementation of the experimental outlooks for weeks 3-4 in September 2015.

The project also has resulted in several papers published, in press, or soon to be submitted that advance our understanding of intraseasonal climate predictability, which focus specifically on North America. In one study, we find that the extratropical response to tropical MJO heating is sensitive to the details of the initial flow pattern in both a simple dynamical model and observations. These results suggest that further improvement of 3-4 week probabilistic forecasts for North America may occur by taking into account the initial state of the extratropics. Another study has investigated the interaction between tropical Indo-Pacific warm pool convection, constructive interference with the climatological stationary wave, and the Northern Hemisphere extratropical circulation over the course of a few weeks. Our findings suggest that inclusion of a stationary wave index and the state of the stratosphere together with the Wheeler and Hendon MJO index may also improve probabilistic forecasts for lead times of up to four weeks. Two other papers have investigated the dynamics of teleconnection patterns over the North Pacific that are known to have significant climate impacts over North America.

We also have gained new knowledge on the intraseasonal variability of El Niño and its teleconnection patterns. We have examined the role of the nonlinearity between deep convection and eastern equatorial Pacific sea surface temperatures on the diversity of El Niño teleconnection patterns. This work reveals that the wintertime climate impacts of El Niño over North America vary based on whether the eastern Pacific is convective (EPC) or non-convective (EPN). In a paper soon to be submitted for publication, we demonstrate that EPC and EPN teleconnection patterns are distinct in form and evolution, which may have significant implications for North American forecasts out to lead times of four weeks.

During the second year of the project, we plan to put substantial effort into examining the feasibility of extreme weather outlooks for weeks 3-4. As an initial investigation into the link between the large-scale circulation and temperature extremes over North America and other land regions of the Northern Hemisphere, we contributed to a study that quantified the role of the circulation on extreme temperature trends. This study identified robust circulation trends contributing to changes in temperature extremes, a result that may guide the development of guidance for extreme weather outlooks. This study resulted in a manuscript that was recently accepted for publication in *Nature*.

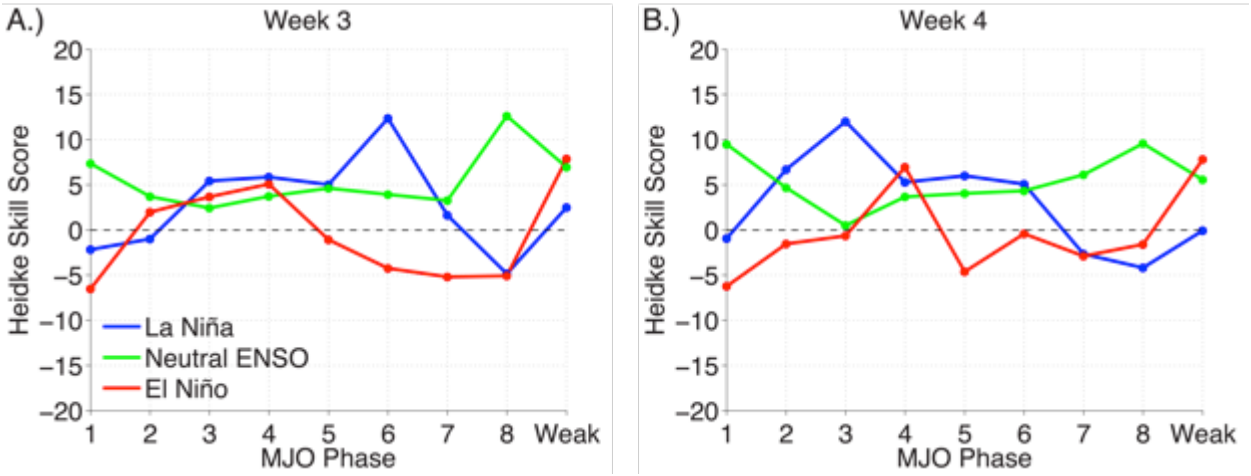

Figure 1: Mean Heidke skill scores (y-axis) sorted by MJO phase (x-axis) for (a) week 3 and (b) week 4 June – August T2m forecasts generated by statistical relationships with the phase of the MJO, the phase of ENSO, and the linear trend, as in Johnson et al. (2014). Blue, green, and red lines indicate La Niña, neutral ENSO, and El Niño initial states, respectively. A Heidke skill score of zero indicates no skill relative to a random forecast. The model is trained with June – August data from 1980 through 2013.

Western Boundary Current Transport as a Climate Index

Nathalie Zilberman, Scripps Institution of Oceanography, UC San Diego
Dean Roemmich, Scripps Institution of Oceanography, UC San Diego
Sarah Gille, Scripps Institution of Oceanography, UC San Diego

NOAA Technical Contact: Jennifer Arrigo
Links to NOAA Strategic Plan:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: NA14OAR4310219 (Competed)

Research Objectives and Specific Plans to Achieve Them
Our purpose is to develop a new method combining altimetric data with High-resolution expendable bathythermograph (HRX) and Argo profiles and trajectories to improve volume transport estimates in five major Western Boundary Currents (WBCs): the Kuroshio, East Australian Current (EAC), Agulhas Current, Gulf Stream, and Brazil Current. The intent of this research is to improve our knowledge of circulation in WBC regions, to increase our understanding of WBC response to wind forcing, and to quantify WBC transport changes in relation to climate variability. The specific objective of this project is to define a new set of ocean climate indicators to track variability in WBC transport.

Research Accomplishments
High-resolution bathythermograph (HRX) profiles to 800-m have been collected along transects crossing the EAC system at 3-month nominal sampling intervals since 1991. EAC transects, with spatial sampling as fine as 10-15 km, were obtained off Brisbane (27°S) and Sydney (34°S), and crossing the related East Auckland Current north of Auckland. We merged HRX profiles collected from 2004 to 2013 off Brisbane with Argo float profiles and 1000 m trajectory-based velocities to expand HRX shear estimates to 2000-m and to estimate absolute geostrophic velocity and transport. The Argo trajectory gridded products

currently available end in 2009 (ANDRO) or have a horizontal resolution too coarse to resolve the flow field in space and time along the narrow path of the EAC (G-YoMaHa). For consistency with Argo and HRX profiles used here, and to better capture the signature of the EAC, trajectory-derived velocities were computed using raw trajectory data from all floats available in our study region from 2004 to 2013. To preserve the sharp velocity gradients associated with the along-coast flow and flow reversal in the EAC region, trajectory-based velocities were sorted into 1/6° latitude x 1/2° longitude bins aligned with the 1000-m isobath. A method was developed for combining altimetric sea surface height from the Archiving, Validation, and Interpretation of Satellite Oceanographic (AVISO) data with HRX and Argo profiles to mitigate temporal aliasing by the HRX transects and to reduce sampling errors in the HRX/Argo datasets.

Our research efforts were focused on interannual variability of the EAC transport, between the sea surface and upper limit of the northward flowing EAC undercurrent (1350 m). Geostrophic transport anomalies in the EAC at 27°S show variability at interannual times scales related to El Niño-Southern Oscillation (ENSO). The ENSO signature seen in EAC transport anomalies is linked to wind-stress curl strengthening in the western Pacific during El Niño events, and wind-stress curl weakening during La Niña.

Modernizing the tropical ocean/atmosphere observing system

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Daniel Rudnick, Scripps Institution of Oceanography, UC San Diego
Bruce Cornuelle, Scripps Institution of Oceanography, UC San Diego
John Gilson, Scripps Institution of Oceanography, UC San Diego

NOAA Technical Contact: David Legler, OAR COD
Links to NOAA Strategic Plan:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Goal 3: Serve Society's Needs for Weather and Water Information
Amendment No.: NA13OAR4830216 and NA14OAR4830302

Research Objectives and Specific Plans to Achieve Them
The project is composed of three distinct but coordinated elements. The overall goal is to demonstrate the scientific potential and cost-effectiveness of modern autonomous instrumentation (floats and underwater gliders) for modernizing the Tropical Pacific Observing System, and the value of Ocean Data Assimilation Modeling in synthesizing these observations. Objectives and plans for each element are:

a) Enhanced coverage of Argo profiling floats. The objective is to provide enhanced spatial resolution of Pacific equatorial variability in relation to El Nino/Southern Oscillation evolution, using Argo profiling floats (Temperature/Salinity/Pressure, 0-2000 m). Production and deployment of 41 SIO SOLO-II Argo floats along the equator between 100°W and 160°E will double the Argo coverage along the equatorial waveguide.

b) Underwater glider missions in the eastern equatorial Pacific. The objective is to demonstrate the utility of underwater gliders to deliver time series of vertical profiles as a replacement of TAO moorings. Two glider years are to be obtained between 2°N and 2°S at 95°W, which is an active location for equatorial upwelling and where mooring survival rates are very low due to vandalism and fishing damage. The

glider operations will be based in the Galapagos and done in collaboration with INOCAR, the oceanographic institution of the Ecuadoran Navy.

c) System evaluation using high-resolution ocean state estimation. The goal of this work is improved estimation of the physical state of the tropical Pacific for resolving intra-seasonal to interannual variability and possibly enabling predictions of ENSO and other air-sea interactions. The benefits of the capabilities enabled by the new observation systems (Argo, gliders, and satellites) will be explored The synthesis of these observations will be compared to the information available from moorings, which provide high temporal sampling, but only at a limited number of locations and depths.

Research Accomplishments

a) Enhanced coverage of Argo profiling floats. The 41 SIO SOLO-II Argo floats have been produced and were deployed along the equator between 100°W (23 January, 2014) and 160°E (26 March, 2014). Each float returns a temperature/salinity/pressure profile from the sea surface to 2000 m depth every 7 days and each has completed 65-70 cycles since deployment. These floats are providing unprecedented coverage of the equatorial Pacific, including a major intraseasonal wind-driven Kelvin wave that crossed the Pacific during March-May 2015l. This is a possible El Niño precursor, and NOAA models that assimilate these data are predicting warm (El Niño) conditions as likely later this year. All Argo data are publicly available in near real-time via http://www.argo.net

b) Underwater glider missions in the eastern equatorial Pacific. Two new SIO Spray gliders were produced, and along with other gliders in the SIO glider pool will support the present mission. The initial glider deployment along 95°W between 2°N and 2°S was carried out in the first week of April, 2014, using a Spray glider equipped with sensors for pressure, temperature, salinity, and chlorophyll fluorescence. After a mission of about 4 months, each glider is recovered and replaced (except for a gap between 12 December 2014 and 6 February 2015). During 3 missions so far, about 1400 dive cycles have been completed. The glider transects along 95°W are coordinated with a separate NSF-funded project obtaining glider transects along 93°W, with a grand total of 1500 glider-days, 25,000 km track length, and 7100 profiles. Data show the sequence of events during this unusual year at the equator. With profiles separated by about 6 km, our data set includes the most highly resolved sustained, repeated sections ever done across the equator.

c) System evaluation using high-resolution ocean state estimation. The state estimation began with a 1/3 degree resolution model spanning the entire tropical Pacific Ocean, using all observation systems now available: Argo, CTDs, XBTs, gliders, and satellite SST and SSH. The state estimation progressed from testing periods in 2007 to 2010. We have automated the state estimation machinery, and have settled on 4-month assimilation windows with 2 month overlap, and recently completed the period 2010-2011. The 4-month estimates do as well in the fits as the 2-month estimates, and the overlap period allows for smooth transitions. We are experimenting with blending methods to find the best. We are comparing the complete set of 2-month state estimates with the 4-month estimates in their performance against TAO and the Argo maps.

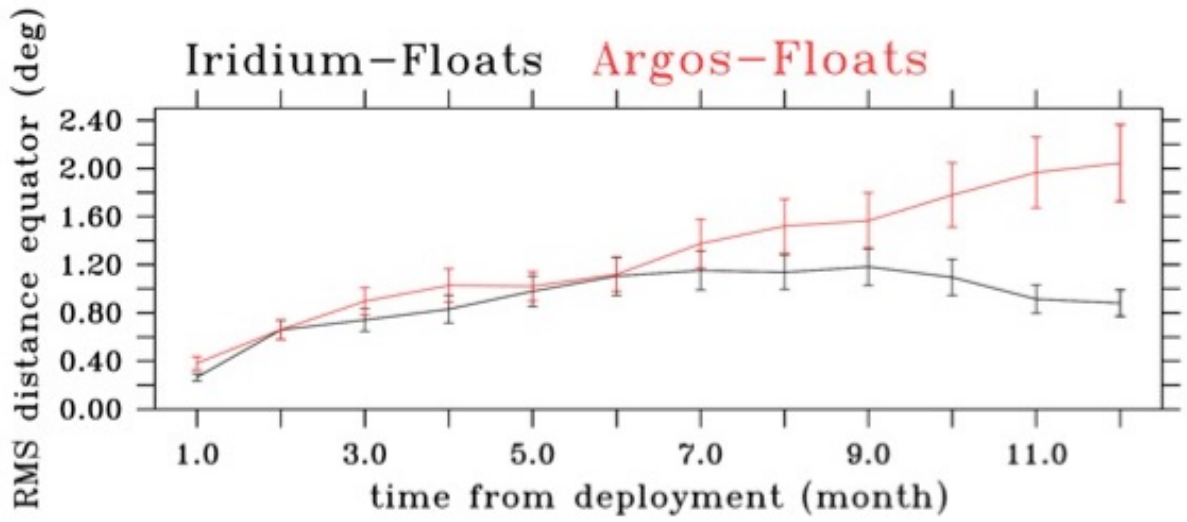

Figure 1: RMS distance to equator as a function of time since deployment for the present (Iridium) 38-float equatorial Pacific array in comparison to previous (ARGOS) floats deployed along the equator. The much shorter time on the sea surface for Iridium floats greatly reduces their tendency to leave the equator (equatorial surface divergence).

A Nudging and Ensemble Forecasting Approach to Identify and Correct Tropical Pacific Bias-Producing Processes in CESM

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NOAA Technical Contact: Sandy Lucas, CPO
Links to NOAA Strategic Plan:
Goal 3: Serve Society's Needs for Weather and Water Information
Amendment No.: NA14OAR4310276 (Competed)

Research Objectives and Specific Plans to Achieve Them

Current short-term tropical climate forecasts (e.g., of the Madden Julian Oscillation (MJO) and of El Niño/Southern Oscillation (ENSO) events) experience both a systematic error (climate drift) that results in sustained biases of the model tropical climatology and an error in representing the space-time scales of the transients (e.g., phase speed errors, etc.). Our objective is to identify the physical mechanisms that lead to the seasonal biases in the tropical Pacific by isolating the parameters and parameterizations that influence the development of biases in short-term climate forecasts. Our overarching scientific objective is to *identify, explain, and correct the climate biases in the Pacific Ocean that occur in the Community Earth System Model (CESM)*. We are currently analyzing the output from a coupled data assimilated CESM-DART model to study the analysis tendencies obtained from data assimilation. These tendencies will inform us regarding the biases in the model that are corrected for by the data assimilation method.

We have commenced our study of the spatiotemporal structures of bias development in CESM forecasts, launched from numerous initial states and during which random ENSO and MJO events occur, to determine the relative importance of poor mean-state representation versus the integrated impacts of

the transient flows. This bias development will be studied as a function of season to account for significant changes in the background state of the coupled ocean- atmosphere system in the tropical Pacific. We will seek to ascribe these effects to well- known physical processes for the specific climate modes of variability. We will test the sensitivity of the bias development to changes in coupled model resolution and model parameter selection. We will also implement nudging experiments (towards observations) to pinpoint where the worst parts of the biases develop apart from the nudged variables. We will use model state variables from the data assimilated CESM model to initialize forecast experiments and nudging experiments to further identify robust biases and physical parameterizations that are likely to be responsible for these biases.

Research Accomplishments

We are now analyzing a 30-member ensemble integration of a CESM model (active ocean, atm, land, ice) with CAM5 prognostic aerosols. In situ ocean data from WOD09 is assimilated daily and NCEP radiosonde temp, winds are assimilated at 6 hourly intervals in the atmospheric model. Currently the run is from 1970 to 1980 and still going. No data is assimilated in land or ice. The DART data assimilation software is used. DART is an Ensemble Adjustment Kalman Filter with adaptive inflation in ocean/atm. There are no cross-model-component covariance, but data assimilated in one component of the model can pass on information to the other coupled components every time they are coupled. The atmospheric data are assimilated every 6 hourly and the forecasts represent only 6 hours of atmospheric error growth. In the ocean the Priors are 1 day forecasts, so the increments will represent 1 day of error growth in the ocean (but the atmosphere, which forces the surface fluxes has been constrained at 6 hourly intervals).

We have begun analyzing the mean state and the variability in this data assimilated CESM run, in collaboration with Dr. Alicia Karspeck and Dr. Gokhan Danabasoglu at NCAR. The model runs for assimilation are performed by Dr. Alicia Karspeck.

Initial model results show high correlation in the surface temperature field globally compared to Hadley-OI SST fields. The SST field in the model is not constrained to data and hence, is an independent measure of verification for the data assimilated model. We then looked at the mean state of the precipitation in the model run. The mean global precipitation has a similar spatial pattern and amplitude as does GPCP observed mean precipitation. The CESM model has long known to have a double Inter-tropical Convergence Zone (ITCZ) bias, where there is anomalous high precipitation south of the equator compared to observations. This bias is not present in the data assimilated CESM-DART. We are currently analyzing the data assimilated tendencies to identify robust analysis tendencies that helped reduce this bias.

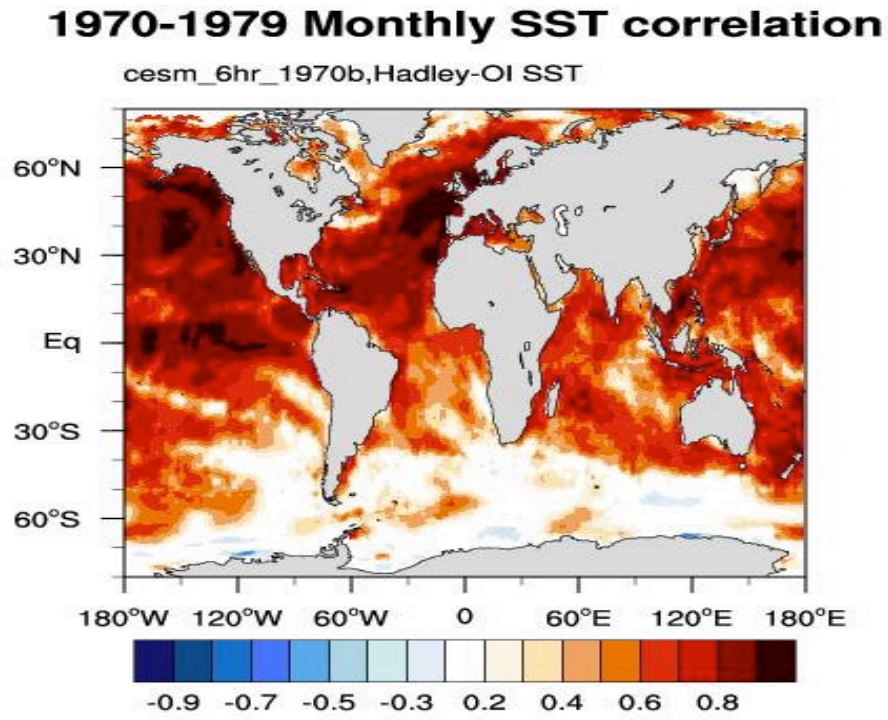

Figure 1: Correlation coefficient of monthly mean SST (1970-1979) from CESM-DART simulations and Hadley-OI Observed SST fields globally.

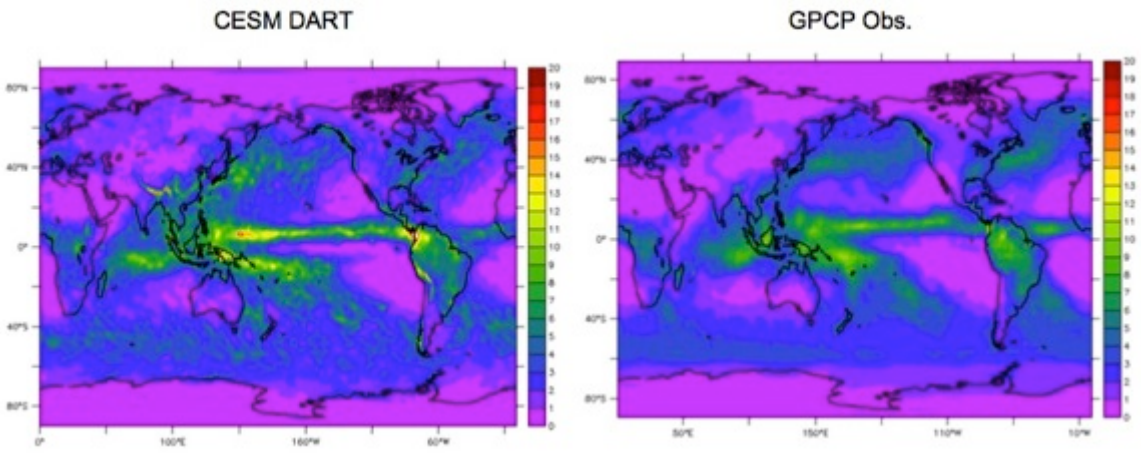

Figure 2: Mean global precipitation (1970-1979) from CESM-DART (left) and Global Precipitaiton Climatology Project (v2.2).

NOAA Ocean Acidification Program CalCOFI OA Monitoring and QA/QC Analytical Support

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NOAA Technical Contact: Libby Jewett, CPO
Links to NOAA Strategic Plan:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: 44, 76, and 121

Research Objectives and Specific Plans to Achieve Them

Activity 1: Collection and Analysis of Samples from the California Coast

The aim of this work is to provide information that can be used to test algorithms developed by Dr. Simone Alin (NOAA/PMEL) and her colleagues for predicting aragonite saturation state in the upper water column of waters off the California coast. Such algorithms are based (for a particular region) on measurements of salinity, temperature, depth, and oxygen concentration. It is thus necessary to collect water samples from cruises such as those of the California Cooperative Oceanic Fisheries Investigations (CalCOFI) where these data are measured routinely, and to analyze these water samples for carbon system parameters so as to allow an independent assessment of the aragonite saturation state for that location and time.

Activity 2: QA/QC analytical support for NOAA Ocean Acidification Program

In this activity, our laboratory continues to work with the NOAA Ocean Acidification Program to ensure improvements in the analytical capacity of laboratories that are involved in research activities for the Program. In this period, we requested support for the following three related activities:

(1) Development of a seawater pH measuring system suitable for OA research;
(2) Development of written quality control protocols for CO_2 measurements;
(3) Conduct proficiency study for CO_2 measurements.

Research Accomplishments

Activity 1: Collection and Analysis of Samples from the California Coast

For each CalCOFI cruise, we supply ~120 clean bottles together with the necessary equipment to poison the samples, and to seal them. These samples are collected by CalCOFI staff in accordance with a sampling plan that had been discussed and agreed upon between Dr. Dickson, Dr. Alin (NOAA/PMEL) and the CalCOFI program. The current status of our analysis program is detailed in the following table.

CalCOFI cruise ID	No. of samples	Analyzed	Data reported?
1407NH	140	100%	Yes
1411NH	140	~ 60%	No
1501NH	140	–	No
1504NH	160	–	No

It is thus apparent that there have been delays in completing the analyses in the laboratory. This was largely a consequence of the principal analyst (Mr. David Cervantes) also having responsibility for a large CLIVAR cruise in the 2015 time period, thus not being able to dedicate sufficient time to this work in the first half of 2015. These analyses are expected to resume in July 2015.

Activity 2: QA/QC analytical support for NOAA Ocean Acidification Program

Development of a seawater pH measuring system suitable for OA research;

There are 2 principal aspects to this work: development of the instrument system and development of a measurement procedure capable of returning data with a predictable uncertainty.

After this NOAA project was funded, Dr. Dickson received a small grant from the Scripps Institution of Oceanography also intended to facilitate development of a suitable instrument system based, largely, on commercially available components. The assembly of this system (which uses a Ocean Optics spectrophotometer together with optical fibers and a Peltier-based temperature control system) is in progress. All parts have been purchased, and the initial testing of individual components is almost complete. The next stage will be the complete assembly and programming / testing of the system.

A primary difference between the *new* system and our current laboratory system (similar to that described by Carter *et al*. Limnology & Oceanography: Methods, 11, 16, 2013) is the use of a much smaller flow-through cell with a 1 cm path-length rather than the 10 cm path-length that is in common use. The advantage of this is that it requires a lot less sample, and uses significantly less indicator dye as a result (such dye needs to be purified, and is expensive and not readily available). The disadvantage is that the dye is more concentrated in the cell and hence requires a larger *correction* for the change in pH caused by adding dye solution to the sample itself. Mr. Michael Fong (a student at SIO, supported through a University of California Ocean Acidification grant) is working to improve (a) our ability to model these corrections using an equilibrium acid-based description of what we believe to be the process involved, and (b) establish a procedure for evaluating and applying the correction that will allow its uncertainty to be characterized. To date, Mr. Fong has developed such a model, and we are now designing experiments that will allow us to evaluate it. We plan to use a 1 cm cell for this, however it will be used in our current Agilent spectrophotometer so that testing can proceed in parallel with instrument development.

Development of written quality control protocols for CO2 measurements;

As an initial activity we have focused on discussing and documenting our own laboratory measurement techniques. In particular we have completed a draft of such protocols for our measurements of total alkalinity (using an open-cell titration technique), and for the measurement of spectrophotometric pH. (One problem we have found is the apparent existence of some cell-to-cell differences that – in principle – should not exist, and we are planning work to clarify the problem and to propose an effective solution.) These quality-control protocols are in use in our laboratory measurements (both in our home laboratory and when we make measurements on board a research vessel at sea), and we plan to review them after the current CLIVAR cruise. We will them make them more widely available as example templates others could adopt / adapt.

Conduct proficiency study for CO_2 measurements;

Our previous proficiency study was published in this project period (Bockmon & Dickson, *Marine Chemistry*, 171, 36, 2015) and has attracted some interest. We are planning to make a new batch of test materials, however these new test materials would also incorporate a change in total alkalinity in addition to in total dissolved inorganic carbon. We are currently studying the stability of a prototype test material where we had explicitly modified the total alkalinity of our seawater.

QA/QC Workshop;

A significant activity that has been carried out as part of the work funded by this project was a 2-day workshop held at the Scripps Institution of Oceanography (June 2-3, 2015). Eleven individuals from a variety of laboratories supported by the NOAA Ocean Acidification Program came to Scripps for a

workshop comprising some lectures, some hands-on laboratory experience of alkalinity titrations, a tour of our reference material certification facilities, and extensive discussions both as a larger group and in small groups. The workshop participants were individuals with direct responsibility (both organizational and hands-on) in their own laboratories for seawater CO_2 measurements. Dr. Andrew Dickson and Mr. Guy Emanuele ran the workshop.

The topics introduced in the workshop were: "How good is good enough?" – a discussion of the combined overall uncertainty required of laboratory CO_2 measurements; "Estimating the uncertainty of the open-cell method for total alkalinity" –provided a concrete example of the many different components of uncertainty and how they can be evaluated; "How do you know that you are achieving this uncertainty routinely?" – a discussion of the basics of laboratory quality control, using the approaches we use in our own laboratory, and "Proficiency Testing" – a description of a recent inter-laboratory study of CO_2 measurements, and a discussion of the lessons that can be learned from such studies. Although participants enjoyed these discussions, and found them helpful, a significant ancillary benefit of the workshop was in providing a meeting place for groups with common problems, and thus allowing them to develop a community of like-minded individuals who can consult with each other in the future (most participants commented that this more social aspect was one of the valuable contributions of the workshop.

Plans to complete, as yet, unfinished activities

As was noted above, there are a number of unfinished tasks. This reflects an over-commitment within the laboratory of the time of a limited number of skilled individuals. As a result, there are significant funds remaining unexpended and a No Cost Extension has recently be granted to continue this work.

The analyses of samples from CalCOFI cruises will be restarted when Mr. David Cervantes returns to the laboratory in July after being away on a long CLIVAR cruise (April–June). We are also currently planning to collect additional samples on the upcoming 1507OC cruise in July 2015 and on 1511OC (Nov ember 2015). At this time, we do not have funding to continue this sampling and analysis program beyond 2015.

The work on the pH system will continue through the rest of 2015. Mr. Guy Emanuele will work to assemble and perform preliminary tests on the prototype system, and a graduate student (probably Mr. Michael Fong) will focus on more involved testing of pH measurements in general, and of the new system in particular. The final proposed product will be a written procedure for making spectrophotometric pH measurements using the new prototype system.

As noted above, we are re-evaluating our draft QC procedures. They will be distributed more widely once this has been done.

We are planning to prepare new test samples later this year. These will be of similar salinity (coastal California seawater S ~ 33), but we plan to change the alkalinity in one of the samples by at least 1000 $\mu mol\ kg^{-1}$, and also to modify its total dissolved inorganic carbon level. As in our previous proficiency test, these samples will initially be distributed to laboratories supported by the NOAA Ocean Acidification Program. If additional samples are available they will be distributed later as alternate reference materials for method validation in labs around the world.

Integrated Boundary Current Observations in the Global Climate System

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Links to NOAA Strategic Plan:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: 44, 76, and 121

Research Objectives and Specific Plans to Achieve Them
For over 20 years the Consortium on the Ocean's Role in Climate (CORC) has focused on implementing new ocean observing technologies and systems. After identifying inadequately measured properties of the ocean circulation that are important to understanding and predicting climate variability, CORC investigators have developed cost-effective technology, methodology and infrastructure to implement observing systems to measure them. These systems have been put into operation to refine and demonstrate their abilities. Examples of past and ongoing projects are the High-Resolution Expendable Bathythermograph network operating from commercial ships, the Surface Velocity Program, the Argo network of profiling floats, the array of California Current glider transects, and moorings to capture high-frequency processes.

Motivated by national and international planning efforts, CORC is now focused on methods to observe boundary currents, both western boundary currents whose powerful circulation signatures affect global climate fluctuations and eastern boundary currents where the circulation affects local weather, ocean acidification, and valuable fisheries. The boundary current data streams are intended primarily for scientists developing societally valuable analyses and prediction products that are influenced by persistent ocean conditions i.e. ocean climate. Examples are developing models to predict seasonal temperature or precipitation anomalies over land, assessing and predicting trends in ocean productivity and fisheries, or planning coastal development in a changing climate.

More specifically, CORC is now developing regional observing systems in the California Current and the Solomon Sea and developing methods to merge these observations with global ocean climate observations like altimetry, winds, Argo profiles and the Surface Velocity Program. In and inshore of the California Current, changes in processes like alongshore currents from the north and south, upwelling, changes in stratification and mixing, and the frequency and strength of near-surface fronts have been implicated in large changes in the abundance of fish and their prey. CORC data is being used to look for relations between ecosystem properties and coastal circulation. The Western Boundary Current in the Solomon Sea is the main source of the Pacific's Equatorial Undercurrent. This makes it a central part of the shallow overturning circulation that influences central Pacific surface temperatures that drive the El Niño – Southern Oscillation (ENSO) fluctuations with global temperature and precipitation consequences. CORC observing systems are delivering data to test and improve methods of predicting ENSO and its decadal-variability relatives as well as ecosystems and local weather along the California coast. This delivery is done primarily through public web sites where data can be plotted or downloaded. CORC does not intend to operate these observing systems indefinitely and hopes to transition them to a program better suited to sustaining them.

CORC has identified circulation in mid-latitude western boundary currents (WBCs) as another type of inadequately observed components of the ocean climate system and is planning to address them with new methods. We are therefore exploring new ways of observing the transport processes of such WBCs with an eye toward sustaining measurements at a reasonable cost.

Research Accomplishments

CORC supports gliders in the California Current (CC) on line 90 off Dana Point, and line 66.7 off Monterey. We produce data products consisting of profiles of temperature, salinity, density, velocity, chlorophyll fluorescence, and acoustic backscatter on uniform grids for each glider transit along all lines. The resulting sections allow calculation of the transport of such quantities as heat, salt, phytoplankton, and zooplankton, directly addressing the Climate Program Office deliverables of Ocean Heat Content and Transport, and Ocean Carbon Uptake and Content. We continue to produce and publish a glider-based SoCal Niño Index, which is remarkably correlated with the Oceanic Niño Index (Nino 3.4 filtered with a 3-month running mean), with the notable exception of the 2014 warm anomaly where the SoCal index departed towards much higher temperatures (figure 1). The CORC moorings and PIES (inverted echosounders with bottom pressure) are starting to capture more fully the cross-shelf circulation on shorter timescale, making use of the CORC3 site with a stationary glider co-located with a PIES, and a glider next to the CCE1 mooring (co-located with a PIES) and between there and the coast. We have also detected an apparent correlation of along-coast bottom pressure gradient with spiciness of the California Undercurrent, which is being explored further. CORC data are contributing to community efforts to analyze the 2014/15 Pacific warm anomaly off California.

We continued the time series of Solomon Sea (SS) transport (now to 1000m depth) begun in 2007. These observations are the only repeated indicator of the subsurface western boundary current in the tropical South Pacific. The 8-year glider time series show transport variability in the WBC to be well correlated to equatorial SST on ENSO scales. Largest interannual anomalies are in the shallowest layer (figure 2, blue) and take the form of "ramps", slow increases before warm events in late 2009 and 2013, followed by abrupt transport decreases after the events. Deeper layers are less variable but all respond to the 2009-10 El Niño with transport increases. These responses are delayed from the Niño 3.4 signal by an amount that grows with depth. The end-point component across the Solomon Sea (moorings and PIES) has provided 2 years of data now, confirming and resolving very rapid transport changes by 10-15 Sv over 10-20 days, and being highly complementary to the glider observations. Two vertical EOFs can capture 99% of the horizontally integrated flow variability, which is well determined by the moorings/PIES. The combination of altimetry and PIES also has good skill at observing the transport and the two leading EOFs.

The combination of High Resolution XBT and Argo data in the East Australian Current (EAC) region near Brisbane was continued and brought to conclusion. While Argo is efficient at broadscale areal coverage, it does not provide sufficiently dense sampling to resolve the energetic, temporally and spatially varying EAC. The HR-XBT network provides the necessary spatial resolution along the sampled routes, and is thus strongly complementary to Argo. Argo trajectory data also provide a reference velocity for absolute transport estimation. One new result is that trajectory-based transport estimates of the EAC and recirculation are less than 2000 m reference-level estimates. Our estimate of the EAC transport at PX30 (19.5 Sv) agrees within uncertainties with observations from PCM3 moored array at 30°S by Mata et al. [2000].

CORC is producing sequential short-term state estimates (STSE) of one-month duration, now covering from late 2010 to mid-2014, to be extended to 2015 soon. Indices are being generated for upwelling strength, undercurrent variability/surfacing, and heat content. There appears to be an increasing trend in undercurrent transport, especially increasing minima, starting in 2013. Tests of the state estimate against independent observation shows that it performs well.

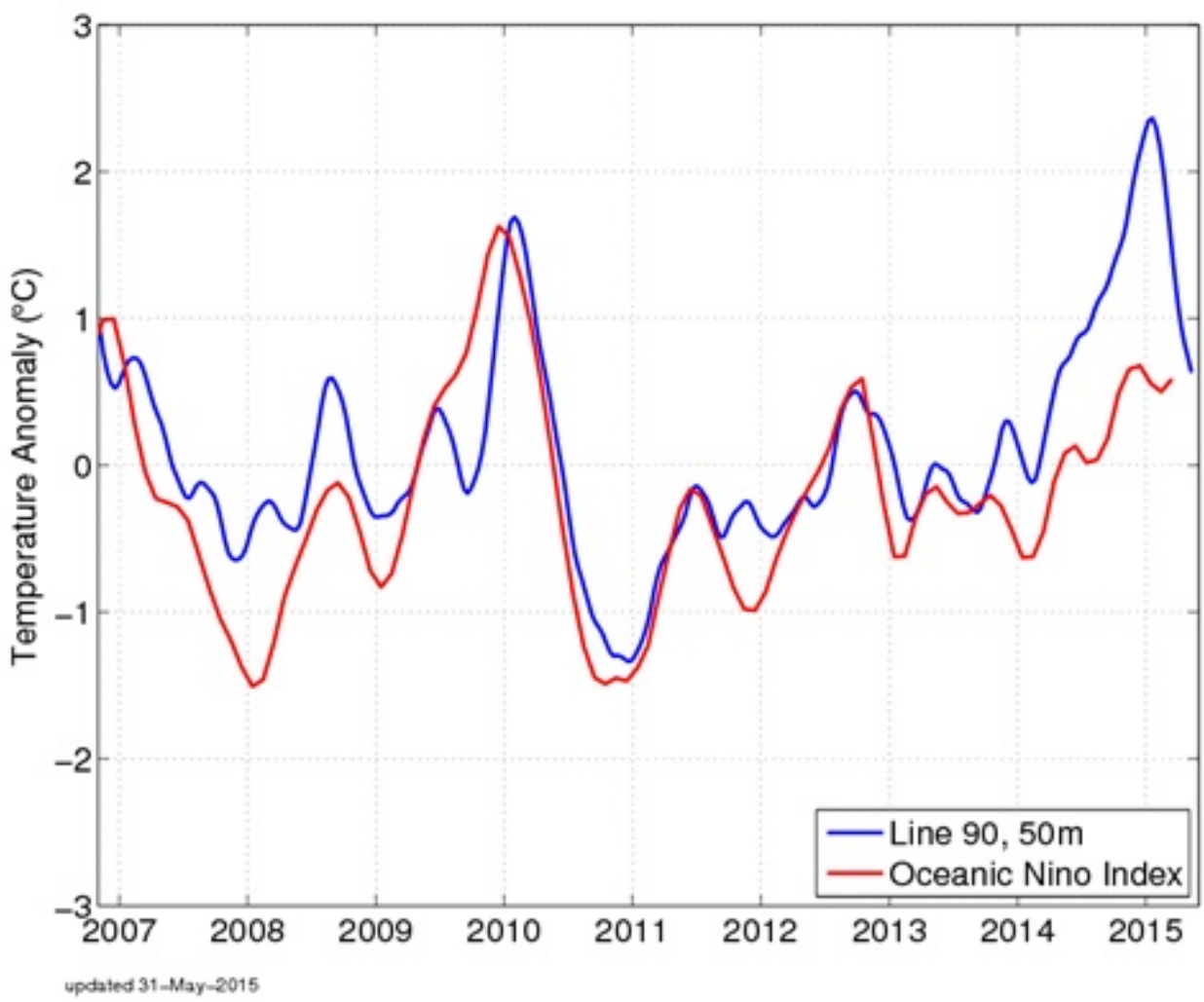

FIGURE 1: The SoCal Niño index is defined as 50-m temperature averaged over the inshore 200 km of line 90, smoothed with a 3-month running mean (blue). Temperature off California is noticeably correlated with temperature at the equator as measured by the Oceanic Nino Index (red). The dominant exception to this pattern of correlation is the recent warm anomaly. While a warming trend began at the equator and off California at the same time, the increase was much stronger off California

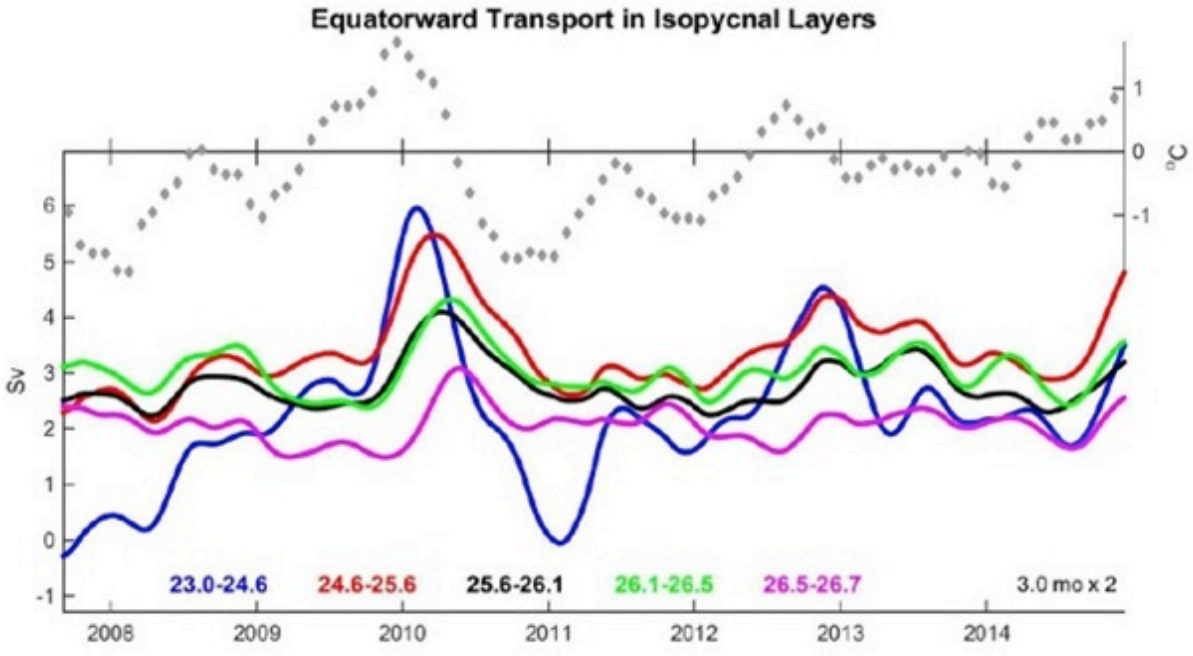

FIGURE 2: Absolute geostrophic transport (Sv) measured by the Spray glider in separate density layers of roughly equal mean transport, with the annual cycle removed. The bottom legend lists the line color and potential-density range for each layer. Gray dots above show the Niño 3.4 anomaly time series.

Theme B: Climate Research and Impacts

The Global Drifter Program

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NOAA Technical Contact: C. Clark, CPO
Links to NOAA Strategic Plan:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Goal 3: Serve Society's Needs for Weather and Water Information
Goal 4: Support the Nation's Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation
Amendment No.: 19, 27, 59, 79, and 125

Research Objectives and Specific Plans to Achieve Them
Provide through the Global Telecommunication System (GTS) a-real time data stream of drifters locations, SST, Sea Level Atmospheric Pressure (SLAP), SSS, sea level wind and subsurface temperature . 2) Observe 15m depth ocean currents on a global basis with a nominal 5.0° resolution and, jointly with satellite altimeter data, produce circulation data of the world ocean at 0.5° resolution that can be used to trace pollution laden particles or turbulent dispersion of vorticity and thermal energy due to the tropical eddy field; 3) develop and implement drifter's technological advances in sensors, electronics, power, methods of assembly and deployment packaging. 4) Provide enhanced research quality data sets of ocean circulation that include drifter data from individual research programs.

All the research objectives were met or exceeded. All drifters' derived data of location; SST and SLAP were posted on the GTS. GTS compatible data of winds, subsurface temperature (Tz) and SSS were also provided basis when these sensors are mounted on the drifters. I collaboration with AOML we maintained an array in excess 1,250 drifters (average) to measure the circulation of the world ocean. In the past two years, these technological advances have introduced new drifter wind sensors integration, drogue-on sensors (strain gauges), improved air pressure ports and improved drogue construction technology; Gridded, global data sets of SST, near surface circulation and dynamic topography, or absolute sea level, are available on line for assimilation into and use in the verification of ocean models, for numerical weather predictions and for SST and SSS satellite products.

Research Accomplishments
Since September 2005 the fully implemented global drifter array has consisted of between 1100-1400 drifters. This required global drifter array size is based on the need to return in-situ observations of SST (+/- 0.10C) over the global ocean at a 5° resolution in order to keep the potential SST satellite bias error smaller than 0.5°C. Surface pressure sensors are also supported NOAA and by national meteorological agencies based on regional needs. The status of the GDP array is updated weekly can be seen at the AOML website: http://www.aoml.noaa.gov/phod/dac/index.php. The present drifter array is 14% bigger than its nominal size.

Over 86 salinity drifters were deployed in the tropical Atlantic in support of NASA's SPURS experiment. The experiment is now concluded and data analysis is in process. See also http://spurs.jpl.nasa.gov/SPURS/. Ongoing-targeted drifter deployments are underway in the Bay of Bengal, in the South China Sea and in the Arabian Sea. Significant capacity building efforts by the PI at DBCP/WMO/UNESCO meetings (12 - 15 May 2014, Port Elizabeth, South Africa; Third Capacity Building Workshop of the WMO/IOC Data Buoy Cooperation Panel (DBCP) for the North Pacific Ocean and Its

Marginal Seas (NPOMS-3) - Application of Regional Ocean Observations for Increasing Society's Understanding and Forecasting of Typhoons, 6 - 8 October 2014, Kyoto, Japan,) has resulted in a significant increase of drifters in the Western Indian Ocean and in the NW Pacific.

- GDP array completed with 1,424 drifter in the array at the time of writing
- SIO is now posting drifter data to the GTS
- Significant increase in the number of drifters in the Indian Ocean
- Coordinated GDP Activities Between Partners and Support of other science programs
- Enhanced the GDP Array with Matching Contributions
- Monitored and Advised the Drifter Manufacturers to Ensure Drifter are Built According to Specifications
- Updated and Maintain the Enhanced GDP dataset/GDP data distribution
- Maintained Statistics of Drifter Performances
- Reported GDP activities and research at several meetings and conferences
- Scientific Analysis of GDP data

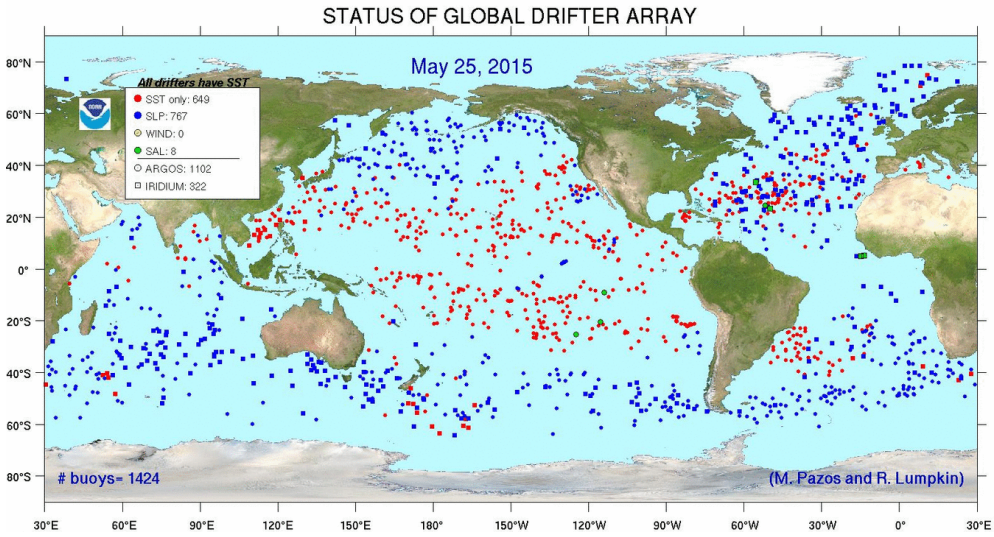

Figure 1: Global drifter population on May 25, 2014.

Measurements of O2/N2 and Ar/N2 ratio by the Scripps O2 program

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NOAA Technical Contact: James Butler, ESRL
Links to NOAA Strategic Plan:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: 16, 40, 71, and 124

Research Objectives and Specific Plans to Achieve Them

This project continues time series of O_2/N_2 and Ar/N_2 ratios at ten background air stations by the Scripps O_2 program. The O_2/N_2 measurements are critical for determining the evolving land and ocean carbon sinks that underpin studies of the global carbon cycle. The Ar/N_2 measurements provide critical insights into changing ocean heat content and its coupling with air-sea O_2 and CO_2 exchange. The program has strong synergies with measurements of CO_2 concentration and CO_2 isotopes by the NOAA-GMD program and the Scripps CO_2 program (also directed under the PI).

The primary funded activity involves measurements of atmospheric composition from flasks collected at an array of ten stations extending from the Arctic to the Antarctic along a (mostly) Pacific transect. Flasks are analyzed at the Scripps Institution of Oceanography through a combination of interferometric, mass spectrometric, and infrared detection methods. Measurements are also made of air pumped continuously at La Jolla. These flask and continuous measurements are calibrated using an extensive suite of reference gases maintained by the Scripps O_2 program since the mid 1980s. The funded activities further include data reduction and data dissemination activities, including maintaining a dedicated website, ScrippsO2.ucsd.edu. The work also supports continued efforts to improve methods and address the merging of measurements from the Scripps O2 program with data from other programs, and it supports international intercomparison and intercalibration activities involving O_2/N_2 measurements, as endorsed by the World Meteorological Organization.

Research Accomplishments

An important accomplishment has been maintaining continuity in the time series based on flask sampling at the ten stations. Results for O_2/N_2 are shown in Figure 1. Data from this program have been disseminated on the website: ScrippsO2.ucsd.edu. The data continue to document clearly resolved seasonal cycles and long-term trends on O_2 and CO_2. The trend data can be used to quantify global land and ocean carbon sinks. Data for Ar/N_2 show a well resolved seasonal cycle and small increase overtime, which is still too small to be well quantified.

The data from this program have been increasingly used by collaborators for improving understanding of ocean and land biogeochemistry and carbon cycling. In the past year, studies have been published that used the seasonal cycles in atmospheric oxygen as a test ocean biogeochemical models, particularly their depiction of biological production and ventilation rates. The O_2 data are especially valuable because they provide a well-observed large-scale constraint.

Several projects using the data from the Scripps O_2 program are in progress at Scripps:

(1) Laure Resplandy (postdoc) is using the O_2/N_2 and CO_2 data to support an analysis showing that these data provide a constraint on the natural transport of heat by the ocean from the southern to the northern hemispheres. The constraint relates to the observed deficit in "atmospheric potential oxygen" (APO) in the northern hemisphere. The analysis supports an estimate of the ocean heat transport from the southern to northern hemispheres that is on the high end of previous estimates. Further work by Laure shows helps to quantify the natural transport of CO_2 by the ocean from north to south, and her estimates

weaken the need for a large northern terrestrial sink in order to explain the north-south CO_2 patterns in the atmosphere.

(2) Manfredi Manizza (Research Associate) is leading an analysis which challenges ocean models based on the observed ratios of the amplitudes of the APO and Ar/N_2 cycles.

(3) Jonathan Bent (former grad student) used the data from the surface network, as well as from the NSF-funded HIPPO airborne campaign to develop a constraint on ocean biogeochemical models in the Southern hemisphere. His thesis also documents a gradient in Ar/N_2 with latitude which, similar to the APO study mentioned above, may constrain ocean heat transport from the southern to northern hemispheres.

(4) Yassir Eddebbar (current grad student) is comparing the observed decadal variability in APO with hindcasts from the NCAR community earth system model (CESM). His work particularly focuses on trying to better understand an acceleration of the downward APO trend which started around year 2000, and may have a relation to the global warming "hiatus", which started around the same time.

Scripps will be hosting two notable conferences related to this project in Sept 2015, including the bi-annual GGMT meeting on greenhouse gases and a workshop on APO. Both meetings will draw an international audience and advance the goals of this project in data intercomparison and intercalibration.

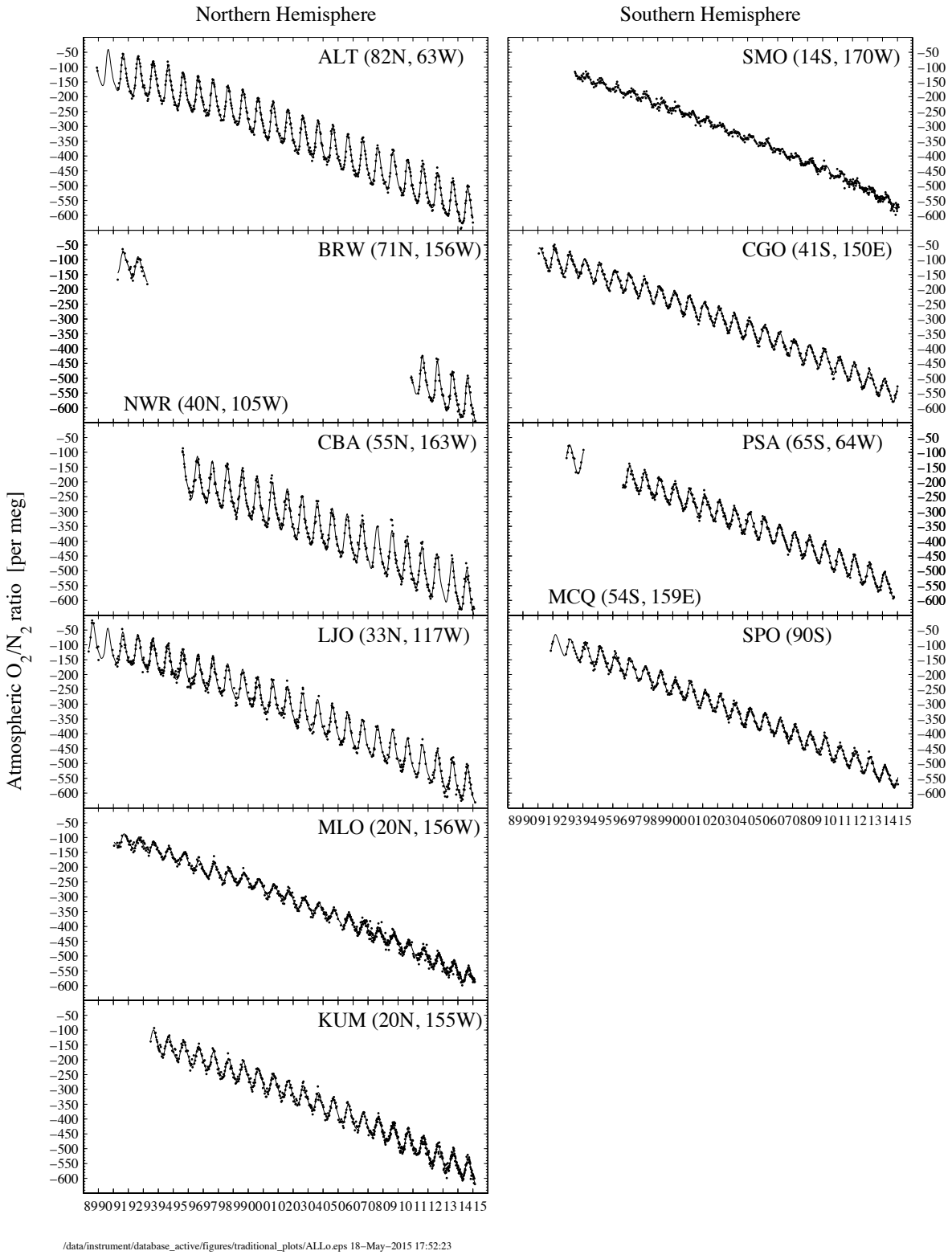

Figure 1: Time series for atmospheric O_2/N_2 ratio at the ten stations in the Scripps O_2 flask network.

Meridional Overturning Variability Experiment (MOVE)

Uwe Send, Scripps Institution of Oceanography, UC San Diego
Matthias Lankhorst, Scripps Institution of Oceanography, UC San Diego

NOAA Technical Contact: Diane Stanitski, CPO
Links to NOAA Strategic Plan:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: 25, 68, 75 and 118

Research Objectives and Specific Plans to Achieve Them
A present gap in the sustained ocean climate observing system are techniques and programs for monitoring the circulation and mass/heat/freshwater transports of major current systems, sometimes called "transport reference sites". For broad-scale and deep-reaching circulations, an accurate and cost-effective method for this consists of fixed-point installations with moored and bottom-mounted instruments to obtain horizontally integrated measurements throughout the watercolumn. The MOVE project applies this approach to obtain sustained observations of a component of the AMOC (Atlantic Meridional Overturning Circulation) which is a national ocean observing priority. This effort had been initiated via the German CLIVAR programme from 2000 to 2006 in the subtropical west Atlantic along 16N, in order to observe the transport fluctuations in the North Atlantic Deep Water layer. Since 2006 is has been operated with NOAA funding, now providing the longest record of direct AMOC observations.

Within the current NOAA MOVE project, SIO/CIMEC/NOAA operates the two geostrophic endpoint moorings and bottom pressure recorders (PIES) between the western boundary and the Midatlantic Ridge (yielding dynamic height and bottom pressure differences), plus a small current meter mooring on the slope. This is complemented on the eastern side of the Atlantic with a German-funded and operated mooring (near the Cape Verde islands). Routine operation is now achieved with two-year long deployments, which enables routine delivery of indicators about the state of the thermohaline overturning circulation at this latitude. The moorings and PIES have recently been equipped with acoustic modems, allowing data retrieval from research vessels or via gliders.

Research Accomplishments
In December 2014, SIO participated in the NTAS/MOVE cruise led by WHOI. During this cruise, one PIES each was recovered and a new one deployed at stations M1 and M3, and data were downloaded acoustically from the other two PIES which have been at these locations for already 2 years, as well as from the moorings M1 and M3. This extends the data record in hand to nearly 15 years.

The new longer data set shows a continuation of the strengthening trend of the southward NADW (North Atlantic Deep Water) transport which has been present since about 2008 (see figure 1). In order to test whether this trend could be an artifact of the chosen geostrophic reference level, the transports were also referenced to 4-year long bottom pressure observations from PIES and to GRACE satellite-gravity derived bottom pressure timeseries. In both cases the trend is confirmed. Collaboration is also underway with RAPID researchers, studying the similarities in changes in the water mass structures at RAPID and MOVE, and with modellers in Hamburg about decadal time scale basin-modes which may explain basin-wide coherences of MOVE transports.

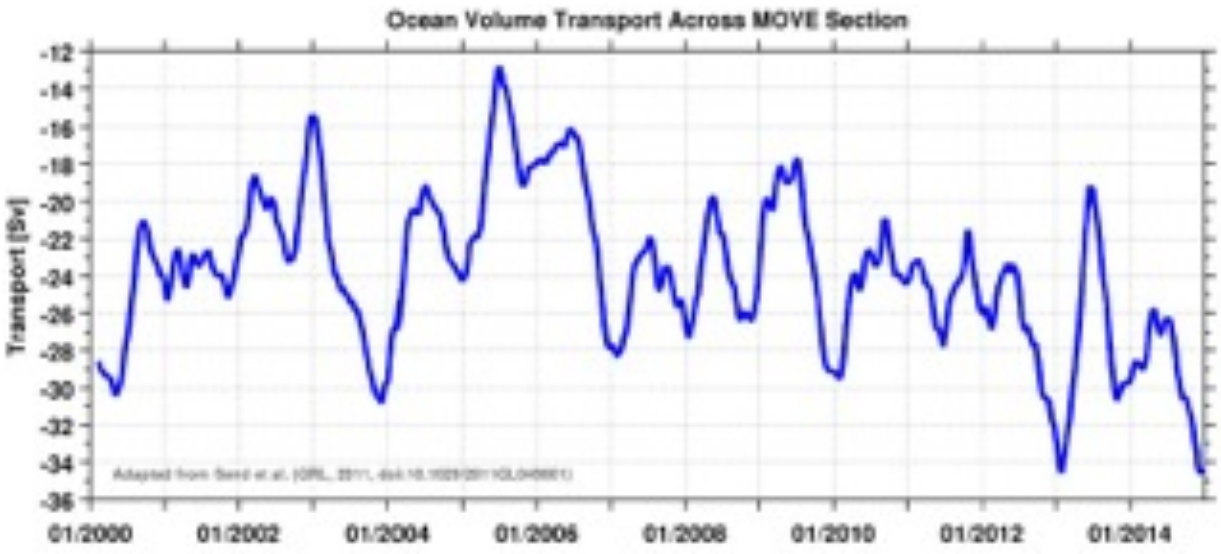

FIGURE 1: Nearly 15 years of quality-controlled North Atlantic Deep Water MOC transport (southward therefore negative), confirming the strengthening trend since 2008.

NOAA Support for the CLIVAR and Carbon Hydrographic Data Office at UC San Diego/SIO, 2013-2015

Dr. James H. Swift, Scripps Institution of Oceanography, UC San Diego
Dr. T. Bruce Appelgate, Scripps Institution of Oceanography, UC San Diego

NOAA Technical Contact: Dr. David Legler, CPO
Links to NOAA Strategic Plan:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: 65, 77, and 112

Research Objectives and Specific Plans to Achieve Them
A) In the CCHDO activities as a CTD/hydrographic/tracer/ocean-carbon data assembly center, the CCHDO will [and does] provide data from specific cruises that are of special interest to NOAA.

B) The CCHDO will [and does] work with NODC to improve transfer of data and integration with related data centers.

C) The CCHDO will [and did] make its holdings more query-able and accessible through modern data management standards and practices (including those that NOAA and the international oceanographic community recommend). A new activity initiated near the end of the reporting period is review by the CCHDO Director (Swift) of selected CTD profiles intended for Argo reference use. The CCHDO also is beginning to report new and updated data to Argo at regular intervals. All CCDHO deliverables are expressed as new and revised data and documentation entries on the CCHDO web site http://cchdo.ucsd.edu.

Research Accomplishments

A) There is a substantial amount of CTD data of value to the Argo and ocean research/modeling communities. The CCHDO continues to work with NOAA to assemble and incorporate into NOAA-related holdings select cruise data sets. This includes continued addition of HOT and BATS profiles and submitting them to OceanSITES, and new profiles added to the Argo reference CTD data set. Near the end of the reporting period the CCHDO Director (Swift) began reviewing for suitability selected CTD profiles intended for Argo reference use. Steve Diggs (CCHDO) continues the role of Chair for the SOOS Data Management Subcommittee for the next three years.

B) The NOAA/NODC works with several data assembly centers, including CCHDO, to bring data into NODC. CCHDO continues to improve their relationship with NODC in the following areas:

i. Continued data assembly of cruise hydrographic data and metadata, particularly those from the GO-SHIP program.

1. The CCHDO continues as the official global DAC for GO-SHIP.
2. The CCHDO continues to coordinate its activities with the JCOMMOPS technical coordinator for the GO-SHIP program, Martin Kramp.

ii. Working with NODC to improve efficiency of transfer of data and to make CCHDO data more "archive ready". The CCHDO and NODC continue to implement incremental technological enhancements which have improved the efficiency of the data transfer. This has led to an overhaul of the underlying structure for holding and serving data to all customers, including NODC, which is being implemented in the period immediately following the reporting period.

iii. Continued CCHDO participation in discussions towards enhancing integration of the related Data Assembly Centers (for example CDIAC and BCO-DMO), to reduce ambiguity and redundancy in data archiving.

C) CCHDO holdings are of great value to a wide audience of climate researchers and other users (e.g. modelers). The CCHDO is making continued progress on changes to make their holdings more query-able and accessible through modern data management standards and practices (including those that NOAA and the international oceanographic community recommend). Data search based on available parameters now available and can be combined with other search features; the CCHDO has enabled bulk download of selected files. A new, easier to maintain and more reliable means for locating and downloading data was developed and is being incrementally put into place in the period immediately after the reporting period.

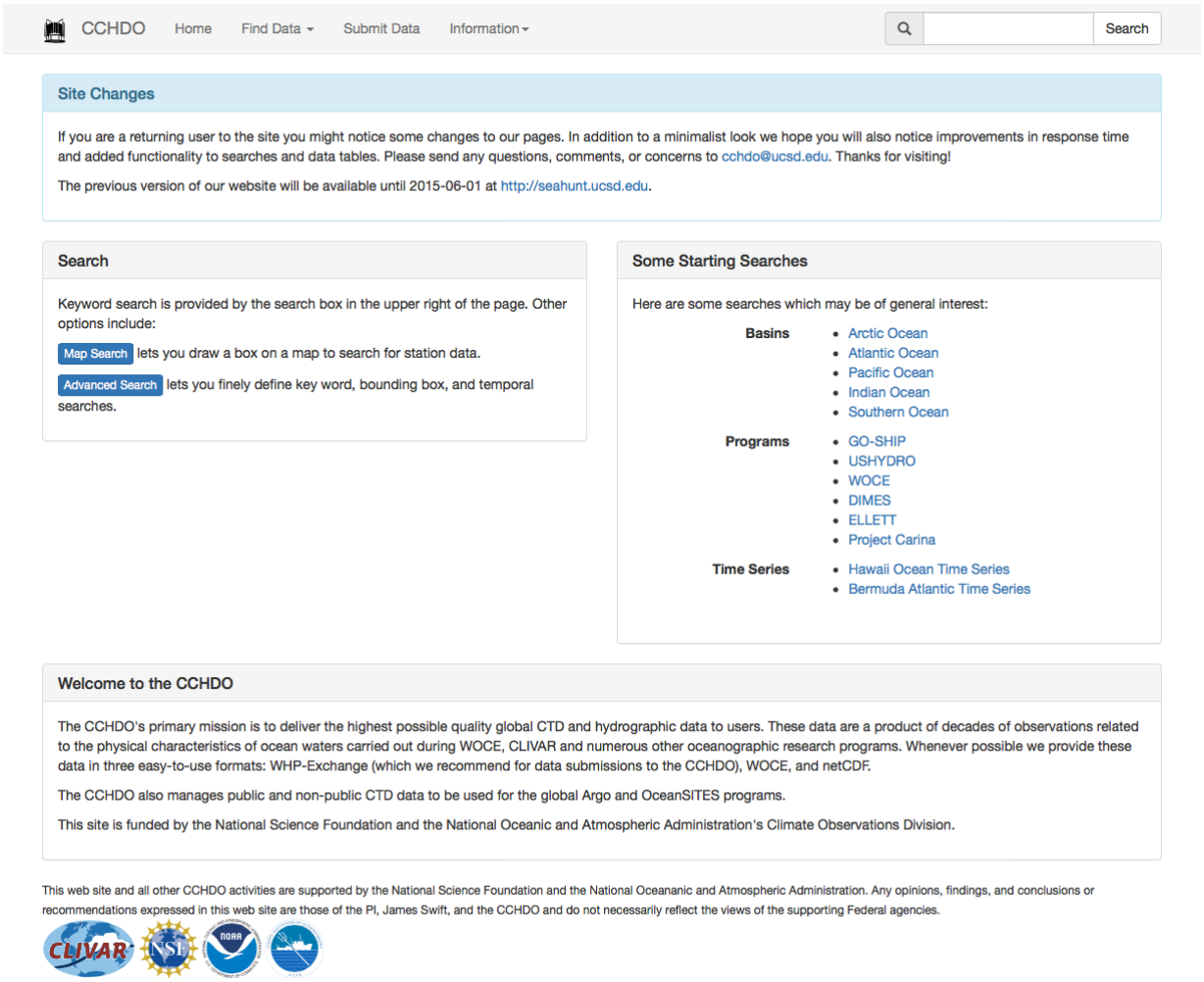

Figure 1: fig 1 May 2015 front page of the CCHDO web site http://cchdo.ucsd.edu. This reflects a new 'minimalist' look for key aspects of the CCHDO web site. More importantly, the underpinnings of the CCHDO web site and data serving are now significantly more powerful, easier-to-support, more reliable, and faster.

Coping with Drought in California's Russian River Watershed

Dr. F. Martin Ralph, Scripps Institution of Oceanography

NOAA Technical Contact: Nancy Beller-Sims, CPO
Links to NOAA Strategic Plan:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: NA14OAR4310241 (Competed)

Research Objectives and Specific Plans to Achieve Them

The project has three main research objectives: 1) evaluate drought ending atmospheric river (AR) characteristics using historical observations and new AR5 climate projections; 2) develop a "drought scenario" for the Russian River by engaging Russian River Stakeholders and using IPCC model analysis in task one; 3) develop and carry out a process to characterize the drought readiness for the Russian River in close partnership with Sonoma County Water Agency. To accomplish the first task, a new automated AR detection tool using integrated vapor transport (IVT) has been developed and is in the process of being verified. The automated AR detection tool will be applied to identify ARs in NCEP/NCAR reanalysis data. This will provide a chronology of land falling ARs along the Russian River Watershed from 1948-2013. Climate model (GCM) data needed to identify and describe ARs is being extracted from a subset of GCMs which have archived the necessary surface and 3-D atmospheric variables. Once this data is processed, the AR detection tool will then be applied to new CMIP5 climate projections. The ARs identified in the climate projections then will be characterized leading to results about how and if drought busting ARs may change in the future.

Tasks 2 and 3 have been integrated during the first several months of the project through receiving feedback both on the impacts of drought and information about the type of mega-drought that would be most informative. We have developed a questionnaire to ask about the impacts of drought in the region. In this survey we asked about how different drought durations, severities and temperature may affect the impacts of a drought. This is being used to inform the development of the mega-drought scenario. In addition, we spoke at four different stakeholder meetings to interact with stakeholders and receive feedback on the questionnaire. This questionnaire also asked about the impacts of drought. We have reached out to individual stakeholders to receive additional information about drought impacts. The questionnaire also asked for input on what type of information is most helpful during a drought and this information will be used to develop drought indicators.

Research Accomplishments

As the project is in the first year, many of the results are yet to materialize. Nonetheless, through the stakeholder outreach we have been conducting we have learned a lot about the impacts of drought in the region. The largest impacts from the current drought were to the agricultural communities with over $27.7 million dollars of losses reported in Mendocino County. Four city water utilities reported less revenue due to the conservation efforts and two city water utilities reported impacts on their recycled water due to less input from large storms. The effects of drought on fisheries and local ecosystems are less clear and need to be explored further, however, the Sonoma County parks and recreation did seem to think that more trees had come down during this past year, though there are currently no numbers to support this. From the questionnaires, the five most important drought indicators are Lake Mendocino water levels, stream flow, groundwater recharge, temperature, and groundwater levels. In discussions with Sonoma County Water Agency we have also learned that soil moisture can be an important indicator of drought because is also affects stream flow which impacts the run off to fill the reservoir. We

are in the process of determining if there is some antecedent soil moisture content that is necessary to enhance runoff to fill the reservoirs.

We have also determined that most stakeholders think a longer drought mega-drought scenario, between 3-7 years, would be more informative and show how their water supplies would respond. Due the 2014 water year many stakeholders have a sense of how the water system responds to a severe one-year drought. In addition, we have a historical tree ring record from the Russian River region that we will use to look at historic drought for the last 465 years. This will be used to inform the mega-drought scenario and help the stakeholders understand that a drought of this magnitude could affect the Russian River at any point, not just in the future.The AR detection tool is in the final stages of being verified and the historical catalogue of AR going back to 1948 is nearly complete. Once this is complete, the detection tool will be applied to climate projections. The necessary data from the climate projections have already been gathered and the tool just needs to be applied.

Intraseasonal to Interannual Variability in the Intra-Americas Sea in Climate Models

Shang-Ping Xie, Scripps Institution of Oceanography

NOAA Technical Contact: Daniel Barrie, CPO
Links to NOAA Strategic Plan:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: NA13OAR4310092 (Competed)

Research Objectives and Specific Plans to Achieve Them
To assess the ability of CMIP models to produce realistic intraseasonal to interannual variability (IAV to ISV) in the Atlantic warm pool (AWP) region and the implications for hurricanes, the ability of parameterization modifications in the GFDL AM3 to improve the simulation of AWP ISV, and how mean state biases in CMIP models develop and the implications for forecast biases in ISV and IAV.

Research Accomplishments
Process-oriented diagnosis of east Pacific warm pool ISV
June-October east Pacific warm pool intraseasonal variability is assessed in eight atmospheric general circulation simulations. The models exhibit a large spread in amplitude of the leading mode about the observed amplitude. Little relationship is demonstrated between amplitude of the leading mode and ability to simulate the observed propagation characteristics.

Diagnostics based on the vertically-integrated moist static energy budget also demonstrate success at discriminating models with strong and weak variability. In particular, the vertical component of gross moist stability (GMS) exhibits a correlation with amplitude of -0.9, suggesting that models in which convection and associated divergent circulations are less efficient at discharging moisture from the column are more able to sustain strong intraseasonal variability. The horizontal component of GMS exhibits a significant positive correlation with amplitude. Consequences of these successful diagnostics for the dynamics of east Pacific intraseasonal variability are discussed.

El Nino teleconnections in a warming climate
Atmospheric general circulation model simulations are used to investigate how ENSO-induced teleconnection patterns during boreal winter might change in response to global warming in the Pacific–

North American sector. As models disagree on changes in the amplitude and spatial pattern of ENSO in response to global warming, for simplicity the same sea surface temperature (SST) pattern of ENSO is prescribed before and after the climate warming. In a warmer climate, precipitation anomalies intensify and move eastward over the equatorial Pacific during El Niño because the enhanced mean SST warming reduces the barrier to deep convection in the eastern basin. Associated with the eastward shift of tropical convective anomalies, the ENSO-forced Pacific–North American (PNA) teleconnection pattern moves eastward and intensifies under the climate warming. As a result, rainfall anomalies are expected to intensify on the west coast of North America, and the El Niño–induced surface warming to expand eastward and occupy all of northern North America.

Variability of Tropical Cyclone Track Density in the North Atlantic

Interannual–decadal variability of tropical cyclone (TC) track density over the North Atlantic (NA) between 1979 and 2008 is studied using observations and simulations with a 25-km-resolution version of the High Resolution Atmospheric Model (HiRAM) forced by observed sea surface temperatures (SSTs). A basin-wide mode dominates, with the time series being related to variations in seasonal TC counts. On decadal time scales, this mode relates to SST contrasts between the tropical NA and the tropical northeast Pacific as well as the tropical South Atlantic, whereas on interannual time scales it is controlled by SSTs over the central–eastern equatorial Pacific and those over the tropical NA. The temporal evolution of the spatial distribution of track density is further investigated by normalizing the track density with seasonal TC counts. Finally, the internal variability and predictability of TC track density are explored and discussed using HiRAM ensemble simulations. The results suggest that basin-wide total TC counts/days are much more predictable than local TC occurrence, posing a serious challenge to the prediction and projection of regional TC threats, especially the U.S. landfall hurricanes.

NOAA MAPP CMIP5 Task Force

Shang-Ping Xie finished his term as a member of the NOAA MAPP CMIP5 Task Force. Accomplishments have included generation of a *Journal of Climate* special collection on North American Climate in CMIP5 Models, which includes the overview papers. The NOAA CMIP5 task force concluded its activities this coming Fall with a celebration at the AGU annual meeting in San Francisco.

Moored carbon, biogeochemical, and ecosystem observations in the Southern California Current

Uwe Send, Scripps Institution of Oceanography
Mark Ohman, Scripps Institution of Oceanography

NOAA Technical Contact: Diane Stanitski, CPO and Libby Jewett, OAP
Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: 36, 67, 98 and 116

Research Objectives and Specific Plans to Achieve Them

The California Current is a region of large ecological significance and known sensitivity to climate forcing. Climate processes, complex physical systems, carbon and nutrient chemistry, and ecosystem dynamics all interact to create a rich, societally important, and scientifically fascinating ocean environment off the west coast of the US. This project establishes a unique highly multidisciplinary

mooring presence in the southern California Current, to complement the flow and transport monitoring system that has been initiated under CORC, and to start building a comprehensive continuous real-time monitoring system for this region.

Two moorings, called CCE(California Current Ecosystems)-1 and -2 are located in the core of the California Current and in the upwelling regime on the continental slope, respectively, along CalCOFI line 80, and measure

- atmospheric conditions (x(CO_2), wind, temperature, humidity, precipitation, irradiance),
- surface ocean conditions (temperature, salinity, p(CO_2), O_2, pH, currents, point and integrated measures of phytoplankton chlorophyll content over the euphotic zone, and nitrate supply), and mixed-layer depth,
- multi-frequency active-acoustic observations of zooplankton and fish biomass over the upper 300m.

The data will be telemetered in real-time and made available via websites to other researchers and agencies. The moorings observe physical climate changes in the CCE, contribute unique timeseries for the US ocean acidification and carbon observing programs, and add a time dimension to regular ship surveys under CalCOFI, CCE-LTER, and fisheries stock assessment programs.

Research Accomplishments

The field work consisted of recovery and redeployment of two nearly identical moorings CCE1 and CCE2 along CalCOFI line 80 in fall March 2014 and spring 2015, in the offshore and the upwelling regimes off Pt.Conception. Both moorings now measure: meteorological parameters, incoming solar radiation in 7 wavelengths, air and water pCO2, surface T/S and pH/oxygen, mixed-layer (15m or 40m) chlorophyll fluorescence/turbidity, pH/oxygen and nitrate, and at the bottom of the euphotic zone (40m or 80m) the downwelling irradiance in the same 7 wavelengths as at the surface. In addition, both moorings have T/S sensors through the upper layer, a longranger ADCP covering the upper 500m, and at 150m depth an acoustic zooplankton/fish sonar from D.Demer/SWFSC which covers the 0-300m layer of the water column. All data are telemetered inductively within the mooring and via Iridium internet connections to shore.

The continuous observations with oxygen and pH data continue to highlight and allow the characterization of short-timescale periods, events, and processes that are believed to have a crucial impact on the ecosystem. One result concerns the variability of dynamic f-ratios – the highpass filtered nitrate to DIC ratio shows on average the expected Redfield ratio, but fluctuates strongly, sometimes reaching zero (regenerated production). On interannual timescales, our water mass analyses reveal more water from southern origin during the preceding 2 years (since about 2012), which appears to match the strong decrease since 2012 in acoustic target detections which are believed to be sardines. The CCE moorings also help to analyze the Pacific warm anomaly of 2014. The aragonite saturation at 75m on CCE2 departed strongly (towards higher levels) in the middle of 2014, compared to prior years. The alongshore currents at CCE2 reveal anomalous northward flow already at the beginning of the year and in the previous year, potentially leading to more depressed isotherm, isopycnal,s and nutrient and carbon horizons.

Data from both CCE moorings are being displayed in real-time on the website http://mooring.ucsd.edu/CCE.

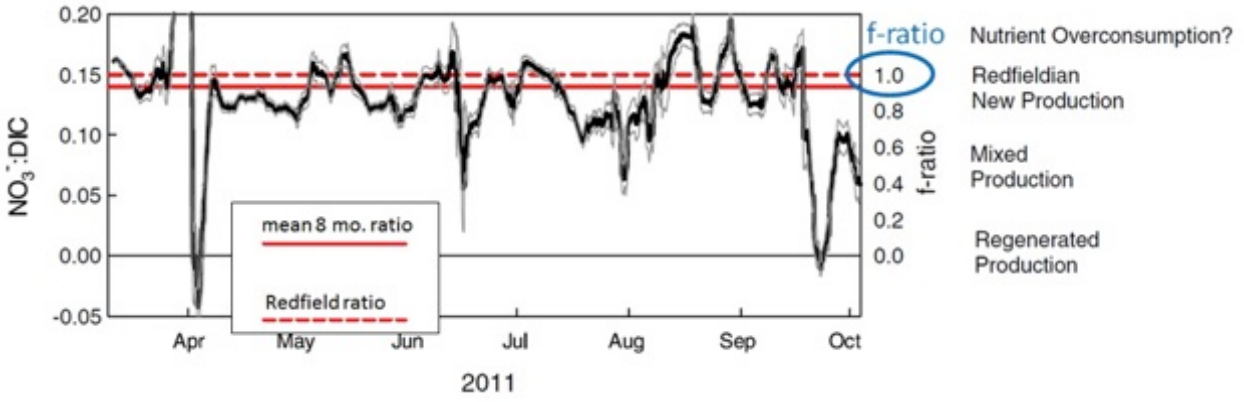

FIGURE 1: Time-dependence of the f-ratio at the CCE2 mooring (15m depth) through most of 2011 (from Martz et al. 2014).

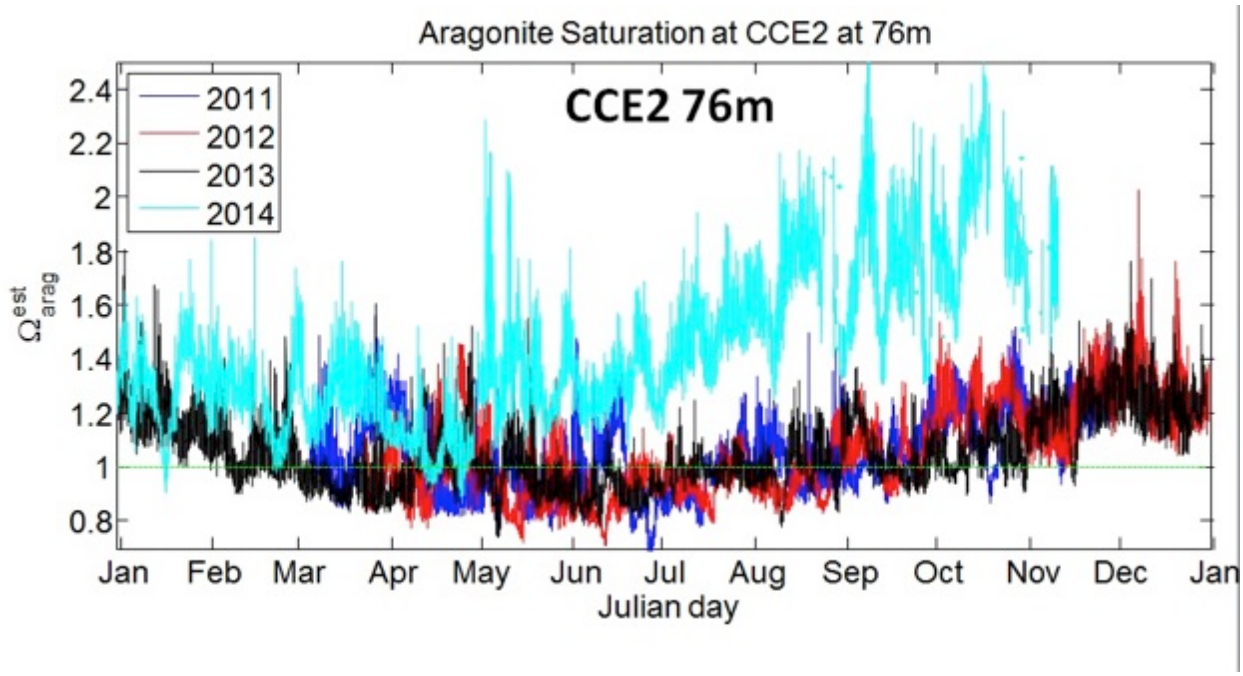

FIGURE 2: Time series of aragonite saturation state (Warag) at a depth of 76 m at CCE2, across 4 years. Note the more typical series of undersaturation events (Warag < 1.0) in 2011-2013, but the marked change in 2014.

Theme C: Marine Ecosystems

Ocean Observing and Fisheries Oceanography Research off Northern California

Brian Tissot, Humboldt State University

NOAA Technical Contact: S. Miller, SWFSC
Links to NOAA Strategic Plan:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management;
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: 128

Research Objectives and Specific Plans to Achieve Them
Goals of this project are (1) to facilitate ongoing ocean observation cruises along the Trinidad Head Line, and to prepare hydrographic and biological data for analysis and inclusion in coastal observation networks, and (2) to support focused research in fisheries oceanography and recruitment dynamics off northern California. The primary strategy for achieving these goals is to support a research technician tasked with the day-to-day operations associated with planning, executing, and demobilizing from observation cruises and assisting with coordination of post-cruise laboratory analysis and data synthesis. This work is based out of Humboldt State University, and represents a collaborative effort between HSU and the Fisheries Ecology Division of NMFS' Southwest Fisheries Science Center.

Research Accomplishments
Roxanne Robertson continued to serve as lead technician and to be a tremendous asset to the program. She has coordinated and in many cases led hydrographic and biological sampling on 12 successful cruises along the Trinidad Head Line, processed hydrographic data, coordinated laboratory efforts to catch up on analysis of archived specimens, and ensured timely calibration and maintenance of instrumentation. Results from this work documented effects of warming conditions, including the arrival of "warm blob" waters in late 2014 (see Figure). Zooplankton communities observed at a mid-shelf station were altered by this event, with an index of copepod community composition showing an unusually strong shift towards warm-water species (including species not previously observed in this time series) and observations of *Euphausia recurva*, a warm-water species not previously observed in this time series. These efforts spanned the end of a previous project ("Ocean observing and fisheries oceanography research of the coastal ocean off northern California", PI: Jeff Abell) and the project described here.

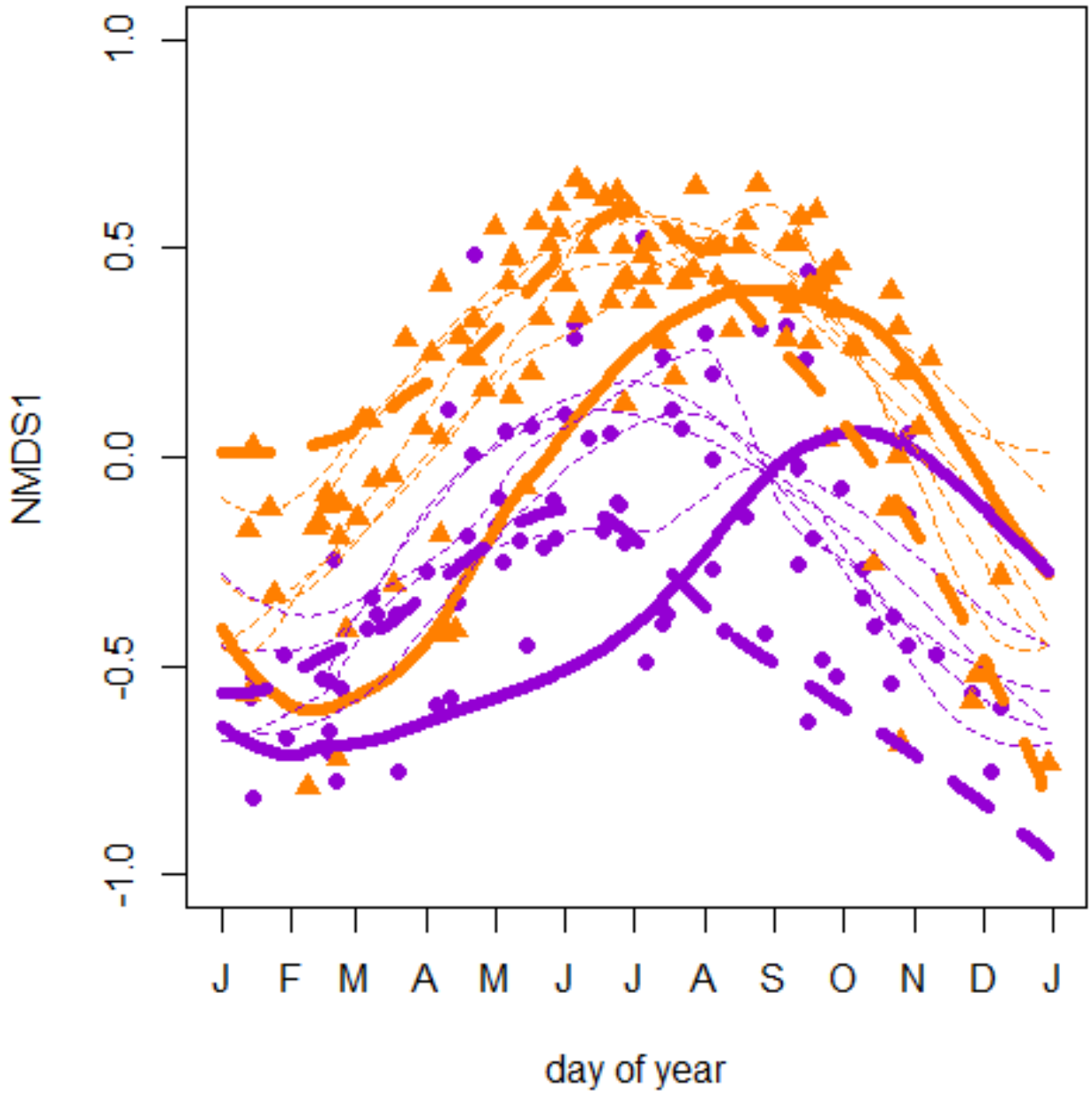

Figure 1: Annual series of values along the first axis from an NMDS analysis applied to copepod data from 2008 through early 2015 from the Newport Hydrographic Line (NHL; orange) and Trinidad Head Line (THL; purple). Positive NMDS1 indicates assemblages dominated by cold-neritic copepod species; negative values indicate dominance by warm-water species. Points indicate individual observations and lines indicate a (continuous) loess fit to the time series. Thin dashed lines show seasonal patterns for each year. Thick solid lines are for 2010, showing delayed recovery from the 2009-10 El Niño. Thick dashed lines show the shift to assemblages dominated by warm-water species (including previously unobserved species) during the warming event of late 2014.

Collaborative Opportunity: Exploring 'omic Technologies to Support Ecosystem Understanding and Fisheries Assessments

Andrew Allen, Scripps Institution of Oceanography

NOAA Technical Contact: K. Goodwin, OAR
Links to NOAA Strategic Plan:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management;
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: 101

Research Objectives and Specific Plans to Achieve Them
Implementation of high throughput molecular and genomic approaches within the framework of an existing ocean observing network (The Southern California Coastal Ocean Observing System; SCCOOS), and a well-established monitoring program (CalCOFI), and an experimental process-oriented program (The California Current Ecosystem Long Term Ecological Research site (CCE-LTER), will create unique opportunities for science and management. This integrated network will facilitate analyses, with high temporal and spatial resolution and specificity, related to how organisms, including those that directly impact food webs and biogeochemical cycles, respond to environmental perturbations, including global-scale changes.

The program objective is to assay the diversity and distribution of microbes and other planktonic organisms. Ability to link analyses of microbial community structure and diversity directly to measurements of ecosystem productivity will enable evaluation of microbial population and community dynamics in the context of other indictors of ecosystem productivity.

To overcome sample throughput bottlenecks, DNA and RNA purification and MiSeq amplicon and HiSeq metatranscriptomics library construction protocols will be used for high throughput epmotion robotics will be optimized for filters and contents of net tows. A BioCell robotics platform at JCVI will be used for high throughput PCR MiSeq amplicon library generation. Amplicon targets include the hypervariableV4 and V5 regions of the 16S rDNA gene for bacteria, archaea, and the chloroplast of eukaryotic phytoplankton; the hypervariable V4 and V9 region of the 18S rDNA gene for microbial eukaryotes, and regions of DNA polymerase and Reverse Transcriptase for DNA and RNA viruses

Research Accomplishments

- Design and implementation of MiSeq technologies
- Implemetion of epmotion robotics platform
- Data generated for 16S and 18S DNA for 2014 samples (all four cruises)
- Preliminary analyses of data suggest large scale contrast between cyano dominated vs diatom dominated food webs

Evaluation of exposure to and infection with Phocine Distemper Virus to the eastern Distinct Population Segment of Steller sea lions (*Eumetopias jubatus*) and continued monitoring of the western Distinct Population Segment

Tracey Goldstein, UC Davis

NOAA Technical Contact: Kim Rivera, NMFS
Links to NOAA Strategic Plan:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management;
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: 84 and 115

Research Objectives and Specific Plans to Achieve Them
The purpose of the project is to evaluate the extent of infection and exposure to the potentially deadly virus, phocine distemper, in the Steller sea lion population off Alaska. The presence of phocine distemper virus was detected in Northern sea otters off the coast of Alaska in 2004, the first confirmation of this virus in marine mammals in the Pacific. Sequence analysis confirmed the viral fragment was identical to that from the 2002 phocine distemper outbreak that caused large-scale mortality in harbor seals in Europe and serological surveys prior to 2000 revealed that marine mammals in Alaska had not been exposed to Phocine Distemper Virus. Thus we hypothesized that the virus may have been transmitted through the Arctic to the North Pacific after the 2002 epidemic by vector species as sea ice reduction may have altered seal haul-out and migration patterns, resulting in contact between Atlantic, Arctic, and Pacific Ocean species that was not possible in 1988, after the previous outbreak in Europe. Through our recent work, funded by the Morris Animal Foundation, we were able to document that the virus is present and circulating in most Arctic and Subarctic seals, sea lions and sea otters off Alaska. Results also supported our hypothesis as they indicated that the virus moved into the Pacific from the Atlantic after the 2002 outbreak in Europe that killed 30,000 seals.

To date limited testing has been performed on samples from Steller sea lions from the eastern Distinct Population Segment, thus to evaluate how widespread this viral infection is in Steller sea lions across their range, additional testing is needed. The goals of this work is to test for evidence of infection and measure exposure to phocine distemper virus in the samples from the eastern Distinct Population Segment of Steller sea lions, in animals from the western Distinct Population Segment in Russia, and to complete testing of samples collected from the animals from the western Distinct Population Segment in Alaska from 2011 to present to evaluate their current exposure and infection status.

A request for an extension was requested as we have not yet received as many samples for testing from Steller sea lions from the Eastern distinct population segment as we had hoped. The no-cost extension would not change the scope of the project but it would allow us to obtain additional samples for testing as samples may become available from additional animals that strand live or dead over the next year, and a field trip is planned during the 2015 field season to obtain additional samples for testing from free ranging Steller sea lion pups on rookeries in Alaska and Oregon. These samples would allow us to better assess the current status of infection from the eastern Distinct Population Segment

Research Accomplishments

The first stage of this work (completed in the first year) was to further evaluate exposure in Steller sea lions in the western Distinct Population Segment in both Alaska and Russia, and also in the eastern Distinct Population Segment off Alaska, Washington, Oregon and California. Archived serum samples (n = 334) were tested for antibodies to Phocine Distemper virus.

During this period, PCR testing was performed in our laboratory at UC Davis to complement the serology results to examine for the presence of current infections in nasal swab samples (n = 352) and tissues (n = 2) from Steller sea lions sampled in 2004, 2011, 2013 and 2014 in the Russian Far East (final results of testing of Russian samples is still pending), the central and eastern Aleutians and Southeast Alaska. This current work focused on increasing the testing of animals from areas not previously examined, in the eastern Gulf of Alaska and Russia; as well as from animals sampled in the central and eastern Aleutians since 2010, to better understand the current status of exposure in these animals.

Results to date showed that animals tested positive (both for antibodies and virus) throughout the Aleutian Islands and in the central Gulf of Alaska had detectable Phocine Distemper viral RNA in nasal swab samples. Positive samples were detected in 2004-2006 and in 2010 (Figure 1). Interestingly, although the prevalence of antibody positive animals has increased since 2009, viral RNA was not detected in nasal swabs and tissues from animals sampled in Alaska during 2011, 2013 and 2014. Given that serology from animals sampled in the Aleutians from 2011 to 2013 was positive for antibodies against the virus, combined with the PCR results, data indicate that exposure to the virus appears to be more widespread than previously thought, as animals as far east/southeast as Hazy Island, near Petersburg, in southeast Alaska, and as far west as Iony Island (Sea of Okhotsk) in Russia have antibodies to the virus.

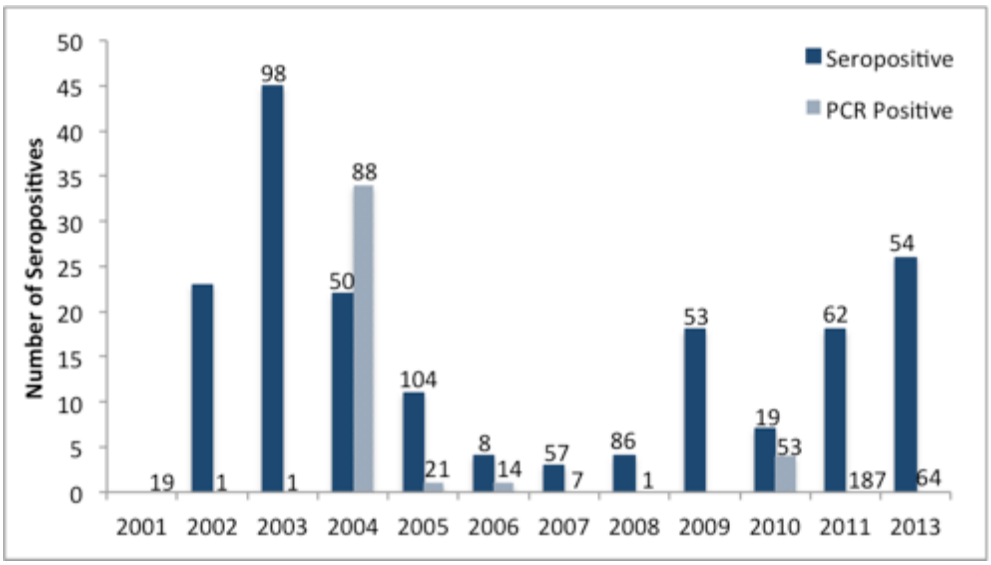

Figure 1: The number of Steller sea lions with antibodies against Phocine Distemper virus (blue bars) and virus detected in nasal swabs (hatched bars) in Alaska tested from 2001 to 2013 (the number if animals tested is above each bar). The PCR data supported the serology, and results indicated that exposure first occurred in 2002. Following the first emergence of the virus in 2002, the proportion of animals with positive antibody titers appeared to decrease through 2008 and increase again in 2009, indicating another exposure event may have occurred during that time.

The Next Generation of CoralNet: Improving Automated Methods Benthic image Analysis and Optimizing for NMFS Benthic Imagery

David Kriegman, Scripps Institution of Oceanography

NOAA Technical Contact: Steve Miller, FED/SWFSC
Links to NOAA Strategic Plan:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management
Amendment No.: 109

Research Objectives and Specific Plans to Achieve Them
The broad objectives of this research project are: (1) Develop better methods for automated annotation of coral reef survey images, and (2) enhance CoralNet (coralnet.ucsd.edu) with new capabilities.

The first objective will be achieved through the research of PI David Kriegman's PhD student Oscar Beijbom. His research involves using convolutional neural networks (CNNs) to automatically annotate coral reef survey images. CNNs have shown great promise on standard computer vision tasks such as object recognition and image segmentation, and OB is working on adapting these models to the specific coral annotation task. OB will also implement the new operational modes of annotation in CoralNet, as well as several user interface improvements. These new features will be open-source, and made available to the public.

Research Accomplishments
The research accomplishments broadly meet the research objectives stated above.

With regards to the first goal: stronger methods for automated annotation were developed using Convolutional Neural Networks (CNNs). Specifically, we used the open-source toolbox from UC Berkeley: caffe (http://caffe.berkeleyvision.org/). This toolbox was used to fine-tune a model (VGG-16) with 138 Million parameters on data from CoralNet. The VGG-16 model was originally designed by the Visual Geometry Group at Oxford and was pre-trained on ImageNet which is a large image classification dataset containing 14 Million images. By fine-tuning it on coral data, it was adapted to the coral image annotation task. Using this procedure a 9.1% improvement in overall accuracy (from 65.3% to 64.4%) was achieved. By comparing this to the accuracy of human experts, we show that CNN based methods enable 78% of the annotation work to be performed automatically, leaving the human expert with a mere 22% of the original annotation work. In comparison, the previous method enabled 52% automation, leaving the human expert with roughly half the original annotation work.

With regards to the second goal, CoralNet was enhanced with three operational modes of annotation. (a) The first is denoted REFINE, and is an interactive annotation mode. In REFINE, a user is presented with suggestions for each annotation decision, which can be rapidly accepted or changed by the user. Our results indicate that REFINE can save 10% of the annotation time, while maintaining full control of the assigned annotations by the user. (b) The second mode is denoted ALLEVIATE and is a semi-automated annotation mode. Alleviate enables a trade-off between the higher accuracy of a human expert, and the speed and efficacy of an automated annotation system, and is also integrated in the random point annotation tool of CoralNet. As mentioned in the previous section, the CNN based algorithms allow for a 78% reduction of the annotation work, with minimal loss of accuracy. (c) The third is denoted ABUNDANCE and is a fully - automated annotation mode. Abundance allows users to export percent coverage estimates of the basic benthic functional groups. These estimates are unbiased, but with higher variance than the actual percent covers. In addition to these annotation modes, several user-

interface improvements have been implemented. Notably, enhanced performance overview of the automated annotator, enhanced graphics of the main landing page, and integration of several instruction-videos throughout the site. The NOAA Coral Reef Ecosystem Division (CRED) has recently taken the first steps towards using CoralNet in their image annotation pipeline.

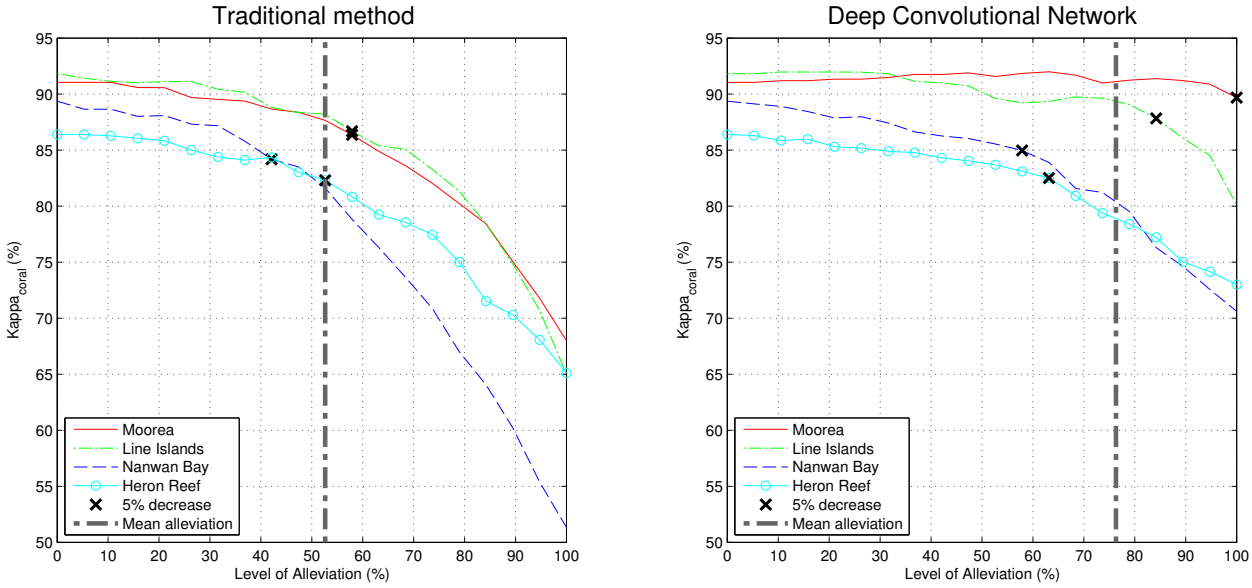

Figure 1: Alleviation levels. Accuracy as measured by Cohen's kappa for the task of discriminating corals from other labels at various levels of Alleviation for four pacific coral reef locations. 100% alleviation corresponds to fully automated annotation, and 0% corresponds to fully manual annotation. The subplots indicate: (Left) accuracy of combined expert and automated annotations based on the traditional method, and (Right) accuracy of combined expert and automated annotations based on the novel CNN-based method. The black x on each curve indicates the point where the accuracy was 5% lower than its maximum value (i.e. a 5% drop compared to the accuracy of the human experts). The gray dash-dotted line indicates average level of alleviation for the four studied locations.

CSTAR - The Center for Stock Assessment Research

Marc Mangel, UC Santa Cruz

NOAA Technical Contact: Steve Miller, FED/SWFSC

Links to NOAA Strategic Plan:

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

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

Amendment No.: 1, 35, 54, and 87

Research Objectives and Specific Plans to Achieve Them

CSTAR was formed in 2001 with the goal of undergraduate, graduate, and post-graduate training in the science associated with the problems of assessing the numerical abundance, spatial distribution, size distribution and reproductive status of commercially important fish species. A broad and deep understanding of population processes is critical to the development and management of sustainable fisheries. 2013-14 was another successful year for CSTAR. Finding means to conserve fish populations and to achieve sustainable fisheries requires understanding the effects of fishing on behavior, life history

and population biology of exploited fishes. At CSTAR, work focuses on using mathematical, statistical, and computer models to solve important environmental and ecological problems. The work is grounded in data, and also seeks to expand the base of basic knowledge that supports rigorous application of science to real-world problems. Furthermore, research on marine fisheries conducted at CSTAR allows testing theoretical predictions via natural and human experiments on a scale that is appropriate for understanding the dynamics of ecosystems. Such large-scale experiments are rarely available to the scientific community.

The CSTAR grant provides level of core support which is then leveraged by teaching assistantships and graduate research assistantships or post-doctoral scholar support from other grants or contracts .This enables us to create a relatively large and interactively group of quantitative scientists working on a wide range of problems in fishery management.

During the review period, members of CSTAR were (those receiving any level of NOAA support shown italics)

- Eric Anderson (Staff Member, NMFS Santa Cruz Laboratory)
- Carl Boettiger (NSF Postdoctoral Scholar in Biology and Mathematics)
- Mariah Boyle (Assistant Project Director, FishWise)
- Edward (EJ) Dick (Staff member, NMFS Santa Cruz Laboratory)
- Ryan Driscoll (PhD student, Ocean Sciences)
- Duran Fiack (PhD student, Environmental Studies)
- John Field (Staff Member, NMFS Santa Cruz Laboratory, co-Director)
- Nick Grunloh (Junior Specialist, UCSC)
- Xi He (Staff member, NMFS Santa Cruz Laboratory)
- Meisha Key (Staff member, California Department of Fish and Wildlife)
- Holly Kindsvater (NSF Postdoctoral Scholar in Biology and Mathematics)
- Thanassis Kottas (Faculty, UCSC)
- Who-Seung Lee (Post-doc)
- Juan Lopez (PhD student, Applied Mathematics; NSF GRF)
- Aaron Mamula (Staff Member NMFS Santa Cruz Laboratory)
- Marc Mangel (Faculty UCSC, Co-director)
- Melissa Hedges Monk (Postdoctoral Scholar; Staff Member NMFS Santa Cruz Laboratory)
- Steve Munch (Staff member, NMFS Santa Cruz Laboratory)
- Valerie Poynor (Postdoctoral scholar)
- Kate Richerson (PhD student, Ecology and Evolutionary Biology)
- Santiago Salinas (Postdoctoral Scholar)
- Cameron Speir (Staff Member NMFS Santa Cruz Laboratory)
- Jarrod Santora (Assistant Researcher, UCSC)
- Will Satterthwaite (Staff member, NMFS Sants Cruz Laboratory)
- Simone Vincenzi (EU Marie Curie Outgoing Fellow)
- Brian Wells (Staff member, NMFS Santa Cruz Laboratory)

Research Accomplishments

CSTAR continues its work of training students and post-docs in quantitative population biology relevant to the mission of NOAA Fisheries and placing them in positions in NOAA Fisheries and beyond. During the review period, CSTAR Representation in the Fisheries Ecology Division Teams are:

- Groundfish Analysis (CSTAR Alumni EJ Dick, Melissa Monk; CSTAR Junior Specialist Nick Grunloh; CSTAR Post-doc Holly Kindsvater)

- Salmon Assessment (CSTAR Alum Will Satterthwaite)
- Landscape Ecology (CSTAR student Juan Lopez, CSTAR, CSTAR Assistant Researcher Jarrod Santora)
- Fisheries Economics (CSTAR student Duran Fiack)
- Early Life History (CSTAR Alum Steve Munch, CSTAR Post-docs Carl Boettiger, Valerie Poynor, Santiago Salinas)
- Molecular Ecology (CSTAR Alum and Visiting EU Marie Curie Fellow Simone Vincenzi)
- and a bit further afield
- US AMLR (CSTAR Students Ryan Driscoll, Kate Richerson)

During the review period, CSTAR students and post-docs continued to do novel and important work in quantitative population biology as it pertains to sustainable fisheries. PhD student Ryan Driscoll participated in the AMLR winter cruise; he and PhD student Kate Richerson are jointly analyzing data that she collected on maturity and life history in *Thysanoessa macrura*. Richerson had accepted a major paper concerning *Euphausia superba* that will have major implications for krill management models. She also completed and submitted the analysis of AMLR acoustic data. PhD student Juan Lopez spent summer 2014 at the University of Amsterdam, working with Professor Andre de Roos on the development of structured population models for steelhead and worked with the Landscape Ecology Team to conduct a major analysis of steelhead on the Carmel River, and the role of environmental factors and management in maintaining anadromous populations. Post-doc Melissa Monk developed new methodologies to analyze the recreational fisheries catch data from California and Oregon and, working with USGS colleague Tim Tinker, lead the first ever stock assessment for sea otters in SE Alaska, including an estimate of carrying capacity. The U.S. Fish and Wildlife Service will use the model for management of the population and to predict future population sizes. Post-doc Carl Boettiger was offered the position of Assistant Professor of Ecoinformatics at UC Berkeley and post-doc Holly Kindsvater a position at the University of Alaska Anchorage. Dr. Jarrod Santora participated in two southern ocean cruises. CSTAR Director Marc Mangel offered a series of 10 lectures on quantitative fisheries science at the FED; this attracted 15 regular participants.

Collaborative Acoustic Studies in the Central and Western Pacific Ocean

Ana Širović, Scripps Institution of Oceanography
Simone Baumann-Pickering, Scripps Institution of Oceanography

NOAA Technical Contact: Erin Oleson, PIFSC
Links to NOAA Strategic Plan:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: 86 and 113

Research Objectives and Specific Plans to Achieve Them
To goal of this project was to collaborate with PIFSC on three tasks: (1) investigations of low frequency noise and baleen whale calls; (2) investigations of high frequency cetacean signals; and (3) provide technical support for continued data collection.

Interannual comparison of noise levels were made at three sites with long term data in the central and western Pacific Ocean to assess overall trends in ambient noise, and we investigated the relationships between ambient noise and changes in local and basin-wide shipping traffic. Also, propagation models to evaluate ranges over which baleen whales are detected in Northern Mariana Islands were developed.

In addition, we analyzed one year of data to determine the presence of beaked whale signals in the waters off Saipan.

Research Accomplishments

Trends in low frequency ocean ambient noise were analyzed for three sites (Kona, Palmyra Atoll, and Saipan) over a total of eight instrument-years of data. All sites exhibited low to medium levels of noise from shipping, with the lowest levels at Palmyra Atoll. Most sites also had a seasonally variable contribution to the soundscape by various baleen whales. In Kona, for example, it was possible to identify changes in humpback whale song over the years from their spectral features (Figure 1). Saipan showed the least amount of baleen whale contributions to the soundscape and had the highest noise levels in shipping frequency bands.

To evaluate propagation ranges of baleen whale calls at two sites in the western Pacific (Tinian and Saipan), blue whale, fin whale, minke whale, and humpback whale calling sequences were sampled and their received levels were measured. In general, fin whale received levels were the highest, however that can be expected given their high source levels and better propagation characteristics at lower frequencies. Based on the measured received levels and our propagation models, there appears to be a spatial separation between different species of baleen whales that occur in the vicinity of Saipan. Thus, at Saipan, minke whales appeared to be closest to the deployment location, mostly at ranges 10-30 km. Calling fin whales occurred from as close as 10 or 20 km to potentially even beyond our modeled detection range (100 km). The one blue whale call sequence we measured was likely from a relatively distant whale (farther than 60 km). Calling humpback whales were most likely found within ranges of 20-60 km, although farther detection was also possible. At Tinian, there was a lot less variation in range distributions in the measured examples of blue, fin and humpback whales, with all three species likely calling at a distance of more than 20 km, but most closer than 100 km.

One year of acoustic data (July 2013-June 2014) collected at site Tinian was analyzed for the occurrence of odontocete signals (Figure 2). Sperm whales were acoustically encountered regularly throughout the year with peak detections in March. Short finned pilot whales had a strong presence but low to no detections from mid December to late March. False killer whales occurred with some regularity throughout the year but overall less frequent than those species mentioned before. They appeared to have a diel pattern of increased daytime foraging activity. Risso's dolphins were detected primarily in mid December to mid January, with one short encounter in February and during one day in April. They showed a distinct nighttime foraging preference. Pygmy or dwarf killer whales (*Kogia* spp.) were detected frequently during very short encounters (small detection range) with a peak occurrence in December. Killer whales passed through the detection range of the recorder on three occasions in October, November, and April. Blainville's beaked whales were detected frequently but with short encounters and peaks in presence in September-October, December-January, and April-June. A beaked whale signal of unknown origin (BWC) occurred in low numbers throughout the recording period. A large number of acoustic detections were from unidentified odontocetes.

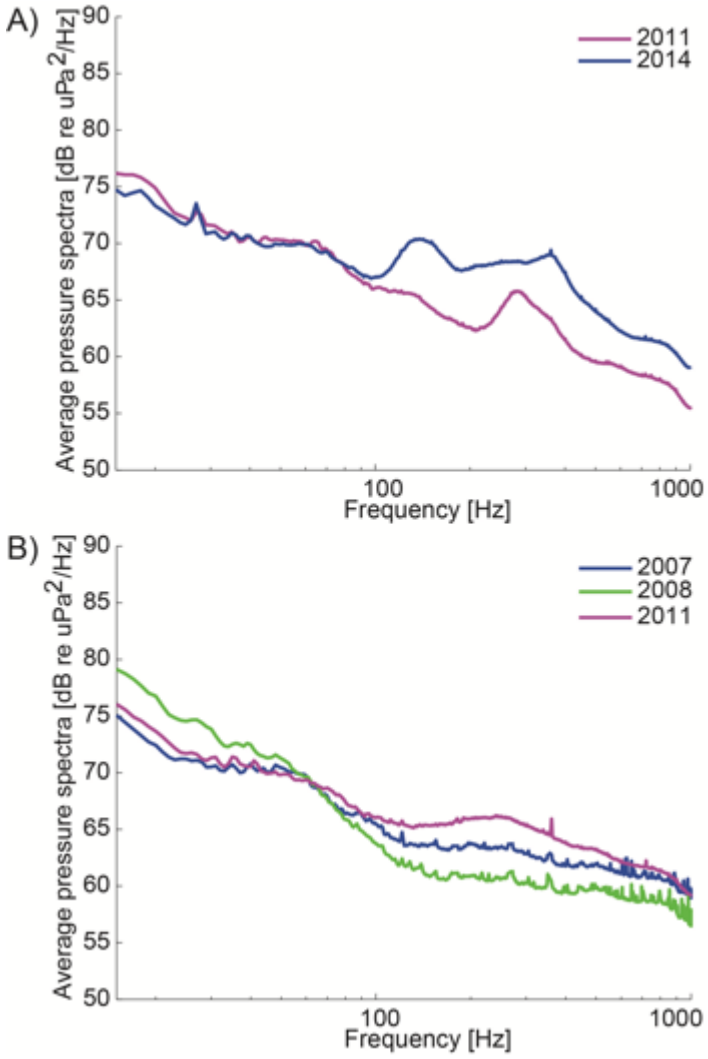

Figure 1: Average monthly sound pressure spectrum levels from 15 to 1000Hz at Kona, Hawaii for (a) March and (b) September. Color denotes different year of data. Note presence of humpback whale "bumps" from 100-500 Hz in March data and their absence in September.

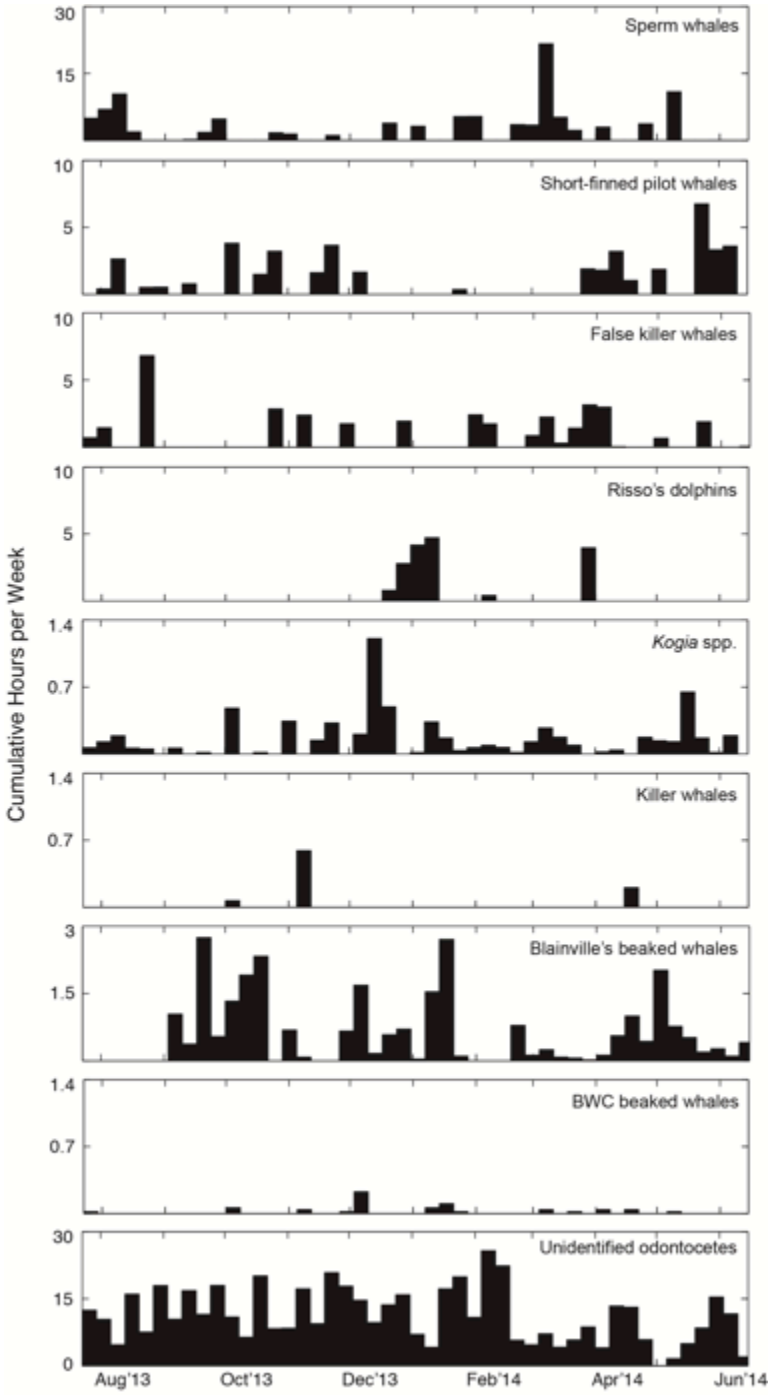

Figure 2: Cumulative hours of acoustic detections of odontocete species per week at site Tinian over one year of acoustic recording effort.

Investigations in Fisheries Ecology

Dr. Eric Palkovacs, UC Santa Cruz

NOAA Technical Contact: Dr. Steven Lindley, SWFSC
Links to NOAA Strategic Plan:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management
Amendment No.: 6, 97, 99 and 122

Research Objectives and Specific Plans to Achieve Them
This cooperative research program encompasses a large number of individual studies conducted by scientists from the University of California Santa Cruz (UCSC), the National Marine Fisheries Service, Southwest Fisheries Science Center, Fisheries Ecology Division (FED) and Environmental Research Division (ERD), and many collaborators at other institutions and agencies. The overall objectives are to conduct research needed to support (1) management and recovery planning for Pacific salmonids and sturgeon listed under the Endangered Species Act; (2) stock and ecosystems assessments and harvest management for West Coast groundfish and Pacific salmon fisheries; and (3) economic assessment of fisheries and fishing communities in California.

Specific research projects addressed 10 objectives: (1) provide groundfish analysis and stock assessment support; (2) conduct comparative studies in salmon ocean and estuarine ecology; (3) evaluate prey as a component of essential fish habitat for Pacific groundfishes; (4) conduct research on climate change and ecosystem variability in the North Pacific Ocean specifically looking at the dynamics of marine populations; (5) assess climate change effects on early life stages of marine and anadromous fishes; (6) conduct Pacific salmon population dynamics and assessment research; (7) conduct research on the landscape ecology of Pacific salmonids; (8) conduct integrated genetic monitoring and evaluation of salmon and steelhead in California; (9) apply economic models to fisheries, protected species and ecosystem management issues; (10) using acoustic-trawl and acoustic optical survey, estimate the distributions, abundances, and habitats of fish and zooplankton in the North Pacific Ocean and the California Delta.

Project scientists used a wide range of methods to address these research questions, including field sampling, laboratory experiments, physical and biological modeling, spatial analysis and modeling using GIS and remote sensing, and economic data collection and analysis.

Research Accomplishments
Project scientists met research goals and milestones for 9 of the 10 projects described above, which addressed a wide range of topics on biology, analytical methods, and economics related to the management of groundfish, salmon, and the California Current ecosystem. One project, evaluating the prey as an essential fish habitat for Pacific groundfishes, has been postponed due to a serious illness and will begin in July 2015. Accomplishments included final completion of a number of major projects resulting in publication of papers and reports; completion of several large field and laboratory data collection efforts, data analyses, and modeling projects; and initiation of a number of new studies through hiring of research staff, developing research plans and protocols, and beginning data collection or model development. Results were published in 25 journal articles and 19 reports or book chapters, five conference proceedings, one PhD dissertation, and an additional 6 articles were in press or submitted. Project scientists engaged in more than 22 conferences, workshops, symposia, and outreach events to present research, network and collaborate with other scientists, contribute to training and professional development within the field, and provide information to the public. Academic

development was provided to undergraduate and graduate students and post-doctoral scholars through employment and support of thesis and dissertation research.

FIGURE 1: Researchers install equipment in the Central Valley of California to evaluate the effect of predators on juvenile salmon.

FIGURE 2: Large hauls of young-of-the-year rockfish off Point Sur, salps and pyrosomes off Piedras Blancas, and pelagic red crabs off San Nicolas Island. The large fish in the top photo is a Pacific electric ray.

Freshwater Ecology Research Collaboration

Dr. Eric Palkovacs, UC Santa Cruz

NOAA Technical Contact: Dr. Steven Lindley, SWFSC

Links to NOAA Strategic Plan:

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

Amendment No.: 9, 21, 52, 88, and 117

Research Objectives and Specific Plans to Achieve Them

My primary objectives were 1) continue to build the Palkovacs Laboratory at UCSC, 2) continue to make progress on existing projects, and 3) establish and fund new projects and collaborations. To accomplish these goals, I extended the appointment for a postdoc (Dr. Daniel Hasselman), took on two new graduate students (Travis Apgar, Ben Wasserman), continued to support two existing PhD students (David Fryxell, Gina Contolini). I was awarded $920,354 in extramural research funding, published 6 peer-reviewed papers, have 4 papers currently in review, and a book chapter in press. I have organized and contributed to several working groups and established new research collaborations.

Research Accomplishments

This year, my lab published a series of papers addressing major questions in anadromous river herring ecology and management. We also published papers addressing the effects of contemporary evolution on ecological processes, including nutrient recycling rates and food web interactions. I was awarded research grants from the National Science Foundation, Atlantic States Marine Fisheries Commission, National Fish and Wildlife Foundation, National Marine Fisheries Service, and The Nature Conservancy to expand ongoing research on eco-evolutionary dynamics and anadromous fish ecology and evolution.

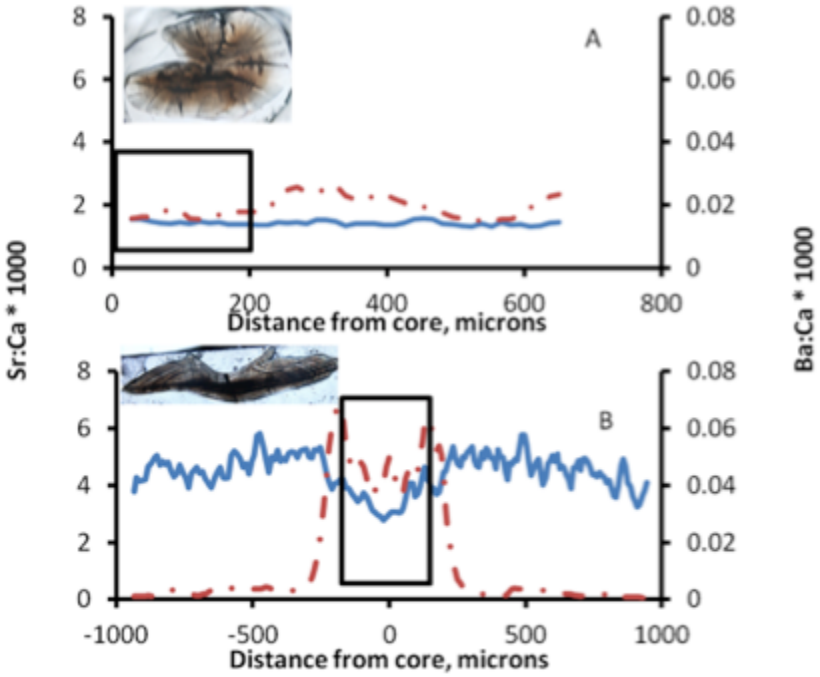

Figure 1: Otolith chemistry transects, illustrating the portion used for natal signatures (indicated by black rectangles) for (A) juvenile and (B) adult river herring. Strontium:Ca is indicated with the solid (blue) line; Ba:Ca is represented with a dashed (red) line. (From Turner, S.M., K.M. Limburg, E.P. Palkovacs. 2015. Can different combinations of natural tags identify river herring natal origins at different levels of stock structure? *Canadian Journal of Fisheries and Aquatic Sciences*. 72:845-854. doi:10.1139/cjfas-2014-0403)

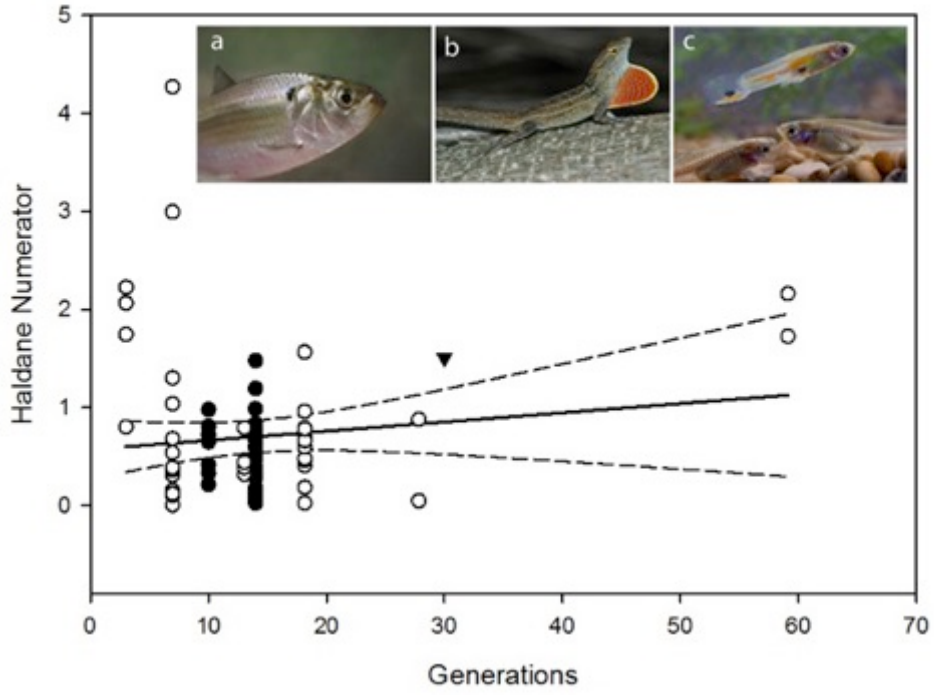

Figure 2: The rate of trait change for Crystal Lake alewives (a; triangle) is comparable to classic cases of experimental introduction and contemporary trait change involving *Anolis* lizards (b; filled circles) and Trinidadian guppies (c; open circles). Least squares regression (with 95% confidence intervals) is shown. (From Palkovacs, E.P., E.G. Mandeville & D.M. Post. 2014. Contemporary trait change in a classic ecological experiment: rapid decrease in alewife gill-raker spacing following introduction to an inland lake. *Freshwater Biology* 59:1897-1901. doi:10.1111/fwb.12392)

Freshwater Fish Ecology Research Collaboration

Darren Ward, Humboldt State University

NOAA Technical Contact: Steve Miller, FED/SWFSC
Links to NOAA Strategic Plan:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management
Amendment No.: 3, 29, 49, 81, and 107

Research Objectives and Specific Plans to Achieve Them
This project provides support for the Department of Fisheries Biology at Humboldt State University (HSU) to maintain a long-term collaboration between HSU and NOAA/NMFS addressing salmon conservation and restoration in Northern California and the Klamath River basin. This objective is implemented through partial funding for a faculty position held by Dr. Darren Ward at HSU to develop research projects focusing on evaluation of restoration effectiveness and assessment of issues related to restoration of salmon production in the Klamath River. Project funding allows this position to continue as a 50% research and 50% teaching appointment, as compared to typical 100% teaching appointments at HSU, to allow research efforts that complement NMFS efforts and fill needs for management and conservation planning.

Research Accomplishments
Research activities for this project are primarily carried out through increased time investment in mentoring graduate students and developing funding proposals. During the 2014-2015 project period, one graduate student from the Ward laboratory- Sean Cochran- completed data analysis and drafted a thesis (scheduled defense data: 15 April 2015). Sean used monitoring data and archived scale samples from coho salmon monitoring projects along the California coast to identify links between freshwater growth, early marine growth, and marine survival.

Four additional students are continuing work on related research projects:
Michelle Krall (expected completion Fall 2015) is evaluating growth and abundance of juvenile coho salmon occupying habitat enhancement sites in Klamath River tributaries to identify site features associated with increased coho production. She has completed field work and is working on processing samples and analyzing data.

Molly Gorman (expected completion Spring 2016) is comparing the fate of juvenile coho salmon that rear in natal habitat in the upper Shasta River and those that emigrate from the lower Shasta River into the main stem Klamath River. Molly was awarded a 2015 California Sea Grant award to incorporate stable isotope analysis of coho salmon otoliths into her project.

Gabe Scheer (expected completion Spring 2016) is constructing a life-history based population model for coastal coho salmon populations in order to predict the relative population effects of different conservation approaches.

Justin Alvarez (expected completion Fall 2016) will measure predation on native salmon by non-native brown trout in the upper Trinity River. Justin recently completed an electrofishing survey of the upper Trinity River that produced the first large-scale population estimate of brown trout in this important salmon habitat.

FIGURE 1: Humboldt State University graduate student Justin Alvarez collecting diet samples from non-native Trinity river brown trout. Many captured brown trout had consumed native salmonids, including wild and hatchery-produced coho and Chinook salmon and steelhead trout.

Molecular mechanisms of response to persistent oil spill pollutants

Andrew Whitehead, UC Davis

NOAA Technical Contact: R. Ricker, ARD/NOS
Links to NOAA Strategic Plan:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management
Amendment No.: 102

Research Objectives and Specific Plans to Achieve Them

Crude oils are complex, highly variable, and contain poorly characterized mixtures of organic compounds; however most oil spill damage assessments focus on the presence of polycyclic aromatic hydrocarbons (PAHs) because they have traditionally been linked to toxicity. Current models for estimating the ecological risks of oil mixtures assume additive toxicities of PAHs, but recent studies suggest mixture effects depend on different combinations of different fractions of oils. Oxyhydrocarbons and other organic constituents are prominent in a number of crude oils, especially weathered oils; these compounds tend to persist in the environment, but their contribution to toxicity is not well understood.

Our research integrates analytical chemistry with developmental biology and genomics tools and approaches to analyze the developmental responses of Atlantic killifish (*Fundulus heteroclitus*) embryos exposed to whole and fractionated Louisiana sweet crude oil (LSC). Killifish are uniquely suited for our studies due to their ecological importance in intertidal marshes, early life stage sensitivity to toxicants, and well-characterized, relatively short embryonic development, which is observable directly through their transparent chorion. We seek to: 1) discover the fractions of LSC oil that are responsible for developmental toxicity and understand their mixture effects within whole LSC; 2) elucidate molecular mechanisms/pathways of toxicant action and response; and 3) determine if early life exposure to oil fractions alters adult fitness and reproductive health. This is being achieved through careful developmental characterization of killifish embryos exposed to ranges of doses of fractionated oil, in combination with genome-wide gene expression profiling to offer insight into similar or different mechanisms of action of different fractions of crude oil.

Research Accomplishments

A complex series of pilot experiments was conducted during summer 2014 that involved killifish embryo exposures to LSC whole oil and three fractions during a timecourse of development, and for a range of concentrations. High-energy water-accommodated fractions (HEWAFs) were prepared for animal exposures using whole LSC and 3 LSC fractions: aromatic fraction (A), dominated by naphthalenes and high molecular weight PAHs; saturated fraction (S), dominated by alkanes; and polar fraction (P), dominated by polar compounds. Embryos were exposed to daily renewals of HEWAF for 6 days post-fertilization (post-organogenesis) and assessed for heart rate, *in ovo* ethoxyresorufin-O-deethylase (EROD) activity, developmental abnormalities (scored as phenotypic rating), hatching, and survival to 7 days post-hatching. Early-to-mid-development embryos were also archived for genome-wide gene expression analysis. Elevated EROD activity in all tests provided new evidence to suggest non-aromatic compounds may activate the aryl hydrocarbon receptor (AhR). Preliminary analyses of phenotypic scores revealed the polar fraction to be most toxic, followed by the saturated then aromatic fractions. Videos captured heart rates of exposed embryos. Data have been collected from videos and analysis is ongoing. We anticipate that analyses of heart rates may reveal additional subtle, but potentially important, differences between exposures, and complementary transcriptomics analyses are planned that will enable mechanistic interpretations that help explain how oil damages living resources.

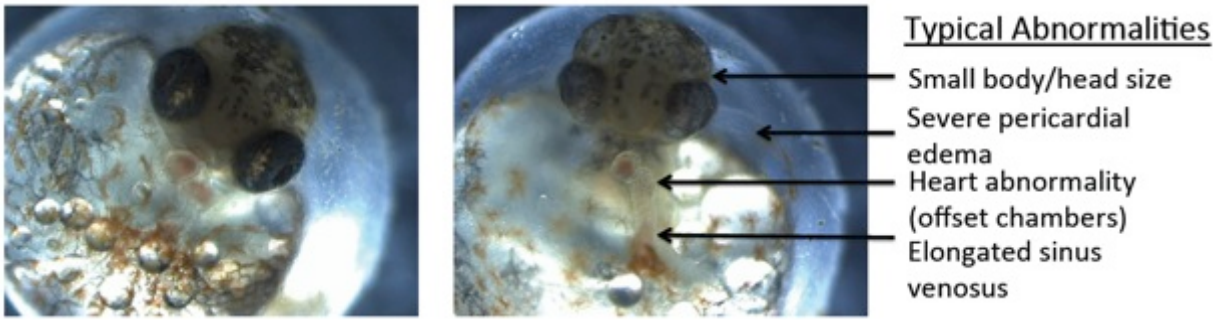

Figure 1: Images of a control embryo (left panel) and an oil-exposed embryo with developmental abnormalities indicated.

NOAA/PMEL/EOI addition of days to Moyer Mariana Expedition: R/V *Roger Revelle* - November-December 2014

Bruce Appelgate, Scripps Institution of Oceanography

NOAA Technical Contact: Thomas Peltzer, PMEL
Links to NOAA Strategic Plan:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management;
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond;
Amendment No.: 104

Research Objectives and Specific Plans to Achieve Them
This grant funded the cost of operating the Research Vessel Roger Revelle as part of a joint NOAA/NSF investigation of the ecosystems and environments associated with volcanic/hydrothermal systems in the Mariana arc. To fulfill this objective, Scripps Institution of Oceanography employed routine cruise planning methods, including dialog with the scientific party, ship's crew, marine technicians, and third-party service providers to coordinate all the logistics related to mounting a major expeditionary oceanography program in the western Pacific. Shipping agents were retained in Guam to handle pre- and post- cruise mobilization and demobilization, and all port logistics were arranged by the Scripps Nimitz Marine Facility staff. Foreign clearance to work in the waters of the Commonwealth of the Northern Mariana Islands was requested and approved on behalf of the science party. All ship crewing and provisioning was arranged following Scripps procedures, and technical services at sea were provided in support of scientific needs.

Research Accomplishments
This was a joint cruise between Dr. Craig Moyer at WWU and PMEL/EOI. The PMEL team consisted of geologists and chemists with expertise in hydrothermal vent fluid and gas sampling, as well as with plume mapping and chemical sensing in the water column. Work at NW Eifuku Seamount focused on co-located sampling of microbial mats and vent fluids to determine the chemical environment of the iron-oxidizing bacteria. Another focus was the spatial distribution of low-pH waters in relation to the CO2 vents and the surrounding biological communities. A third focus involved incubation experiments on the seafloor to assess the effects of the acidic conditions on mussel growth in collaboration with biologist Dr. Verena Tunnicliffe (University of Victoria). In addition, the summit of NW Eifuku was mapped in high-

resolution to reveal the geological setting of the hydrothermal vents. The overall goal to explore the ecosystem of macro- and micro-biological habitats that are impacted by the poorly understood process of ocean acidification.

Figure 1: Remotely-Operated Vehicle JASON being loaded aboard the R/V *Roger Revelle*.

Figure 2: R/V *Roger Revelle* is a highly capable Global Class research vessel that operates worldwide. Operated by Scripps Institution of Oceanography as a shared-use facility within the University-National Oceanographic Laboratory System (UNOLS), Roger Revelle is available to all scientists supported by any US federal, state, and other agencies.

NOAA/SWFSC Winter 2015 CalCOFI Cruise Ship Time: R/V New Horizon Cruise Dates January 10 – February 08 2015

Bruce Appelgate, Scripps Institution of Oceanography

NOAA Technical Contact: Roger Hewett, SWFSC
Links to NOAA Strategic Plan:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Goal 3: Serve Society's Needs for Weather and Water Information
Amendment No.: 131

Research Objectives and Specific Plans to Achieve Them
This grant funded the cost of operating the Research Vessel Roger Revelle as part of a joint NOAA/NSF investigation of the ecosystems and environments associated with volcanic/hydrothermal systems in the Mariana arc. To fulfill this objective, Scripps Institution of Oceanography employed routine cruise planning methods, including dialog with the scientific party, ship's crew, marine technicians, and third-party service providers to coordinate all the logistics related to mounting a major expeditionary oceanography program in the western Pacific. Shipping agents were retained in Guam to handle pre- and post- cruise mobilization and demobilization, and the Scripps Nimitz Marine Facility staff arranged all port logistics. Foreign clearance to work in the waters of the Commonwealth of the Northern Mariana Islands was requested and approved on behalf of the science party. All ship crewing and provisioning was arranged following Scripps procedures, and technical services at sea were provided in support of scientific needs.

Research Accomplishments
The primary mission for the winter CalCOFI cruise is to continue an ongoing assessment of pelagic fish stocks between La Jolla and San Francisco, California. This included monitoring the environmental conditions within the CalCOFI survey area and conducting continuous underway sampling of surface waters. Temperature, salinity and chlorophyll were automatically logged by computer with the output from the GPS navigational unit and to record current profiles throughout the duration of the cruise with the Acoustic Doppler Current Profiler (ADCP).

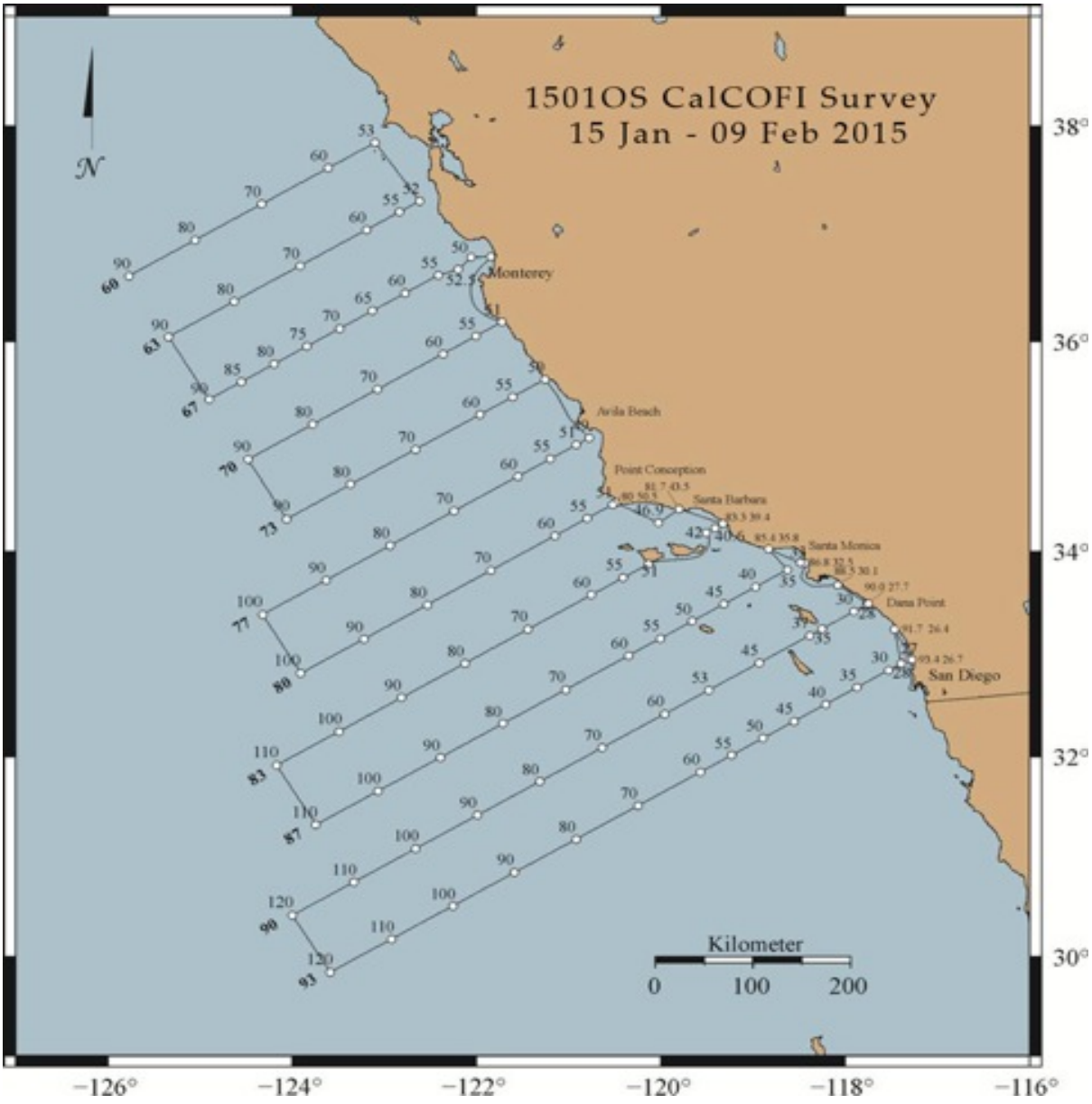

Figure 1: Locations of sampling stations during this cruise aboard R/V New Horizon.

Figure 2: R/V *New Horizon* is a highly capable Intermediate Class research vessel that operates across the Pacific Ocean. Operated by Scripps Institution of Oceanography as a shared-use facility within the University-National Oceanographic Laboratory System (UNOLS), Roger Revelle is available to all scientists supported by any US federal, state, and other agencies. In this photo, a CTD rosette is recovered during the CalCOFI program. Photo: ©James R Wilkinson/SIO-CalCOFI.

Measurements of North Atlantic Ambient Noise

John A. Hildebrand, Scripps Institution of Oceanography

NOAA Technical Contact: Jason Gedamke, MED
Links to NOAA Strategic Plan:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management
Amendment No.: 53

Research Objectives and Specific Plans to Achieve Them
This project examines changes in North Atlantic ocean ambient noise by comparing measurements conducted south of Bermuda in 1966 with current noise levels. An autonomous acoustic recorder was deployed at a previously studied location south of Bermuda. Data were compared for shipping and other anthropogenic noise sources as well as environmental contributions (wind and waves).

Research Accomplishments

Calibrated passive acoustic recordings were collected from June 2013 to March 2014 on the south side of Bermuda in the North Atlantic, at a location where ambient noise data were collected in 1966. Monthly and hourly mean power spectra (15-1,000 Hz) were calculated. Average spectrum levels at 40 Hz, representing shipping noise, ranged from 78-80 dB re: 1 μPa^2/Hz, with a peak in March and minimum in July and August. Values recorded during this recent period were similar to those recorded during 1966. This trend is different from what has been observed in the Northern Pacific, where ocean ambient noise has been increasing; however, the location of this monitoring site was not exposed to major shipping lanes in the North Atlantic. At frequencies dominated by wind and waves (500 Hz), noise levels ranged from 55-66 dB re: 1 μPa^2/Hz, indicating low sea states (2-3) prevailed during the summer, and higher sea states (4-5) during the winter. Seasonally important contribution to ambient sound also came from marine mammals, such as blue and fin whales.

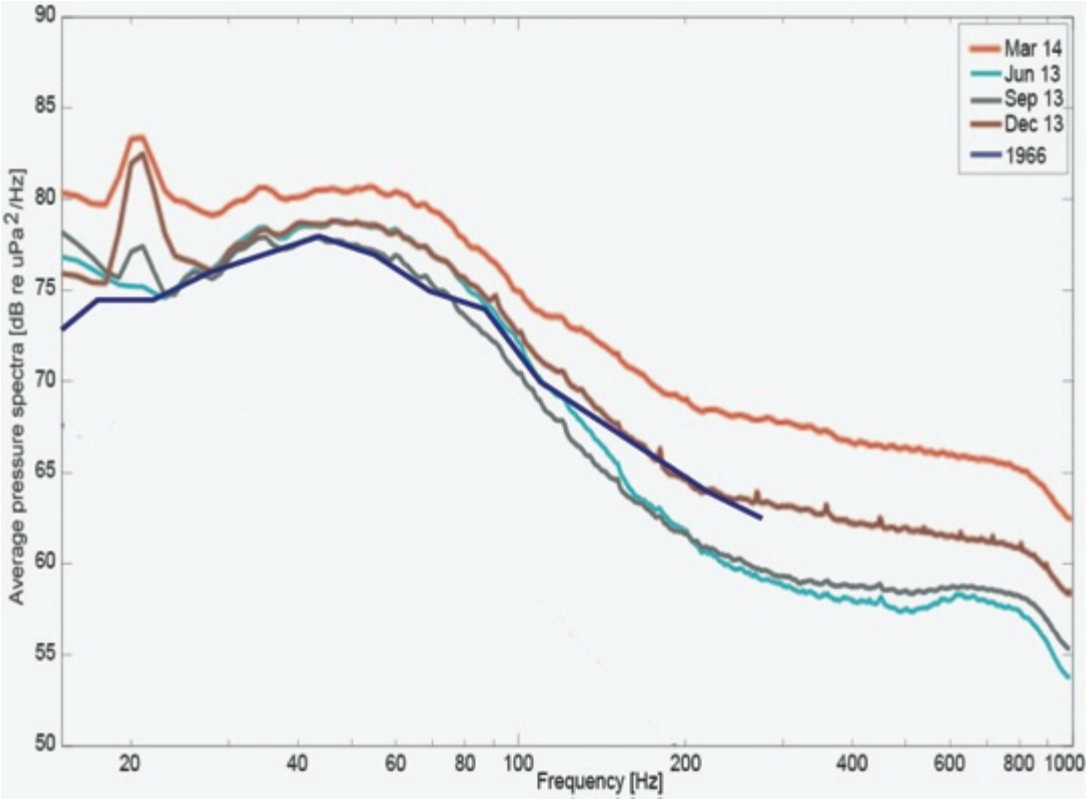

FIGURE 1 Ambient ocean noise is shown for Bermuda from historical data (1966 – Dark Blue Line) and for recent data (2013-2014):

Ocean observing and fisheries oceanography research of the coastal ocean off northern California

Dr. Jeffery Abell, Humboldt State University

NOAA Technical Contact: Steve Miller, NMFS
Links to NOAA Strategic Plan:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: 34

Research Objectives and Specific Plans to Achieve Them
Goals of this project are (1) to facilitate ongoing ocean observation cruises along the Trinidad Head Line, and to prepare hydrographic and biological data for analysis and inclusion in coastal observation networks, and (2) to support focused research in fisheries oceanography and recruitment dynamics off northern California. The primary strategy for achieving these goals is to support a research technician tasked with the day-to-day operations associated with planning, executing, and demobilizing from observation cruises and assisting with coordination of post-cruise laboratory analysis and data synthesis. This work is based out of Humboldt State University, and represents a collaborative effort between HSU and the Fisheries Ecology Division of NMFS' Southwest Fisheries Science Center.

Research Accomplishments
Roxanne Robertson continued to serve as lead technician and to be a tremendous asset to the program. She has coordinated and in many cases led hydrographic and biological sampling on 12 successful cruises along the Trinidad Head Line (including several collaborative cruises focused on ocean acidification), processed hydrographic data, coordinated laboratory efforts to catch up on analysis of archived specimens (technical support for plankton sorting augmented by funding from the Ocean Protection Council), and ensured timely calibration and maintenance of instrumentation. These efforts spanned the end of the project described here and the onset of new work under "Ocean observing and fisheries oceanography research off northern California" (Brian Tissot, PI).

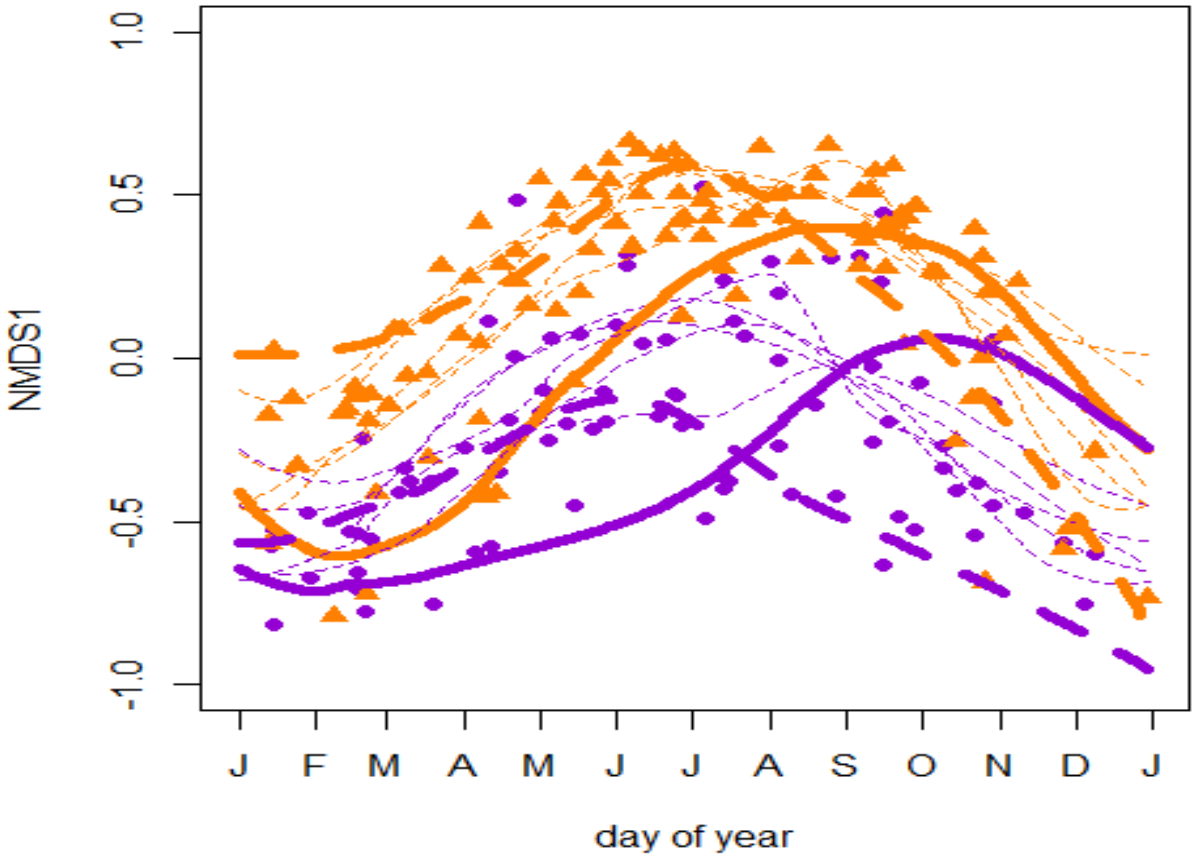

Figure 1: THL-KRILL: Upper left color photos: example of mass stranding of euphausiids observed from northern California and Oregon in June 2013. Lower left color plot: Cross shelf section of issolved oxygen (color) and temperature (contours) observed along the Trinidad Head Line 18 June 2013 showing low DO water over the shelf. Upper right panel: DO measured at Trinidad Head Wharf (data courtesy Frank Shaughnessy and CeNCOOS). Lower right panel: Annual time series of temperature, salinity and DO at 60 m at station TH02 (approximately mid-shelf) along the Trinidad Head line. Solid symbols indicate observations for 2013, open symbols are for 2012, and grey symbols are for previous years (2007-2011).

Theme D: Ecosystem-Based Management

Frontiers of Marine Resources Course

Mark Jacobsen, UC San Diego (Department of Economics)

NOAA Technical Contact: D. Squires, SWFSC
Links to NOAA Strategic Plan:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management
Amendment No.: 83

Research Objectives and Specific Plans to Achieve Them
We seek to increase the educational opportunities available for economics graduate students with an interest in marine resources. The grant is enabling formal coursework (in the form of a short course that combined lecturers from inside and outside the university) as well as additional lectures at the frontier of marine resource economics. Our aim is to expose the students to ideas and methods that they would not receive in the their regular economics classes.

Research Accomplishments
We first offered a short course on deep ocean resources targeted to economics graduate students (April 2014) and have since followed up with additional visitors to the department. William Gibbons-Fly (U.S. Department of State) visited in October of 2014 and led an engaging discussion of U.S. and international policy on the exploitation of marine fisheries. Jeffrey Englin (Arizona State University) then visited in March 2015, speaking about the economic valuation of natural resources and appealing more directly to core theory in economics. Both speakers also met individually with our PhD students in natural resources: this provides a valuable opportunity to get perspectives from outside the department and broaden the research agendas of our students entering the dissertation phase.

Center for the Advancement of Population Assessment Methodologies (CAPAM)

Brice Semmens, Scripps Institution of Oceanography

NOAA Technical Contact: J. McDaniels, SWFSC
Links to NOAA Strategic Plan:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management
Amendment No.: 66

Research Objectives and Specific Plans to Achieve Them
The goals of the Center for the Advancement of Population Assessment Methodology (CAPAM) are to improve quantitative methods generally used in stock assessment modeling efforts, provide guidance regarding good practices in stock assessment methods, and afford the educational opportunities necessary to train the next generation of highly skilled stock assessment scientists. Specifically, emphasis will be on assumptions used in contemporary stock assessment models, e.g., selectivity/catchability, growth, natural mortality, stock-recruitment relationship, covariates, spatial structure, data/likelihoods weighting, multi-species and ecosystem considerations, and diagnostics.

Research will be carried out through collaboration among CAPAM research candidates (e.g., postdoctoral researchers), SIO faculty (Dr. Semmens), SWFSC/IATTC staff (Drs. Crone and Maunder), and visiting scientists. Visiting scientists will be involved on a systematic basis to provide expertise for more complex problems associated with topics of interest. The candidates will also work alongside analysts (collaborators) on formal species-specific assessments to ensure the integration of practical aspects of stock assessment modeling in their independent research projects, and to provide them with invaluable training/mentorship for working in permanent stock assessment positions in the near future. Workshops will be held to disseminate the research efforts of CAPAM candidates, staff, and visiting scientists, as well as receive input from interested parties and outside experts. An advisory committee will act in the role of a 'review' panel by ensuring the research is timely, sound, and relevant to the needs of stock assessment practitioners (committee membership: R. Methot, A. Punt, J. Ianelli, R. Deriso, and S. Cadrin). Links will be made with developers of general stock assessment programs (e.g., *Stock Synthesis*) so that results generated through CAPAM can be formally implemented as default options in the respective modeling programs. Finally, support of a core group of researchers devoted to stock assessment-related analysis at SIO, SWFSC and IATTC will attract interest from other working groups attempting to achieve similar goals, which will broaden the scope, enhance this effort, and provide a potential source of collaborative funding/research in the future. During the first two years of CAPAM activities, research will be focused on developing a stock assessment *Good Practices* guide, and on research related to selectivity parameterization in stock assessments. To that end, the specific aim is to fund a highly skilled postdoctoral fellow over a two-year period to work closely with the PI and project collaborators in developing the *Good Practices* guide, and carry out cutting edge research in stock assessment methodologies.

Research Accomplishments

Good Practices in Stock Assessment Modeling, November 2014

The Center for the Advancement of Population Assessment Methodology (CAPAM) hosted a technical workshop on *Growth: theory, estimation, and application in fishery stock assessment models* in La Jolla, CA, USA from November 3-7, 2014. Sessions were attended on site by over 100 fishery researchers from around the world and over 15 participants online. Attendees included approximately 10 graduate students from across the country. The primary goal of the workshop was to provide advice and guidance on practices for modeling growth in fishery assessments. The focus was on model specification, parameter estimation, and management consequences, and did not cover growth estimates for specific species. The 5-day forum included an interactive modeling session, keynote and research presentations, and focused discussions. All of the workshop presentations are archived and available for viewing at http://www.capamresearch.org/growth/workshop. A special issue in Fisheries Research based on the meeting is currently in the works with several manuscripts already inpress and online.

Graduate Student and Postdoctoral Research Mentoring

Graduate student and post-doctoral research associated with CAPAM programs had broad reach, in large part due to active support, guidance, and mentoring from CAPAM personnel. For instance, SIO graduate student Lynn Waterhouse continues to collaborate with CAPAM researcher Juan Valero and the CAPAM PIs in carrying out a stock assessment for white seabass (*Atractoscion nobilis*) in California. This effort is part of a collaborative project with the Pfleger Institute of Environmental Research (PIER) and California Department of Fish and Wildlife (CDFW). CAPAM took on this project in order to provide SIO graduate students with "real world" stock assessment experience, and to participate in a marine resource assessment associated with a stock actively managed by the state of California (currently ongoing and expected to be completed by Fall 2015.). As another example, SIO graduate student Brian Stock is collaborating with PI Semmens, Eric Ward (NWFSC) and Tomo Iguchi (SWFSC) on the

development of "next generation" spatial bycatch modeling and prediction. Finally, graduate student Lyall Bellquist continues to work with PI Semmens on field and modeling based methods for assessing local stocks of basses (*Paralabrax spp.*) along the Southern California Coast.

Research and Publications

CAPAM personnel continue to publish at an extraordinary rate, with 13 peer-reviewed publications in 2015, and 9 in 2014. Collectively, these publications continue to push the application of quantitative science in fisheries, with an emphasis on tool development and innovation in the assessment sciences.

FIGURE 1: Group photo from the CAPAM workshop on Growth: theory, estimation, and application in fishery stock assessment models (NOAA/NMFS/SWFSC, La Jolla, CA 92037, November 3-7, 2014)

Identifying Critical Habitat for Highly-Mobile Marine Vertebrates under the Endangered Species Act

Brice Semmens, Scripps Institution of Oceanography

NOAA Technical Contact: Roger Hewitt, SWFSC
Links to NOAA Strategic Plan:
UNKNOWN
Amendment No.: 123 and 135

Research Objectives and Specific Plans to Achieve Them

In collaboration with colleagues at SWFSC and NWFSC, Dr Charlotte Boyd is developing a spatially-explicit individual based model (IBM) to explore the effects of changes in prey availability at various locations on the energy balances of endangered Southern Resident Killer Whales (*Orcinus orca*).

The key deliverable for Phase I of this project was the development of a model framework for review by project partners.

Pending continued funding, Phase II will include development of a second generation model designed to investigate one or more specific hypotheses on the relationship between habitat/prey attributes and

killer whale survival and fecundity. A manuscript describing the model and analytical results will be submitted to a peer-reviewed journal by end of June 2016.

Research Accomplishments

The IBM framework has been developed. Current work is focused on integrating available data on the abundance and distribution of salmon stocks and other coastal fishes off California, Oregon, Washington, and British Columbia. A meeting with project partners to review the model framework and agree priorities for further development will be held in Seattle by end of July 2015.

FIGURE 1: Postdoc Charlotte Boyd conducting marine mammal surveys on the 3rd leg of the California Current Cetacean and Ecosystem Assessment Survey (CalCurCEAS) October-November 2015.

Using Combined Video/Acoustic Recordings of Marine Mammal/Fishing Gear Interactions to Evaluate Utility of Passive Acoustic Monitoring

Aaron Thode, Scripps Institution of Oceanography

NOAA Technical Contact: Derek Orner, NMFS
Links to NOAA Strategic Plan:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management
Amendment No.: NA12NMF4720253 (Competed)

Research Objectives and Specific Plans to Achieve Them
A prominent issue in reducing bycatch is minimizing or preferably eliminating marine mammal interactions with longline gear, particularly for species which remove the catch or bait off gear, a behavior known as depredation. Depredation is the active intentional removal of prey, in contrast to a whale inadvertently stumbling into a net or line. Sperm whales (*Physeter macrocephalus)*, killer whales (*Orcinus orca*), and false killer whales (*Pseudorca crassidens*) are among the cetacean species actively engaging in depredation. These whales risk entanglement for presumably easier or more efficient feeding. Fishermen experiencing depredation take longer to catch their quota or have economic loss. Exploring ways to reduce depredation is hampered by lack of knowledge about the basic behavior itself, and the lack of an inexpensive way of quantifying depredation activity on deployments where human observers are impractical and expensive. Passive acoustic monitoring may be a useful cost-effective tool for detecting the presence of certain species around fishing gear, and thereby gaining insight into gear depredation rates and behavior as a function of time and location.

A fundamental assumption behind using passive acoustic monitoring, however, is that animals are acoustically active when interacting with the gear, an assumption that may not be true during daylight conditions, since many odontocetes have good visual acuity. The one published study on false killer whale acoustics around longline gear found no correlation between depredation activity and passive acoustic detections of false killer whales. A preliminary analysis of killer whale interactions with vessels in the Bering Sea found uncertain correlations between acoustic and depredation activities. Essentially, relatively few (9) click trains or buzzes were detected on a longline with 100% depredation (2600 hooks) deployed during daylight hours, and thus killer whales may use vision, along with echolocation, to interact with gear, at least during the daytime.

Our proposed solution is to simultaneously deploy cameras and acoustic recorders from fishing gear, in order to determine whether visually-documented interactions are accompanied by distinctive acoustic cues, such as echolocation sounds by the species of interest.

Research Accomplishments
Twelve TadPro devices extended and redesigned.
Between October 2014 and February 2015, twelve TadPro units (including all units funded with this BREP support) were modified with by adding a new circuit board design, built to fit into the back of a GoPro Hero 3+ camera. The boards provide a reliable timing circuit to wake up the system between 0-20 hours delay with minimal power consumption. The board also allows the delay timer to be set "on the fly" via an external programming box. The boards also introduce a heterodyning circuit that allows the left channel of the GoPro to record ultrasonic sounds between 17 and 30 kHz, while the right channel records audio between 0-15 kHz.

Successful TadPro deployments off Hawaii Jan. 2015

The camera/acoustic/accelerometer systems were first deployed off Hawaii in Jan. 2015, using substantial logistical help and arrangements by Ali Bayless and Erin Oleson (NOAA Pacific Islands Fisheries Science Center, and previous BREP recipients), and Jit Sarkar (SIO) and Toby Robinson (Alaska Longline Fishermens' Association).

Between Jan. 14 and Jan. 28, 2015 six TadPros were deployed off the F/V Katy-Mary (skipper Jerry Ray; owner Sean Martin) by NOAA observer Dustin Barnes for a total of 14 sets, with five cameras per set (one camera system would not activate).

A video by Dustin Barnes illustrating how the systems were deployed and recovered from the monofilament line can be accessed here: https://jonah.ucsd.edu:5001/fbsharing/TnDwzAW3

The major constraints on the work turned out to be the time required to download video from five cameras after each set (three laptops were needed to download video fast enough), and the need to have the cameras record only during daylight hours, since it is illegal to attach external lights to Hawaiian pelagic fishing gear. Thus the cameras had to be clustered together along the line in order to take advantage of a narrow daylight window (since most hauling took place at night).

False killer whale and mahi-mahi footage obtained

A first quick pass of the footage (by checking whether bait attached to the hook was gone by the end of a recording, and then locating the time where the bait vanished) yielded two false killer whale depredation encounters (Camera 1, sets 4 and 14) and two mahi-mahi encounters (sets 2 and 3, Cameras 2 and 4 respectively), with video, audio, and line movements (acceleration) successfully logged.

A short video of the Set 14 encounter with cleaned-up audio can be downloaded here: https://jonah.ucsd.edu:5001/fbsharing/byl7aJCj

The footage is now being scanned for situations where marine mammals have approached, but not touched, the gear.

Results of Hawaii field work presented to NOAA Take Reduction Team for False Killer Whale Bycatch

On April 28 2015 the results of the Hawaiian fieldwork and some preliminary analysis results were presented to the False Killer Whale Take Reduction Team Meeting in Honolulu HI.

Preparations for opportunistic Alaska fieldwork beginning Summer 2015

Twelve cameras have been repaired, checked, and inventoried for opportunistic trips with demersal longline fishermen during Summer 2015.

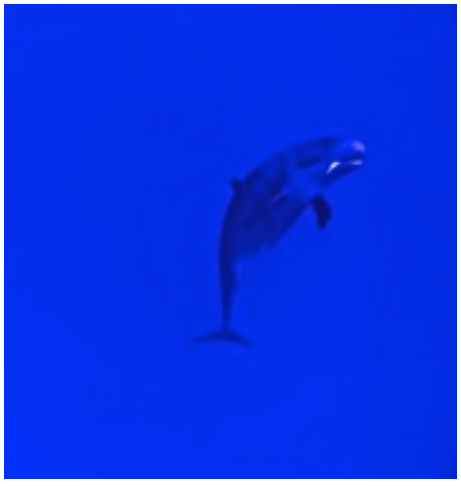

FIGURE 1 : Video still from Jan. 28, 2015 documentation of false killer whale depredation off the F/V Katy Mary in Hawaiian offshore waters. Sound and line acceleration were also recorded.

Using Combined Video, Acoustic, and Accelerometer Measurements to Determine the Conceptual Viability of a "Smart" Hook

Aaron Thode, Scripps Institution of Oceanography
Victoria O'Connell, Scripps Institution of Oceanography
Janice Straley, Sitka Sound Science Center

NOAA Technical Contact: D. Orner NMFS/OHC
Links to NOAA Strategic Plan:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management
Amendment No.: NA14NMF47 20328

Research Objectives and Specific Plans to Achieve Them

Pelagic longline operations face bycatch issues with sharks, sea turtles, and marine mammals (such as false killer whales (*Pseudorca crassidens*)), while demersal longline operations face bycatch issues with rockfish and skates, and interactions with sperm whales (*Physeter macrocephalus)* and killer whales (*Orcinus orca*). Time-area closures and dehooking equipment are strategies being used to reduce sea turtle mortality and whale bycatch in pelagic longline fisheries. Another specific regulatory action recently adopted to reduce false killer whale bycatch in Hawaiian waters is the implementation of "weak hooks": hooks constructed to yield when enough force is implemented

Given recent rapid decreases in the cost and size of consumer electronics, one might ask whether the concept of a "smart" hook is viable: a sensor that measures not only the magnitude, but other features of the acceleration time series of an animal's struggle with the line, such as the duration and persistence of tugs on a line, and rhythms of struggling and other temporal patterns in the tugging during both the initial hook ("first strike") and the subsequent haul. Additional cues to species identification could be obtained from sounds generated by both an animal's struggles and (in the case of marine mammals) vocalizations from the animal itself. If some combination of accelerometer and acoustic measurement pattern could be found to flag the presence of a bycatch or endangered species, then the hook could release via a variety of simple methods, such as a burn wire or relay. Multiple hooks might be monitored by such a system by looking at the spectral content of the accelerometer data: the more distant the hook, the less bandwidth a single tug should display. The concept, in principle, could be applied to a large range of bycatch species on longlines, or other fishing techniques that catch individual fish on individual hooks.

While these questions could in principle be addressed without underwater video, relying instead on visual observers or video recordings of items hauled onto a vessel's deck, the use of a combined video/acoustic/accelerometer system would provide some significant logistical advantages, such as eliminating the need for intrusive or inconvenient video recording during an in-progress haul, and also enabling a larger sample size, in that animals that spin off, escape, or otherwise release before reaching the surface could be documented and analyzed.

Research Accomplishments

Twelve TadPro devices extended and redesigned.

Between October 2014 and February 2015, twelve TadPro units (including all units funded with previous BREP support) were modified with by adding a new circuit board design (built around an Arduino Pro Mini microprocessor), built to fit into the back of a GoPro Hero 3+ camera. The boards provide a reliable timing circuit to wake up the system between 0-20 hours delay with minimal power

consumption. The board also allows the delay timer to be set "on the fly" via an external programming box, which allows the timer to be reset in the field without opening the case.

Successful TadPro deployments off Hawaii Jan. 2015

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Between Jan. 14 and Jan. 28, 2015 six TadPros were deployed off the F/V Katy-Mary (skipper Jerry Ray; owner Sean Martin) by NOAA observer Dustin Barnes for a total of 14 sets, with five cameras per set (one camera system would not activate).

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A first quick pass of the footage (by checking whether bait attached to the hook was gone by the end of a recording, and then locating the time where the bait vanished) yielded two false killer whale depredation encounters (Camera 1, sets 4 and 14) and two mahi-mahi encounters (sets 2 and 3, Cameras 2 and 4 respectively), with video, audio, and line movements (acceleration) successfully logged.

Preliminary acoustic and accelerometer analysis of Hawaii deployments

Acoustic and accelerometer analysis (A/A) has begun on the Set 14 false killer whale encounter, as it was the first one discovered on video in early February.

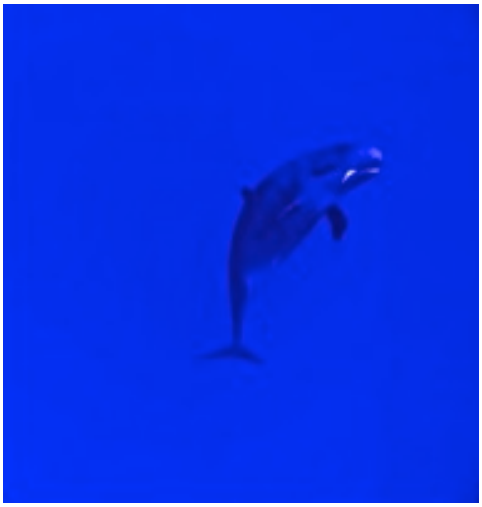

FIGURE 1: Video still from Jan. 28, 2015 documentation of false killer whale depredation off the F/V Katy Mary in Hawaiian offshore waters. Sound and line acceleration were also recorded.

Training the Next Generation of Marine Population Dynamics Scientists

Brice Semmens, Scripps Institution of Oceanography

NOAA Technical Contact: Roger Hewitt, SWFSC

Links to NOAA Strategic Plan:

Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management

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

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

Amendment No.:

5, 31, 45, 91 and 100

Research Objectives and Specific Plans to Achieve Them

The goal of this project was to facilitate the initiation of a research program for new faculty member Brice Semmens. Brice Semmens was hired during a search for a marine population dynamics scientist with the ability to train future practitioners in the science of population assessment and development of enhanced assessment methods that incorporate environmental variability, food web linkages and spatial heterogeneity. The intent of the appointment was to build upon a long record of accomplishment and collaboration between Scripps Institution of Oceanography and NOAA Fisheries Service. Thus, the objective of these funds included: build a working laboratory suitable for both research and training, initiate field studies, and jumpstart the overall research program on population assessment and dynamics, and characterization of community interactions.

Research Accomplishments

This past year I continued my collaboration with other scientists through the Center for the Advancement of Population Assessment Methodology (CAPAM). Other CAPAM principal investigators include Mark Maunder (Inter-American Tropical Tuna Commission, IATTC) and Paul R. Crone (Southwest Fisheries Science Center, SWFSC). To date, CAPAM personnel have authored over 30 publications directly related to stock assessment methods. In November 2014, CAPAM hosted a 5-day workshop on growth models on the Scripps Institution of Oceanography (SIO) campus in La Jolla, CA. This workshop was attended by 100 assessment scientists from around the world, and importantly, also included 23 graduate students from SIO, Oregon State University, UC Santa Cruz, San Diego State University, and the University of Washington. These graduate students participated in Stock Synthesis training sessions, heard presentations on emerging assessment methods, and had the opportunity to interact with leaders in the field.

My lab continues to maintain the La Jolla Acoustic Array (LJAA), a series of ~50 Vemco passive hydrophone receivers capable of monitoring the movements of acoustically tagged fish along the San Diego coast. The LJAA allows precise monitoring of spatial movement patterns of tagged fish inside and outside of local Marine Protected Areas along Southern California. Since last year, we have tagged ~50 local bass (*Paralabrax spp.*), and contributed to monitoring the movements of tagged leopard shark (*Triakis semifasciata*), soupfin shark (*Galeorhinus galeus*), white shark (*Carcharodon carcharias*), and yellowtail (*Seriola lalandi*) as part of the Southern California Acoustic Tag Tracking Network, a partnership with Chris Lowe (California State Long Beach), Michael Shane (Hubbs Seaworld Research Institute), John Hyde (SWFSC), Nick Wegner (SWFSC), Doug McCauley (UCSD), and Chris Caldow (Channel Islands National Marine Sanctuary). A manuscript on the movement and behavior of local basses is currently in preparation. From a training perspective, the data generated by the LJAA provide

a valuable teaching resource for instructing students in the parameterization and use of animal movement models associated with fisheries resource assessment.

Over the project period, I invested considerable time and effort in formal and informal teaching at both the undergraduate and graduate levels. During the academic year I taught a graduate level course on Bayesian population analysis (including mark-re-capture analysis), an undergraduate course in frequentist statistics and an undergraduate course in marine biology lab and field techniques. Outside of formal teaching activities, my lab has jointly coordinated a quantitative seminar series with SWFSC that meets monthly, and I participate as a faculty representative to the R-users group weekly meeting held on the SIO campus. During the project period I oversaw 4 PhD students (Lynn Waterhouse, Brian Stock, Josh Stewart, Lyall Bellquist), and one postdoc (Charlotte Boyd). Members in my lab continue to pursue a diverse array of projects related to fisheries population dynamics and marine resource assessment.

Graduate student Lyall Bellquist and I continue to maintain the *Coastal Angler Tagging Cooperative*, a collaboration between the recreational fishing community, the California Department of Fish and Game, and the San Diego Oceans Foundation to implement an assessment of *Paralabrax* spp. populations, vital rates, and movement patterns. The project aims to generate important demographic rate parameters used in stock assessments (e.g., mortality and growth). This information will help clarify *Paralabrax* spp. status and trends for the purpose of identifying appropriate population monitoring metrics for adaptive management. Completing his field work this year, over 16,000 individuals of three species, calico bass (*Paralabrax clathratus*), sand bass (*Paralabrax nebulifer*), and spotted bay bass (*Paralabrax maculatofasciatus*), have been tagged.

Graduate student Brian Stock is collaborating with NOAA scientists Tomo Iguchi (SWFSC) and Eric Ward (Northwest Fisheries Science Center, NWFSC) on the development of "next generation" spatial bycatch modeling and prediction using powerful new tools, integrated nested Laplace approximations (INLA), and stochastic partial differential equations (SPDE), to spatially model bycatch in two large U.S. fisheries observer datasets (West Coast Groundfish and Hawaii Longline Observer Programs). As part of NOAA's "protected species toolkit" development, this project aims to inform ongoing efforts of the Marine Mammal and Turtle Division (MMTD) at the SWFSC. The outcome of this project can directly inform how to analyze bycatch in many SWFSC-managed fisheries, such as the California Drift Gillnet Fishery. Also note that while Brian is testing these spatial models' ability to predict bycatch in space, the models can be applied to survey data to generate density distributions, a primary goal of the California Current Cetacean and Ecosystem Assessment Survey (CalCurCEAS).

Graduate student Lynn Waterhouse continues to collaborate with CAPAM researcher Juan Valero and the CAPAM PIs in carrying out a stock assessment for white seabass (*Atractoscion nobilis*) in California. This effort is part of a collaborative project with the Pfleger Institute of Environmental Research and California Department of Fish and Wildlife. CAPAM took on this project in order to provide SIO graduate students with "real world" stock assessment experience, and to participate in a marine resource assessment associated with a stock actively managed by the state of California. This assessment is currently ongoing and expected to be completed by Fall 2015.

Graduate student Josh Stewart is using a combination of satellite telemetry, stable isotope analyses, and next-generation genetics to study the population structure and spatial ecology of the oceanic manta ray (*Manta birostris*), a CITES listed species. The findings from his work, recently submitted to Nature Communications, indicate that the existing management paradigm associated with highly-mobile marine vertebrates may not be a "one size fits all" approach, and demonstrate the importance of studying the spatial ecology of marine megafauna using a diverse array of analytic and quantitative techniques.

Semmens Lab graduate students mentor undergraduate research assistants, providing excellent opportunities for graduate student career development and valuable experiences for the undergraduates. The lab currently mentors four undergraduates informally, and has arranged to work with three more undergraduates through formal summer research programs. The Scripps Undergraduate Research Fellowship (SURF) and Summer Training Academy for Research in the Sciences (STARS) programs "seek to increase the diversity of students successfully prepared to pursue earth and ocean sciences career pathways, and to recruit individuals from institutions with limited undergraduate research opportunities."

Finally, each year I coordinate the Grouper Moon program, a collaboration between SIO, REEF (Reef Environmental Education Foundation), and Cayman Islands Department of Environment, aimed at monitoring one of the last remaining large aggregations of Nassau grouper (*Epinephelus striatus*) in the Caribbean. As part of this effort, I cooordinate a K-12 education and outreach program that uses in-class activities and live-from-the-field Web streaming to teach students the importance of top marine predators and effective fisheries management. Each year hundreds of students and teachers throughout the Caribbean and the US participate in the program.

FIGURE 1: Grouper Moon educator Todd Bohannon leads a K-12 teacher-training workshop in Grand Cayman, Cayman Islands. Teachers from both the Cayman Islands and the Bahamas participated.

FIGURE 2: PI Semmens conducts a live-chat with hundreds of school children from the field site on Little Cayman, Cayman Islands.

OUTREACH

Fish Biology and Fisheries Science Workshops
Darren Ward worked with Humboldt county Office of Education Gifted and Talented Education (GATE) to present two hour-long workshops on fish habitat, ecology and morphology for fifth-grade students in an effort to introduce elementary students to fish biology and fisheries science.

Volunteering on CalCOFI cruises
Approximately 6 people per year provided opportunity to experience oceanographic research while volunteering on CalCOFI cruises.

CSTAR presentation
Ryan Driscoll presented a guest talk on CSTAR complete with Q&A at Tatnall School in Delaware.

Antarctic Scientific Cruise Ship Logs
Jarrod Santora – Schools reached via Moss Landing Marine Labs, San Jose State University.

Graduate Students advise high school science projects
Duran Fiack – Graduate Students advise high school students on year-long science projects carried out in Elkhorn Slough National Estuarine Research Reserve - Monterey Bay Aquarium Research Institute, CSU.

Science Colloquium
Participated in the Science Colloquium at Presentation High School in San Jose, CA.

SEREAD Program
Develop curricular units and conduct teacher-training seminars for teaching of weather, climate, sea level, and the ocean's role in climate in Pacific islands school systems.
http://www.argo.ucsd.edu/FrEducational_use.html

ARGP floats
Lecture on ARGO floats and climate change to 6th grade classes at San Diego French American School.

Integrated Surface Currents in Aquarium Display
To educate and bring awareness of ocean energy to general public: Boundless Energy Exhibit at Birch Aquarium.

Santa Cruz-Watsonville Inquiry Based Learning in Environmental Sciences
Graduate Students work with high school teachers to develop and teach inquiry-based modules based on the next generation science standards to high school students. Partnered with Watsonville High School; Department of Environmental Studies, UC Santa Cruz; Department of Ecology and Evolutionary Biology, UC Santa Cruz.

UCSC Hellman Fellowship
Dr. Eric Palkovacs was awarded the UCSC Hellman Fellowship to support "An experimental test for eco-evolutionary feedbacks along a classic evolutionary pathway in threespine stickleback."

Develop online integrated mathematics course materials for high school
Graduate student Lynn Waterhouse finished her NSF GK-12 Fellowship at Kearny SCT, a San Diego High School and developed online course materials for integrated mathematics into the high school biology

curriculum. Lynn continued interacting with the class in the 2014-2015 school year, with the goal to provide science and research opportunities to high school students.

Volunteer divers/educators at Birch Aquarium
Graduate students Lynn Waterhouse and Brian Stock participate as volunteer diver/educators at the Birch Aquarium - Birch aquarium divers help communicate ocean science and research to youth.

Independent study mentor
Graduate student Josh Stewart mentored an Independent study student working with Manta Ray mobuild tissue. The goal is to provide science and research supervision for an Independent study.

K-12 web-based outreach in the Caribbean
PI Semmens coordinated and lead a K-12 Web-based outreach program associated with Nassau Grouper Research in the Caribbean - Use field-based live streaming and in-person classroom visits to educate K-12 students throughout the Caribbean regarding the importance of large marine predators and spawning aggregations. - SIO, Reef Environmental Education Foundation, Cayman Islands Department of the Environment.

Discovery Channel K-6 educational video series available for classroom education
Train K-6 students on salmon biology and careers in environmental sciences in support of a video series on Rachel Carson.

Undergraduate internships
Provide training and experience for undergraduate students at UC Santa Cruz in salmon biology and other environmental sciences.

COMMUNICATIONS, NETWORKING, ACADEMIC DEVELOPMENT and AWARDS

Communications

ACTIVITY	OBJECTIVE	PARTNERS
Nerd Nite Vancouver	Holly Kindsvater did a public talk to discuss the evolution of fish biodiversity, and conservation in science-themed public venues.	Science Nerds of Vancouver Nerd Nite Vancouver
Public Talk at the Beaty Biodiversity Museum in Vancouver, BC	Holly Kindsvater did a public talk at the Beaty Biodiversity Museum to discuss the evolution of fish biodiversity, and conservation in science-themed public venues.	Beaty Biodiversity Museum
Marine Biodiversity Observation Network	Jarrod Santora is developing a coordinated Marine Biodiversity Observation Network (MBON)	CSU universities
Science and Justice Program	Kate Richerson spoke at a UCSC Science and Justice class to share experiences as part of the Science and Justice Program	University of California, Santa Cruz
Argo Science Team website	Provide information on the Argo project, its objectives, status and data system, including how to access Argo data http://www.argo.ucsd.edu	International Argo partnership
Argonautics Newsletter	Distribute information on Argo status, applications, and progress on key issues.	International Argo partnership
Argo Marine Atlas project	Develop a data display tool to allow students and educators to view Argo and other ocean datasets as maps, vertical sections, time-series plots, and line drawings	PI-GOOS, SEREAD

Climate phenomena explanations	Explain climate phenomena to general public, e.g., The Blob's impacts	Interviews by: KPBS (tv and radio) ABC 10 San Diego NBC 7 San Diego San Jose Mercury News
Scripps Orbit and Permanent Array Center data	Precise hourly orbits are published and freely available on the SOPAC Website. http://sopac.ucsd.edu	International GNSS Service (IGS)
Presentations to legislators, water managers and the public	Inform the public and policy community on the difficulties of managing a reservoir for both flood control and water supply.	Sonoma Country Water Agency
Presentation to Western States Water Council on the observing system	Inform policy makers and water managers about the importance of an observing system and provide a pathway to develop such as system	Sonoma Country Water Agency
High Resolution XBT Network website	Describe scope and objectives of the Pacific/Indian HRX network; display data from all cruises; provide downloadable datasets on a cruise-by-cruise basis. http://www-hrx.ucsd.edu	CSIRO, Australia NIWA, New Zealand Tohoku University
HF Radar Network Data Access	Provide online access to surface current mapping sites, radial data, and diagnostics for participating sites http://cordc.ucsd.edu/projects/mapping/	
SIO Argo website	Provide information on the status and location of SIO Argo floats. http://sio-argo.ucsd.edu	
Spray glider website	Provide real time status and plots of glider data http://spray.ucsd.edu	
Spray public data access	Public access to Spray glider data	
The Guardian Article on 12/4/14	Promote Global Drifter Program Jonathan Franklin The Guardian, UK 12/4/2014	The Guardian UK

Boston Globe Article on 12/31/14	Promote Global Drifter Program http://www.bostonglobe.com/news/world/2014/12/31/airasia-plane-debris-and-bodies-found-little-hope-any-survivors/kRBcyXrEFnMflkfqmMGFSO/story.html	The Boston Globe
New York Times Article on 12/30/14	Promote Global Drifter Program	The New York Times
Keynote at Harvard	On May 5, 2014, Ralph Keeling gave a Keynote at Harvard titled, "O Brave New World! Entering an Age of Climate Change Beyond 400 ppm".	Harvard University Center for the Environment
Symposium at University of San Diego	On May 13, 2014, Ralph Keeling gave the Keynote at a Symposium on Energy and Climate at the University of San Diego, titled "The World at 400 ppm and beyond"	University of San Diego
Symposium at Scripps Institution of Oceanography	On August 28, 2015, Ralph Keeling spoke at a Symposium on "Science in the 21st Century" aka "Charlie (Kennel) Fest" talking stock of the "great geophysical experiment."	Scripps Institution of Oceanography, UC San Diego
Speaker in Resilient San Diego Awareness Series	On October 21, 2015, Ralph Keeling spoke at the Resilient San Diego Awareness Series, held at the San Diego Public Library, titled "An update on the Status of Climate Change."	San Diego Public Library
Falkoner lecture at U. Albany:	On April 30, 2015, Ralph Keeling gave a Falkoner lecture at the University of Albany, titled, "Atmospheric signatures of changing biogeochemistry."	University of Albany
CCHDO public data dissemination	Disseminate all public CCHDO data, documentation, and data information via the CCHDO website. http://cchdo.ucsd.edu.	CLIVAR NSF NOAA SIO
Inform about the project and receive feedback	We attended 4 different stakeholder meetings in the Russian River region including the Russian River Watershed Association, Santa Rosa Basin Advisory Panel, North Bay Climate Adaptation Initiative, and Upper River Managers Meeting. The purpose was to seek input on the impacts of droughts and identified the type of drought to use in the mega-drought scenario. We also presented at the Sonoma County We attended the Sonoma County Adaptation	Sonoma County Water Agency

NOAA & CalCOFI community announcement	Project and partnership announcement to the NOAA and CalCOFI community http://oceanexplorer.noaa.gov/about/what-we-do/oer-updates/2014/calcofi-111914.html http://oceanexplorer.noaa.gov/about/who-we-are/partnerships.html http://www.calcofi.org/field-work/bottle-sampling/ncog-project.html	SIO NOAA JCVI
	HiSeasNet real-time HD video transmission http://hiseasnet.ucsd.edu	
CalCOFI data sharing	CalCOFI data sharing program. http://data.calcofi.org	NOAA/NMFS IOD/SIO CDF&G
website and outreach	Public outreach on marine underwater sound http://www.voicesinthesea.org	Pacific Life Foundation Aquarium of the Pacific
	To raise awareness about marine mammal depredation off Alaska and highlight collaborative research efforts. www.seaswap.info	North Pacific Research Board Alaska Longline FIshermens' Association
Inside Sportfishing on the Fox Sports Network.	PI Semmens and Graduate Student Lyall Bellquist participated in two episodes of Inside Sportfishing on the Fox Sports Network to educate the public about the Coastal Angler Tagging Cooperative tagging and research in local San Diego coastal marine ecosystems.	Fox Sports Inside West Network
PI Semmens and Graduate student Lyall Bellquist launched the CATCH application for mobile-friendly use of reporting tagged fish.	Offer a service to the public to release the fish without removing the tag, and you don't need to write down the tag number or catch details. HookUp1090.com	SIO Fox Inside Sportsfishing CDF&G The Sportfishing Association of CA Fred Hall & Associates Shimano San Diego Anglers Oceanside Senior Anglers

		Fisherman's Landing
Graduate student Lyall Bellquist was on Let's Talk Hook-Up fishing radio show	Engage the public about the Coastal Angler Tagging Cooperative tagging and research in local San Diego coastal marine ecosystems.	Scripps Institution of Oceanography, UC San Diego HookUo1090.com
Article published in the Clairmount Times about Capt. Paul Fisher and the tagging project run by Lyall Bellquist	Update the public about the Coastal Angler Tagging Cooperative tagging and research in local San Diego coastal marine ecosystems.	Scripps Institution of Oceanography, UC San Diego Claremont Times
Article and short film in the NY Times called Now Boarding featuring student Josh Stewart.	Educate people about Josh's story and his research with The Manta Trust.	NY Times Emirates Airlines Scripps Institution of Oceanography The Manta Trust
Department Seminar, Biology, San Francisco State University	Described a suite of research projects focused on Sacramento River winter Chinook Salmon.	San Francisco State University faculty and students
Presentation at the 2015 CDFW Salmon Information Meeting	Presented salmon abundance forecasts and a preliminary outlook for 2015 ocean salmon fisheries.	CDFW, fishing groups, general public
Presentations to Pacific Salmon Commission	Presented an analysis of the potential for parental-based tagging to supplement or replace the current coded-wire tag system use din international salmon management	Managers and scientists from the US and Canada
Presentation to graduate Conservation Ecology course at UC Davis	Discussed current and potential future uses of ecosystem-based fisheries management in the Pacific Fisheries Management Council	UC Davis students and faculty

Department Seminar, Ocean Sciences, UC Santa Cruz	Presentation on ongoing research relevant to understanding reproductive ecology of rockfish	UC Santa Cruz faculty and students
Public Panel Exploratorium, San Francisco	Discuss current California Drought	Exploratorium
Presentation to Pacific Fisheries Management Council (PFMC)	Review of ecosystem assessment	PFMC
North Pacific Anadromous Fisheries Commission (NPAFC)	Provide leadership on the use of ecosystem simulation models to explore salmon recruitment variability	NPAFC
Spring-run and fall-run Chinook life cycle model workshops	Provide information on the development of the Chinook life cycle models to interested parties	USGS USBOR USFWS CDFW CDWR UCSC
Presentation to the Collaborative Adaptive Management Team (CAMT)	Provide information on the development of the Chinook Life cycles models to stakeholders, decision makers, and other interested parties	USGS USFWS USBOR CDFW CDWR UCSC
High Resolution XBT Network web site	Describe scope and objectives of the Pacific/Indian HRX network; display data from all cruises; provide downloadable datasets on a cruise-by-cruise basis. In future this site will provide time-series of western boundary current transport. http://www-hrx.ucsd.edu	CSIRO Australia NIWA New Zealand Tohoku University Japan
News Coverage Re: oil spill off Santa Barbara in May	D. Rudnick was interviewed twice for the local news concerning the oil spill off Santa Barbara in May. Gliders funded by CORC send data 24/7 that go into models that forecast currents used to predict the spread of spilled oil. http://www.10news.com/news/local-researchers-send-underwater-robots-to-assist-in-response-to-santa-barbara-oil-spill http://fox5sandiego.com/2015/05/21/underwater-robot-from-scripps-aids-in-santa-barbara-oil-spill/	10 News San Diego Fox 5 news San Diego

Networking

ACTIVITY	OBJECTIVE	PARTNERS
Seminar & Workshop on various topics	Holly Kindsvater organized seminar speakers and workshops on various topics including: open data, marine conservation, mapping and graphics. (Invited seminar speakers: Heather Piwowar, Impactstory; Bob Warner, UC Santa Barbara; Workshop leaders: Lindsay Davidson, Natascia Tamburello, SFU)	SIO
Southern Ocean euphausiids with AERD	Kate Richerson networked with researchers at AERD and Scripps to discuss research on Southern Ocean euphausiids. Gave an informal presentation to AERD researchers.	AERD SIO
Cal-Neva AFS special session	Organized special session at Cal-Neva AFS meeting in Santa Cruz, CA	Cal-Neva AFS
Collaborative relationships	Continuing collaborative relationships with other ocean observation programs on the West Coast	Partner to CenCOOS, close collaboration with SCCOOS
CalCOFI input – California Current ecosystem model	Provide CalCOFI input to end-to-end coupled biophysical California Current ecosystem model including pelagic fish and fisheries	Co-PIs in collaboration with CAMEO project (Rose, Curchitser, et al.)
CalCOFI data distribution	Provide CalCOFI data to global ocean time series data center	CalCOFI partnership with OceanSites
Maintain observation partnerships	Ongoing partnerships to maintain ancillary observations of seabirds, marine mammals, and biogeochemistry and lower trophic levels	Collaborations with Farallon Institute, Hildebrand SIO laboratory and CCE-LTER program
CalCOFI input provided	Provide CalCOFI input to integrated ecosystem assessment and ecosystem-based management of the California Current	Pacific Fisheries Environment Lab/SWFSC/NOAA
Ocean Acidification Monitoring	Establish ocean acidification monitoring	Network with PMEL/NOAA

California south coast MPAs monitoring	Workshops to monitor California south coast MPAs	MPA Monitoring Enterprise, California Conservancy and Ocean Protection Council (OPC)
Foster CalCOFI partnerships	Foster CalCOFI partnerships with North Pacific rim marine research	Active member of PICES, joined PICES Technical Committee on Data Exchange (TCODE)
Foster CalCOFI partnerships	Foster collaboration with fisheries acoustics groups in ICES and globally	ICES Fisheries Acoustics Science and Technology Working Group (WGFAST)
Pacific Island Global Ocean Observing System (PI-GOOS) Advisory Committee	Assist Pacific island nations in gaining benefit from global ocean observations and products.	South Pacific Regional Environmental Program (SPREP), NOAA, BoM Australia, NIWA New Zealand, Intergovernmental Oceanographic Commission, South Pacific nations
Presented at Oil Spill Area Committee Meetings in San Diego	Provided updated information regarding HJF radar surface current application to oil spill response	U.S. Coast Guard, Office of Spill Prevention and Response (OSPR), Marine Resources Advisory Committee (MRC), Chevron
Correspondence NOAA ORR and CA	Data integration from THREDDS versus shapefiles for Oil Spill Response	NOAA OR & R and Office of Spill Prevention and Response
EuroGOOS	To promote HF radar derived surface currents standards and distribution	NOAA and International Partners
Federal Archive Data Sharing	Data sharing with federal archives such as NGDC and NODC and NSF-sponsored Rolling Deck to Repository program	NGDC NODC NSF

The Center for the Advancement of Population Assessment Methodology (CAPAM) hosted a technical workshop on Growth: theory, estimation, and application in fishery stock assessment models in La Jolla, CA, USA from November 3-7, 2014.	The primary goal of the workshop was to provide advice and guidance on practices for modeling growth in fishery assessments. The focus was on model specification, parameter estimation, and management consequences, and will not cover growth estimates for specific species. The 5-day forum included an interactive modeling session, keynote and research presentations, and focused discussions.	SIO, UC San Diego IATTC, SWFSC
	PI Semmens co-coordinated a special session at the International Marine Conservation Congress in Scotland entitled "End-to-end marine conservation: Case studies in successfully translating science into management action through communication and outreach" To bring together scientists from the UK, Europe, and the US, and share case studies in marine conservation science and communication.	SIO, Reef Environmental Education Foundation, Oregon State University
PI Semmens co-instructed a short-course in stable isotope tools and techniques at Estación Biológica de Doñana (CSIC), Sevilla, Spain	To train international graduate students in quantitative techniques associated with stable isotope analysis.	SCIC, SIO
Graduate student Lynn Waterhouse continued to be a SIO representative for the Graduate Student Association (GSA)	To advocate the rights and interests of graduate students at UCSD.	UCSD Associated Students
Graduate student Lynn Waterhouse maintains role as secretary for the Estuaries Section of American Fisheries Society (AFS)	The Estuaries Section is dedicated to protecting, maintaining and enhancing the viability of the fisheries and other aquatic living resources dependent upon healthy estuaries.	AFS

Lynn Waterhouse served on diversity committee	Graduate student Lynn Waterhouse was a member of Search Committee, Vice Chancellor for Equity, Diversity, Inclusion at UC San Diego from Fall 2014 to January 2015 in order to advocate the rights and interests of diversity, inclusion, and equity amongst students at UCSD.	UCSD Associated Students
CO2 chemistry workshops	Variety of workshops and short courses where Dr. Dickson lectured and led discussion on CO2 chemistry	
Ocean Acidification short course	Dr. Dickson held a South American Ocean Acidification short course in Puerto Morelos, Mexico	
IOCCP workshop	Dr. Dickson and a IOCCP workshop in Kristineberg, Sweden that focused on best practices for using biogeochemical sensors.	IOCCP

Academic Development

ACTIVITY	OBJECTIVE	PARTNERS
Fisheries Biology training	Train undergraduate and graduate students in Fisheries Biology. Teach the following coerces: Fish Conservation and Management (31 students), Advanced Fish Conservation and Management (28 students), Biology of Pacific Salmon Graduate Seminar (25 students). Primary research advisor for 5 graduate students. Serve on graduate committees for 7 graduate students.	Humboldt State University
Hands-on graduate workshop with Holly Kindsvater	Hands-on workshops introducing graduate students to the philosophical and practical approaches to statistical analysis in the R programming language.	
Quantitative fisheries science at the SWFSC	Kate Richerson attended series of lectures on quantitative fisheries science at the SWFSC given by Dr. Mangel	
Graduate Advisor	Dr. Eric Palkovacs served as primary advisor for 4 graduate students and committee member for 5 additional students	
Mentor early career scientists	Dr. Arthur J. Miller and Dr. Aneesh Subramanian served as mentors to early career scientists.	Mr. Jonathan Eliashiv, Ph.D. student, SIO
	Developed PPP (Precise Point Positioning) based real-time tropospheric delay estimation procedure as a part of hazard early warning system. Provide ongoing scientific and technical consultations to scientists and graduate students from USA as well as worldwide.	
	SIO's High Resolution XBT Network provides a primary data set for Ph.D. thesis of SIO graduate students	NSF
Partnership with WHOI researchers	To further examine radial Metrics	Woods Hole Oceanographic Institution
Data Center Operations training	Train undergraduate research assistants in under-the-hood operations of a data center and website via real-world experience with ongoing CCHDO activities	CCHDO
Brice Semmens taught a graduate level Introduction to	This 4-credit course introduces many key models used in the analysis of distribution, abundance	SIO, UC San Diego

Bayesian Population Analysis course	and survival, as well as their spatial and temporal patterns, in a Bayesian analysis framework.	
Brice Semmens taught undergraduate Statistical Methods in Marine Biology course	This 4-credit course introduces marine biology students to statistical inference. Emphasis is on constructing statistics for specific problems in marine biology. Topics include probability, distributions, sampling, replication, and experimental design.	SIO, UC San Diego
Independent marine mammal observer on the 3rd leg of the California Current Cetacean and Ecosystem Assessment Survey (CalCurCEAS) October-November 2015.	Allow Postdoc Charlotte Boyd to participate in data collection associated with the larger data set used to generate modeling tools associated with cetacean movement and behavior	SWFSC
Graduate student Brian Stock started his second year of PhD coursework and passed his first year Marine Biology examination.	The goal of second-year coursework is to establish a strong educational foundation in the marine sciences during the beginning of a marine biology PhD.	SIO, UCSD
Graduate student Brian Stock trained as motorboat operator	Motorboat operator training and certification is required for students to safely and effectively use small boats during fieldwork.	SIO, UCSD
Graduate students Lynn Waterhouse, Josh Stewart, Lyall Bellquist, Noah Ben-Aderet and Brian Stock attended CAPAM's Growth	Introduce students to modern statistical models used in fisheries stock assessment and natural resource modeling, providing instruction, demonstration, and exercises in Growth: theory, estimation, and application.	CAPAM, SIO, SWFSC, IATTC
Graduate student Brian Stock and Lynn Waterhouse took an online course in numerical computing for natural resource management (FISH559 offered by Andre Punt)	Take advantage of distributed learning opportunities in graduate-level quantitative tools and techniques.	SIO, University of Washington, Oregon State University
	One Graduate Student was supported by Meridional Overturning Variability Experiment (MOVE)	
Graduate Student Support	Erick Palkovacs' support of graduate education and research encompassed 3PhD students and 2 MS students.	UC Santa Cruz Humboldt State University Moss Landing Marine

		Labs
Professional Development Support	Eric Palkovacs' support of professional development encompassed 1 postdoctoral scholar and 2 graduate MS students.	UC Santa Cruz UC Berkeley Moss Landing Marine Labs
Graduate Student Support	The CCE project supports Ph.D. students C. Nickels and S. Wilson, who are benefitting from this interdisciplinary training. Several other graduate students have participated in mooring services cruises.	
Pacific Island Global Ocean Observing System (PI-GOOS) Advisory Committee	Assist Pacific island nations in gaining benefit from global ocean observations and products.	South Pacific Regional Environmental Program (SPREP), NOAA, BoM Australia, NIWA New Zealand, Intergovernmental Oceanographic Commission, South Pacific nations
Pacific Anomalies Workshop	D. Rudnick was part of the group that initiated the Pacific Anomalies workshop in May.	
La Jolla Warm Anomaly Workshop	CORC team members were authors/co-authors on presentations at the La Jolla Warm Anomaly workshop	
National Glider Network development	D. Rudnck continues to be involved in efforts to create a national glider network, including participation in a webinar on gliders in the Gulf of Mexico, and the review of the national glider DAC.	
Students supported by CORC	1 postdoc and 2 graduate students were partially supported by CORC	

Honors and Awards

AWARD	RECIPIENT	YEAR
Grant from Sloan Foundation for rOpenSci	Karthik Ram Carl Boettiger Scott Chamberlain Ted Hart	2014-2015
2013 SWFSC Team Member of the Year Award	Melissa Monk	2014
NSF GROW	Juan Lopez Arriaza	2014-2015
Doctor of Science *honoris causa*, University of Guelph	Marc Mangel	June 2014
AAAS Fellow	Mark Ohman	2015
AGU Fellow	Ralph Keeling	2014
Highly cited researcher 2014, Thomson Reuters	Shang-Ping Xie	2014
NSF Graduate Research Fellowship	Josh Stewart	2012-2015
NMFS/Sea Grant Population Dynamics Fellowship	Lynn Waterhouse	2013-2016
NSF Graduate Research Fellowship	Brian Stock	2014-2018
Jeff Graham Marine Biology Fellowship	Lyall Bellquist	2014-2015
Nancy Foster Fellowship NMFS	Josh Stewart	2015-2018
NMFS/Sea Grant Population Dynamics Fellowship	Brian Stock	2014 (declined)
NSF GK-12 Fellowship	Lynn Waterhouse	2013-2014
American Institute of Fishery Research Biologists (AIFRB) Clark Hubbs Research Assistance Award	Lynn Waterhouse	2014
Switzer Fellowship	Josh Stewart	2015
Best Student Presentations, WDAFS	Alicia Abadia-Cardoso	2014
UCSC Hellman Fellowship	Eric Palkovacs	2015

REPRESENTING CIMEC

CONFERENCE NAME	DATES/LOCATION	REPRESENTATIVES
Invited Seminar	12 November 2014 University of the Pacific	Santiago Salinas
Invited Seminar	6 November 2014 Kalamazoo College	Santiago Salinas
Society Study of Evolution/American Society of Naturalists Joint Meeting	24-28 June 2014 Raleigh, NC	Holly Kindsvater
International Marine Conservation Congress	12-18 August 2014 Glasgow, Scotland	Holly Kindsvater
University of Alaska	20 November 2014 Anchorage, AK	Holly Kindsvater
NOAA NWFSC Monster JAM	12 February 2015 Seattle, WA	Holly Kindsvater
Zoology Seminar, University of Wisconsin	April 2014 Madison, WI	Carl Boettiger
DIMACS Global Change Biology	May 2014 Berkeley, CA	Carl Boettiger
Ecological Society of America	August 2014 Sacramento, CA	Carl Boettiger
Berkeley Institute for Global Change Biology (BiGCB)	October 2014 Berkeley, CA	Carl Boettiger
WSSSPE 2.0 NSF Workshop for Sustainable Software	November 2014 New Orleans, LA	Carl Boettiger
Reproducible Research Curriculum Working Group	December 2014 Durham, NC	Carl Boettiger
PDG Control working group, NIMBIOS	January 2015 Knoxville, TN	Carl Boettiger
NCEAS Scientific Advisers Meeting	February 2015 Santa Barbara, CA	Carl Boettiger
rOpenSci Unconference	March 2015 San Francisco, CA	Carl Boettiger
International Statistical Ecology Conference	July 2014 Montpelier, France	Melissa Hedges Monk

North Pacific Marine Science Organization	October 2014 Yesou, Korea	Jarrod Santora
Pacific Seabird Group	February 2014 San Jose, CA	Jarrod Santora
Western Regional Science Association	15-18 February 2015 Tucson, AZ	Duran Fiack
International Society for Bayesian Analysis World Meeting	14-18 July 2014 Cancun, Mexico	Valerie Poynbor
Institute Seminars, Inland Fisheries Research Institute, National Fisheries Research and Development Institute, Korea	10 July 2014 Chongpyong, Korea	Who-Seung Lee
Seminar, Department of Biology, Kyung Hee University	11 July 2014 Seoul, Korea	Who-Seung Lee
Seminar, Department of Biology, EWHA WOMAN University	14 July 2014 Seoul, Korea	Who-Seung Lee
Seminar, Department of Biology, Busan National University	16 July 2014 Daegu, Korea	Who-Seung Lee
Ecotoxicology Group Seminar, Department of Biology, Chonnam National University	22 July 2014 Yeous, Korea	Who-Seung Lee
Southern Steelhead Research and Monitoring Colloquium	4-5 November 2014 Santa Barbara, CA	Juan Lopez
Two seminars, Department of Zoology	5 May 2014 University of Oxford	Marc Mangel
Seminar, Department of Mathematics/Biostatistics	28 May 2014 University of Bergen	Marc Mangel
Hjort Center Lecture	28 May 2014 University of Bergen	Marc Mangel
Seminar, Department of Environmental Sciences	12 June 2014 University of Guelph	Marc Mangel
Two seminars, School of Marine Sciences	17, 18 November 2014 Rutgers University	Marc Mangel
Bevan Lecture	15 January 2015 University of Washington	Marc Mangel
Public Lecture, Seymoure Marine Discovery Center	18 January 2015 Santa Cruz, CA	Marc Mangel

Invited Talk, UC-wide meeting on Food from the Sea	18 February 2015 UC Santa Barbara	Marc Mangel
Semina, Department of Statistics and Biostatistics	4 March 2015 UC San Francisco	Marc Mangel
Seminar, Department of Environmental Science, Policy, and Management	20 March 2015 UC Berkeley	Marc Mangel
Cal-Neva AFS	2015 Santa Cruz, CA	Dr. Eric Palkovacs
Tidewater goby recovery workshop	2014 Santa Cruz, CA	Dr. Eric Palkovacs
Southern steelhead workshop	2014 Santa Cruz, CA	Dr. Eric Palkovacs
McGill University seminar	2015 Montreal, Canada	Dr. Eric Palkovacs
UC Berkeley seminar	2015 Berkeley, CA	Dr. Eric Palkovacs
NSF long-term research workshop	2015 Kellogg Biological Station, Hickory Corners, Mi	Dr. Eric Palkovacs
Oceanoise 2015	11-15 May 2015 Vilanova i la Geltru, Spain	Ana Širović
International Argo Data Management Team Meeting	October 2014 Ottawa, Canada	John Gilson Megan Scanderbeg
International Argo Steering Team Meeting	March 2015 Brest, France	Dean Roemmich Megan Scanderbeg Nathalie Zilberman
Ocean Surface Topography Science Team Meeting	October 2014 Lake Constance, Germany	Nathalie Zilberman Dean Roemmich
Winter Conference on Applications of Computer Vision (WACV)	6-9 January 2015 Kona, HI	Oscar Deijbom David Kriegman
NOAA Fisheries Strategic Initiative on Automated Image Analysis	10-11 January 2015 Kona, HI	David Kriegman Oscar Beijbom
CLIVAR SSC Meeting	11-13 March 2015 Washington, D.C.	Art Miller

2014 AGU Fall	18 December 2014 San Francisco, CA	Angelyn W. Moore
Gordon Research Conference	1 July 2014 Waterville Valley, NH	Mark Ohman
CalCOFI Conference	8 December 2014 La Jolla, CA	Steven Bograd Dave Checkley John Field Tony Koslow Selina Heppell Sam McClatchie John McGowan Lindsey Sala Bill Sydeman …and others
2nd Seafloor Observatory Conference	7-10 November 2014 Xiamen, China	Mark Ohman
S California Marine Mammal Workshop	31 January 2015 Newport Beach, CA	Mark Ohman
ASLO Annual Meeting	23 February 2015 Granda, Spain	Mark Ohman George Sugihara
Institute for Systems Biology International Symposium	1 April 2015 Seattle WA	George Sugihara
Ecological Society of America Annual Meeting	1 August 2014 Sacramento, CA	George Sugihara
PICES Conference	10 October 2014 Yeosu, Korea	Tony Koslow Dave Checkley
IMBER symposium	1 June 2014 Bergen, Norway	Tony Koslow
3rd International Large Marine Ecosystems Conference	1 October 2014 Swakopmund, Namibia	Tony Koslow
California Fish and Game Commission	16 April 2014 Ventura, CA	Dave Checkley
NASA Ocean Color research team meeting	5 May 2014 Silver Springs, MD	Mati Kahru Greg Mitchell
Western States Water Council	June 2014	Marty Ralph
CA Water Policy Conference	March 2015 Claremont, CA	Marty Ralph

AMS Annual Meeting	January 2015 Phoenix, AZ	Marty Ralph
Bay Area Flood Protection Association	February 2015 Oakland, CA	Marty Ralph
AGU Fall Meeting 2014	December 2014 San Francisco, CA	Marty Ralph
CalWater2 Media Day	January 2015 San Diego, CA	Marty Ralph
Oceans '14 MTS/IEEE and Group on Earth Observations (GEO)	7-10 April 2014 Taipei, Taiwan	L. Hazard M. Otero
IOOS HR Radar Steering Team	24-25 July 2014 Boulder, CO	L. Hazard (remotely) T. Cook (remotely)
EuroGOOS Meeting	28-30 October 2014 Lisbon, Portugal	E. Terrill
OSPR-Chevron Response Technology Workshop	24-26 February 2015	L. Hazard (prepared)
39th Annual Climate Diagnostics and Prediction Workshop	20-23 October 2014 St. Louis, MO	Nathaniel Johnson
2014 AGU Fall Meeting	15-19 December 2014 San Francisco, CA	Shang-Ping Xie Nathaniel Johnson
95th AMS Annual Meeting	4-8 January 2015 Phoenix, AZ	Shang-Ping Xie Nathaniel Johnson Michelle L'Heureux
New Frontiers of Altimetry Meeting	29-31 October 2014 Lake Constance, Germany	
European Geosciences Meeting	April 2014 Vienna, Austria	F. Gasparin
Argo Steering Team Meeting	March 2015 Brest, France	D. Roemmich N. Zilberman F. Gasparin
Euro-Argo User Workshop	March 2015 Brest, France	F. Gasparin
Surface Drifter Technology and Examples of Lagrangian Experiments Planning. Fifth In-Region Western Indian Ocean Capacity Building Workshop	12-15 May 2014 Port Elizabeth, South Africa	

Sea Surface Salinity under rain cells: SMOS satellite and in-situ drifters observations, Earth Observation for Ocean-Atmosphere Interactions Science 2014 Conference - Responding to the new scientific challenges of SOLAS, Jointly organized by ESA, SOLAS and EGU	28-31 October 2014 Frascati, Italy	J. Boutin N. Martin G. Reverdin S. Morisset X. Lin L. Centurioni N. Reul
2013: From Monsoons to Mixing: the Multi-scale Mosaic of Air-Sea Interactions in the Bay of Bengal, *EOS*,		A.J. Lucas E.L. Shroyer H.W. Wijesekera H.J.S. Fernando E. D'Asaro M. Ravichandran S.U.P. Jinadasa J.A. MacKinnon J.D. Nash R. Sharma L. Centurioni J.T. Farrar R. Weller R. Pinkel A. Mahadevan D. Sengupta A. Tandon
Mesoscale contribution to salinity transport in the North Atlantic subtropics (2011-2013), Geophysical Research Abstracts, Vol. 16, EGU2014-7442, 2014	EGU General Assembly 2014	G. Reverdin J. Boutin L. Centurioni B. Hormann N. Kolodziejczyk J. Font J. Salvador A. Sommer N. Martian S. Morisset
On the upwelling dynamics off northwest Africa in 2009-2012, Geophysical Research Abstracts, Vol. 16, EGU2014-13018, 2014	EGU General Assembly 2014.	M. Menna P.M. Poulain S. Faye B. Diaw L. Centurioni A. Lazar A. Gaye B.A. Sow D. Dragone

Coastlab 2104 - Optimal siting for marine renewables energy installations along the California coast using a marine spatial planning approach	29 September – 2 October 2014 Varna, Bulgaria	C. Lanfredi A. Azzellino L. Centurioni
Coastlab 2014 - The role of spectral wave components, bandwidth and wave grouping on runup: Preliminary results from Large-scale experiments	29 September – 2 October 2014 Varna, Bulgaria	L. Riefolo P. Contestabile L. Centurioni D. Vicinanza
Coastlab 2014 - Wave energy potential along the coast of Ischia Island (South Italy)	29 September – 2 October 2014 Varna, Bulgaria	V. Ferrante M. Polette D. Vicinanza L. Centurioni
Sea Surface Salinity under rain cells: SMOS satellite and in-situ drifters observations, Earth Observation for Ocean-Atmosphere Interactions Science 2014 Conference - Responding to the new scientific challenges of SOLAS, Jointly organized by ESA, SOLAS and EGU	28-31 October 2014 European Space Agency Frascati, Italy	J. Boutin N. Martin G. Reverdin S. Morisset X. Yin L. Centurioni N. Reul
Principles of Lagrangian Data Analysis and Examples of Scientific Interpretation of Surface Drifter Data. Fifth In-Region Western Indian Ocean Capacity Building Workshop	12-15 May 2014 Port Elizabeth, South Africa	
2014 Ocean Surface Topography Science Team Meeting - New mean dynamic ocean topography, derived from a synthesis of satellite altimeter, gravity, and scatterometer data and trajectories of Lagrangian drifters	28-31 October 2014 Lake Constance, Germany	N. Maximenko P. Knudsen L. Centurioni O. Anderson J. Hafner O. Melnichenko
Overview of the Global Drifter Program, Australian Bureau of Meteorology	25 February 2015 Melbourne, Australia	L. Centurioni
NOAA ESRL/GMD annual meeting	6-7 May 2014 Boulder, CO	Ralph Keeling Replandy
Scripps Cabinet Meeting	27 June 2014 Scripps Institution of Oceanography La Jolla, CA	Ralph Keeling
ICESOCC meeting at Scripps	22 Sep 2014 Scripps Institution of Oceanography La Jolla, CA	Ralph Keeling

Scripps AOS seminar series	23 October 2014 Scripps Institution of Oceanography La Jolla, CA	Ralph Keeling
Fall AGU meeting	14 December 2014 San Francisco, CA	Ralph Keeling
North American Carbon Program Annual Meeting	26 January 2014 Washington DC	Ralph Keeling
CalTech Southern Ocean meeting	26 January 2015 CalTech	Ralph Keeling
SUNY Albany research seminar	1 May 2015 Albany, NY	Ralph Keeling
NOAA ESRL/GMD annual meeting	19-20 May 2015 Boulder, CO	Resplandy
DIMES Meeting	14 November 2014 Exeter, UK	S. Diggs
Fall AGU	15 December 2014 San Francisco, CA	S. Diggs A. Bama
Argo/AST-16	19 March 2015 Brest, France	
Sonoma County Adaptation Forum	8 April 2015 Sonoma State University	F. Martin Ralph Julie Kalansky
Center for Western Weather and Water Extreme Seminar	19 May 2015 Scripps Institution of Oceanography	Julie Kalansky
Chapman Conference on Drought	20 April 2015 UC Irvine	Dan Cayan
AMS Annual Meeting	January 2015 Phoenix, AZ	Marty Ralph
Bay Area Flood Protection Association	February 2015 Oakland, CA	Marty Ralph
AGU Fall Meeting 2014	December 2014 San Francisco, CA	Marty Ralph
CalWater2 Media Day	January 2015 San Diego, CA	Marty Ralph

Eastern Pacific Ocean Conference	17-20 September 2014 Mt. Hood, OR	Christine Cass Eric Bjorkstedt
CalCOFI Annual Meeting	8-10 December 2014 La Jolla, CA	Eric Bjorkstedt
NOAA CalCOFI Genomics Project (NCOG): Microbial 'Omics in the Southern California Bight. California Cooperative Oceanic Fisheries Investigations Annual Conference	8-10 December 2014 La Jolla, CA	T. Konotchick A. Rabines H. Sheng S. Dovel M. Roadman K. Goodwin M. Bohan A. Thompson F. Werner R. Goericke
RAPIDD Marine Mammal Morbillivirus Workshop	5-6 August 2014 Princeton University	Tracey Goldstein
3rd International One Health Conference	15-18 March 2015 Amsterdam, The Netherlands	Tracey Goldstein
Winter Conference on Applications of Computer Vision (WACV)	6-9 January 2015 Kona, HI	Oscar Beijbom David Kriegman
NOAA Fisheries Strategic Initiative On Automated Image Analysis	10-11 January 2015 Kona, HI	Oscar Beijbom David Kriegman
Oceanoise 2015	11-15 May 2015 Barcelona, Spain	Ana Širović
Society for Environmental Toxicology and Chemistry (SETAC)	November 2014 Vancouver, BC, Canada	Andrew Whitehead Diane Nacci Rachel Struch
Western Society of Naturalists	November 2014 Seattle, WA	Andrew Whitehead Rachel Struch
Northern California Chapter of SETAC	April 2015 Sacramento, CA	Andrew Whitehead Rachel Struch
NOAA-SWFSC Monster Jam	22 January 2015 Seattle, WA	Mark Maunder
Regional expert workshop to test the draft criteria used in the identification of Important Marine Mammal Areas	November 2014 Adelaide, Australia	Charlotte Boyd

3rd International Marine Conservation Congress	August 2014 Glasgow, Scotland	Charlotte Boyd
Biology Seminar, San Diego State University	December 2014 San Diego, CA	Charlotte Boyd
A global standard to identity key biodiversity areas at the World Parks Congress	November 2014 Sydney, Australia	Charlotte Boyd
NOAA False Killer Whale Take Reduction Team Meeting	28 April 2015 Honolulu, HI	Victoria O'Connell
Ecological Society of America	August, 2014 Sacramento, CA	Brian Stock (Presenter)
Northwest Fisheries Science Center	August 29, 2014 Seattle, WA	Brian Stock (Presenter)
University of Alaska	April 15, 2014 Anchorage, AK	Brian Stock (Presenter)
Open Science for Synthesis, NCEAS	July 21 - Aug 8, 2014 Santa Barbara, CA	Brian Stock, Lynn Waterhouse (Attendees)
Seagrant/NOAA Fisheries Graduate Fellowships in Population Dynamics and Marine Resource Economics	June 15-18, 2014 Seattle, WA	Lynn Waterhouse
American Fisheries Society Annual Meeting	August 17-27, 2014 Quebec, Canada	Lynn Waterhouse (Attendee)
2014 Graybill/ENVR Conference	August 17-27, 2014 Quebec, Canada	Lynn Waterhouse (Attendee) Lynn Waterhouse (Attendee)
Fish 559- ADMB Workshop (at OSU, UW)	September 26-30, 2014 Newport, OR	Lynn Waterhouse, Brian Stock (Attendees)
CAPAM Growth Workshop	Nov 3-7, 2014 La Jolla, CA	Juan Valero (Instructor) Brian Semmens (Organizer), Lynn Waterhouse (Organizer), Lyall Bellquist, Brian Stock, Noah Ben-Aderet, Josh Stewart (Attendees)
SIO Donor Brunch	April 6, 2014 La Jolla, CA	Lyall Bellquist (Presenter)
3rd International Marine Conservation Congress (IMCC3)	August 4-18, 2014 Glasgow, Scotland	Brice Semmens (Presenter) Devon O'meara (Attendee)
IMBER Open Science Conference	June 23-27, 2014 Bergen, Norway	Josh Stewart (Presenter)

Implementing California's Marine Life Protection Act: A Collaborative Approach for a Sustainable Future	May 2014 Irvine, CA	Brice Semmens (Invited Speaker)
Ecology Seminar SIO	February 2015 La Jolla, CA	Brice Semmens (Presenter)
Quantitative Ecology Seminar SIO/SWFSC	March 11, 2015 La Jolla, CA	Brice Semmens (Presenter)
Fred Hall Fishing and Boat Show	March 11, 2015 Long Beach, CA	Lyall Bellquist (Presenter)
US AMOC meeting	September 2014 Seattle, WA	Uwe Send
16th Annual POGO meeting	27-29 January 2015 Santa Cruz de Tenerife, Spain	Uwe Send
OceanSITES 2014	November 2014 Recife, Brazil	Uwe Send Matthias Lankhorst
International Flatfish Symposium	November 2014, Cle Elum, WA	Lyndsey Lefebvre
American Fisheries Society Annual Meeting	August 2014, Quebec City, QC, Canada	Michael O'Farrell, Susan Sogard, Elizabeth Gilbert-Horvath
California Coastal Chinook salmon fishery management: future prospects workshop	September 2014, Santa Rosa, CA	Michael Mohr, Michael O'Farrell, Will Satterthwaite, Allen Grover, Shanae Allen-Moran
Salmonid Restoration Federation	March 2015, Santa Rosa, CA	Joe Kiernan, Sean Hayes, Devon Pearse, Elizabeth Gilbert-Horvath, Rachel Johnson
Salmon Ocean Ecology Meeting	March 2015, Victoria, BC	Sean Hayes, Megan Sabal
Bay Delta Science Conference	Oct 2014, Sacramento, CA	Sean Hayes, Megan Sabal, Cyril Michel, Jeremy Notch, David Demer, Anthony Clemento, John Carlos Garza, Rachel Johnson, Doug Jackson, Flora Cordoleani, Coleen Petrik
IEP Science Conference	March 2015, Folsom, CA	Sean Hayes, Joe Smith, Megan Sabal, David Demer, Eric Danner, Doug Jackson, Flora Cordoleani, Coleen Petrik

NPAFC Salmon and Climate Change	May 2015, Osaka, Japan	Steve Lindley, David Huff, Sean Hayes
NASA Applied Sciences Meeting	May 2014, Washington D.C.	Eric Danner
American Fisheries Society - Cal-Neva	April 2015, Santa Cruz, CA	Rachel Johnson, Flora Cordoleani
North Pacific Marine Science Organization (PICES)	October 2014, Yeosu, South Korea	John Field
Gordon Research Conference	July 2014, Waterville Valley, NH	Mark Ohman
2nd Seafloor Observing Symposium	November 2014, Xiamen, China	Mark Ohman
Seminar at NOAA HQ	November 2014, Silver Spring	U.Send, M.Ohman, D.Demer
CalCOFI Conference	December 2014, La Jolla, CA	M. Ohman, U. Send, D. Rudnick, D. Demer, T. Martz, R. Feely
POGO meeting	January 2015, Tenerife	Uwe Send
Southern California Marine Mammal Workshop	January 2015, Newport Beach, CA	Mark Ohman
ASLO Meeting	February 2015, Granada, Spain	N. Bednaršek and M. Ohman
OceanSITES meeting	November 2014, Recife	Uwe Send
Ocean University of China	April 2015, Qingdao	Mark Ohman
NSF OA PI meeting	June 2015, WHOI	Uwe Send
New Frontiers of Altimetry Meeting	October 2014, Lake Constance, Germany	N. Zilberman, D. Roemmich, S. Gille
Pacific Anomalies Workshop	May 2015, La Jolla	D.Rudnick, U.Send, K.Zaba
COD Annual Meeting	June 2015, College Park	U.Send, D.Roemmich, D.Rudnick
Blue Planet Symposium	MAY 2014, CAIRNS AUSTRALOA	U.Send
OceanSITES meeting	NOVEMBER 2014, RECIFE	U.Send

CIMEC PARTNERS AND COLLABORATORS

Interagency

Environmental Protection Agency (EPA)
National Health and Environmental Effects Research Laboratory (NHEERL)
National Aeronautics and Space Administration (NASA)
Jet Propulsion Laboratory (JPL)
National Oceanic and Atmospheric Administration (NOAA)
- National Centers for Environmental Information (NCEI) - formerly NODC
- National Marine Fisheries Service (NMFS)
  - International Science Strategy (ISS)
  - Northeast Fisheries Science Center (NEFSC)
  - Northwest Fisheries Science Center (NWFSC)
  - Office of Protected Resources (OPR)
  - Southeast Fisheries Science Center (SEFSC)
  - Southwest Fisheries Science Center (SWFSC)
- National Ocean Service (NOS)
  - Center for Operational Oceanographic Products and Services (CO-OPS)
  - Office of Response and Restoration (OR&R)
    - Assessment and Restoration Division (ARD)
- Emergency Response Division (ERD)
  - National Weather Service (NWS)
- National Data Buoy Center (NDBC)
- Oceanic & Atmospheric Research (OAR)
  - Atlantic Oceanographic and Meteorological Laboratory (AOML)
  - Climate Program Office (CPO)
  - Earth System Research Laboratory (ESRL)
    - Global Monitoring Division (GMD)
  - Geophysical and Fluid Dynamics Laboratory (GFDL)
  - Pacific Marine Environmental Laboratory (PMEL)

National Science Foundation (NSF)
- National Center for Atmospheric Research (NCAR)

US Bureau of Reclamation
US Coast Guard
US Fish and Wildlife Service
US Geological Survey (USGS)
- Conte Anadromous Fish Laboratory (CAFB)

United States Navy
Naval Research laboratory, Monterey
Office of Naval Research (ONR)

Partnerships

Alaska Department of Fish and Game
Alaska Fisheries Science Center
AOML, NOAA
Argo: Woods Hole Oceanographic Institution
Australian Bureau of Meteorology
BCO-DMO (WHOI)
Bermuda Institute of Ocean Sciences
Bigelow Laboratory for Ocean Sciences
Bodega Marine Lab, UC Davis
BSH, Germany
California Department of Fish and Wildlife (CDFW)
California Department of Water Resources (CDWR)
California Polytechnic State University San Luis Obispo (CalPoly)
California State University, Long Beach (CSULB)
California State University, Monterey Bay (CSUMB)
California Trout (CT)
Carbon Dioxide Information and Analysis Center (CDIAC)
Catlin Seaview Survey, University of Brisbane, UQ
Center for Ecological and Evolutionary Synthesis (Oslo, Norway)
Center for Research into Ecological and Environmental Modeling, St. Andrews University, Scotland
Center for Stock Assessment Research (CSTAR)
Central Weather Bureau, Taipei, Taiwan
Centro Regional de Investigacion Pesquera, Instituto Nacional de la Pesca, Ensenada/La Paz, Mexico
Columbia River Intertribal Fish Commission (CRITFC)
Commonwealth Scientific and Industrial Research Organization (CSIRO)
Dalhousie University
Data Buoy Cooperation Panel
Earth to Ocean Research Group, Simon Fraser University
ECMWF
Environment Canada
Farallon Institute
Georgia Institute of Technology
Hoopa Tribal Fisheries Program
Hubbs-SeaWorld Research Institute (HSWRI)
Humboldt State University
Idaho Department of Fish and Game (IDFG)
IFREMER (France)
INCOIS (India)
INOCAR (Ecuadoran Navy)
Inter-American Tropical Tuna Commission (IATTC)
Investigaciones Mexicanas de la Corriente de California (IMECOCAL)
IOS (Canada)
IOS, Canada
J. Craig Venter Institute,

NOAA (SWFSC, AMOL, OER)
JAMSTEC (Japan)
JAMSTEC, Japan
Karuk Tribe Department of Natural Resources
Kenya Meteorological Office KMA,
Korea KORDI (Korea)
Leibniz Institute of Marine Sciences (IFM-GEOMAR)
Linneaus University (LU)
Los Angeles County Museum (LACM)
Manta Trust
Mid-Klamath Watershed Council
Misool Eco-Resort Conservation Center
Monterey Bay Aquarium Research Institute (MBARI)
Monterey Bay National Marine Sanctuaries
Monterey Bay Water District
Moss Landing Marine Laboratory (MLML)
Program National Oceanographic Center,
U.K. National Oceanographic Centre (U.K.)
National Marine Mammal Laboratory
National Science Foundation
National Sun Yat Sen University of Taiwan
National Taiwan University, Busan University
NCAR
NIWA (New Zealand)
Northwest Indian Fisheries Commission (NWIFC)
Office of Spill Prevention and Response (OSPR), California Department of Fish and Wildlife
Oregon Department of Fish and Wildlife (ODFW)
Oregon State University
Oregon State University (OSU), College of Oceanic and Atmospheric Sciences
Osservatorio Geofisico Sperimentale of Trieste
Pacific Blue Foundation
Pacific Islands Fisheries Science Center
Pacific States Marine Fisheries Commission
Pfleger Institute of Environmental Research (PIER)
Point Reyes Bird Observatory and Farallon Institute for Advanced Ecosystem
Remote Sensing Solutions
Research Politecnico di Milano
Polytechnic of Milan
Rosenstiel Schools of Marine and Atmospheric Science
Rutgers University, Coastal Ocean Observation Lab (COOL)
Sacramento-Yolo Mosquito and Vector Control District
San Diego Oceans Foundation (SDOF)
San Francisco State University (SFSU)
Santa Cruz Mosquito and Vector Control District
Scripps Institution of Oceanography, University of California San Diego
Second Institute of Oceanography (China)
Second Institute of Oceanography, China

Seymour Marine Discovery Center
SHN, Argentina
SHOA, Chile
Sierra Nevada Aquatic Research Laboratory
Sitka Sound Science Center, Sitka, AK
Sonoma County Water Agency
Sonoma County Water Agency (SCWA)
Southeast Fisheries Science Center
Southern California Coastal Ocean Observing System (SCCOOS)
Southwest Fisheries Science Center (SWFSC)
Spatial Ecosystems,
Olympia, WA
Sportfishing Association of California (SAC)
Tenera Environmental, California
Texas A&M University (TAMU)
Tohoku University-Japan
Trinity College Dublin
UK Met Office
University of Hawaii
University Of Naples
University Of Porto
University of Washington
Universidad Autonomo de Baja California Sur (UABS)
Universita' Politecnica delle Marche
University College Dublin
University of Alaska, Fairbanks
University of Auckland (New Zealand)
University of California, Berkeley
University of California, Davis
University of California, Los Angeles (UCLA)
University of California, Santa Barbara (UCSB), Institute for Computational Earth System Science (ICESS)
University of California, Santa Cruz (UCSC)
University of Delaware University of Hawaii
University of Honolulu
University of Maine (UMA)
University of Massachusetts-Amherst
University of Miami (UM)
University of Miami, Miami, FL (UM)
University of Southern California (USC)
University of Southern Mississippi (USM)
University of Victoria (Canada)
University of Washington
University of Washington
University of Washington
US Antarctic Research Program (USARP)
Washington Department of Fish and Wildlife (WDFW)
Western Washington University

Woods Hole Oceanographic Institution
World Meteorological Organization
Younger Lagoon UC Reserve

Collaborators

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Brian Wells NOAA/NMFS
Brice Semmens, Scripps Institution of Oceanography

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David Hankin, Humboldt State University
David Huff, UC Santa Cruz
David Sampson, Oregon State University
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Demetri Dokos, Sacramento-Yolo Mosquito and Vector Control District
Donald L. Phillips, National Health & Environmental Effects Research Laboratory, Environmental Protection Agency
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Dr. Diego Vicinanaza, Univ Naples
Dr. Eric D,ÄôAsaro, UW
Dr. Gage Dayton, Younger Lagoon UC Reserve
Dr. George Voulgaris, University of Maine
Dr. Gille Reverdin, Unversity of Paris
Dr. Gokhan Danabasoglu
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Dr. Harvey Seim, University of North Carolina
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Dr. Jonathon Rutz, University of Utah
Dr. Josh Kohut, Rutgers University
Dr. Kenneth Laws, UC Santa Cruz
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	PUBLICATION SUMMARY														
	CIMEC Lead Author					NOAA Lead Author					Other Lead Author				
	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015
Peer Reviewed	22	30	76	89	60	24	6	38	15	42	11	38	40	69	45
Non Peer Reviewed	19	9	29	23	12	14	8	10	5	20	7	14	13	10	7
Total Publications	41	39	105	112	72	38	14	48	25	62	18	52	53	79	52

ACRONYMS

AMLR	Antarctic Marine Living Resources Program
AOML	NOAA/Atlantic Oceanographic and Meteorological Lab
BAS	Birch Aquarium at Scripps
BML	Bodega Marine Laboratory, UC Davis
CA COSEE	California Center for Ocean Science Excellence in Education
CalIT	California Institute of Technology
Cal State	California State University system
Caltrans	California Department of Transportation
CAP	California Applications Program
CBNMS	Cordell Banks National Marine Sanctuary
CCMA	Center for Coastal Monitoring and Assessment
CDFG	California Department of Fish and Game
CEC	California Energy Commission
CEFA	Climate, Ecosystem and Fire Applications
CeNCOOS	Central and Northern California Ocean Observing System
CEOP	Coordinated Enhanced Observing Period
ChESS	Biogeography of Deep-Water Chemosynthetic Ecosystems / Census of Marine Life
CICAR	Cooperative Institute for Climate Applications and Research, Palisades, New York
CICOR	Cooperative Institute for Climate and Ocean Research, Woods Hole, Massachusetts
CICS	Cooperative Institute for Climate Science, Princeton, New Jersey
CIFAR	Cooperative Institute for Arctic Research, Fairbanks, Alaska
CILER	Cooperative Institute for Limnology and Ecosystems Research, Ann Arbor, Michigan
CIMAS	Cooperative Institute for Marine and Atmospheric Studies, Miami, Florida
CIMMS	Cooperative Institute for Mesoscale Meteorological Studies, Norman, Oklahoma
CIMRS	Cooperative Institute for Marine Resource Studies
CIMSS	Cooperative Institute for Meteorological Satellite Studies, University

	of Wisconsin, Madison
CIOSS	Cooperative Institute for Oceanographic Satellite Studies
CIRA	Cooperative Institute for Research in the Atmosphere
CIRES	Cooperative Institute for Research in Environmental Sciences
CLIMAS	Climate Assessment for the Southwest
CLSA	California Land Surveyors Association
CMER	Cooperative Marine Education and Research
CNES	Centre National d'Etudes Spatiales
COML	Census of Marine Life
COP	NOAA/NOS/Center for Sponsored Coastal Ocean Research/Coastal Ocean Program
CPO	NOAA/Climate Programs Office (formerly, Office of Global Programs (OGP))
CRIP	Centro Regional de Investigacion Pesquera, Instituto Nacional de la Pesca, Ensenada/La Paz, Mexico
CRTN	California Real Time Network
CSIRO	Commonwealth Scientific and Industrial Research Organisation--Australia
CSRC	California Spatial Reference Center
CTD	Conductivity Temperature and Depth (as in, Underway CTD)
DBCP	Data Buoy Cooperation Panel, WMO-IOC
DOE	U.S. Department of Energy
DWR	California Department of Water Resources
ECCO	SIO's Estimating the Circulation and Climate of Oceans Consortium
ENSO	El Niño and Southern Oscillation
ESRL	NOAA/Earth System Research Laboratory
FKNMS	NOAA/Florida Keys National Marine Sanctuary
GACC	Geographic Area Coordination Centers
GEOSS	Global Earth Observation System of Systems
GEWEX	Global Energy and Water-cycle Experiment
GIS	Geographic Information Systems
GMD	NOAA/ESRL/Global Monitoring Division
GODAE	Global Ocean Data Assimilation Experiment
GPS	Global Positioning System

GSD	NOAA/ESRL/Global Systems Division
GTS	GNU Triangulated Surface
HRC	Hydrologic Research Center, San Diego, CA
HRX	Repeat high resolution expendable Bathythermograph
ICARTT	International Consortium for Atmospheric Research on Transport and Transformation
IOC	Intergovernmental Oceanographic Commission
IOOS	Integrated and Sustained Ocean Observations
IRD	Institut de Recherche pour le Développement
IRI	International Research Institute for Climate Prediction
JCOMM	Joint WMO-10C Technical Commission for Oceanography and Marine Meteorology
JIMAR	Joint Institute for Marine and Atmospheric Research
JIMO	Joint Institute for Marine Observations
JISAO	Joint Institute for the Study of Atmosphere and Ocean
JPL	Jet Propulsion Laboratory, NASA
MBARI	Monterey Bay Aquarium Research Institute
MIT	Massachusetts Institute of Technology, Harvard
MPI	Max Planck Institute, Germany
MPL	Marine Physical Laboratory, SIO, UCSD
NASA	National Aeronautics and Space Administration
NDBC	NOAA/NWS/National Data Buoy Center
NCAR	National Center for Atmospheric Research
NCCOS	National Centers for Coastal Ocean Science
NCEP	NOAA/National Centers for Environmental Predictions
NEFSC	NOAA/Northeast Fisheries Science Center
NESDIS	NOAA/National Environmental Satellite, Data, and Information Services
NGI	Northern Gulf Institute
NGS	NOAA/National Geodetic Survey
NIWA	National Institute of Water and Atmospheric Research, New Zealand
NMFS	NOAA/National Marine Fisheries Service
NMSP	National Marine Sanctuary Program

NOS	NOAA/National Ocean Service
NSF	National Science Foundation
NWFSC	NOAA/Northwest Fisheries Science Center, NMFS
NWS	NOAA/National Weather Service
OAP	NOAA/Ocean Assessment Program
OAR	NOAA/Ocean and Atmospheric Research
OE	NOAA/Office of Ocean Exploration
OGCM	Oceanic General Circulation Model
OGP	See CPO
ONR	Office of Naval Research
ORA	NOAA/Office of Research and Applications
PDO	Pacific Decadal Oscillation
PFEG	NOAA/NMFS/Pacific Fisheries Environmental Group
PIFSC	NOAA/NMFS/Pacific Islands Fisheries Science Center
PMEL	NOAA/Pacific Marine Environment Lab
R/V	Research Vessel
ROWG	Radio Operators Working Group
SAS	Simplified Arakawa-Schubert cumulus convection scheme
SCCWRP	Southern California Coastal Water Research Project
SDG&E	San Diego Gas & Electric
SEFSC	NOAA/Southeast Fisheries Science Center, Panama City, FL
SIO	Scripps Institution of Oceanography, UCSD
SOPAC	Scripps Orbit and Permanent Array Center
SST	Sea surface temperature
SVP	Surface Velocity Program
SWFSC	NOAA/Southwest Fisheries Science Center, NMFS
UC	University of California
UCD	University of California, Davis
UCLA	University of California, Los Angeles
UCSB	University of California, Santa Barbara
UCSC	University of California, Santa Cruz
UCSD	University of California, San Diego

UNAM	Universidad Nacional Autonoma de Mexico
USARP	U.S. Antarctic Research Program
USC	University of Southern California
USFS	U.S. Fire Service
USGS	U.S. Geological Survey
UW	University of Washington, Seattle
VAdm	Vice Admiral
VOS	Voluntary Observing Ship
WECC	Western Electricity Coordinating Council
WHOI	Woods Hole Oceanographic Institution
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment
XBT	Expendable Bathythermograph
XCTD	Expendable Conductivity Temperature and Depth

Credits

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