CIMEC

Cooperative Institute for Marine Ecosystems and Climate

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

PROGRESS REPORT

2012-2013

Cooperative Institute for Marine Ecosystems and Climate

Progress Report
Prepared for the
National Oceanic and Atmospheric Administration
NOAA NA10OAR4320156
2012-2013

CIMEC

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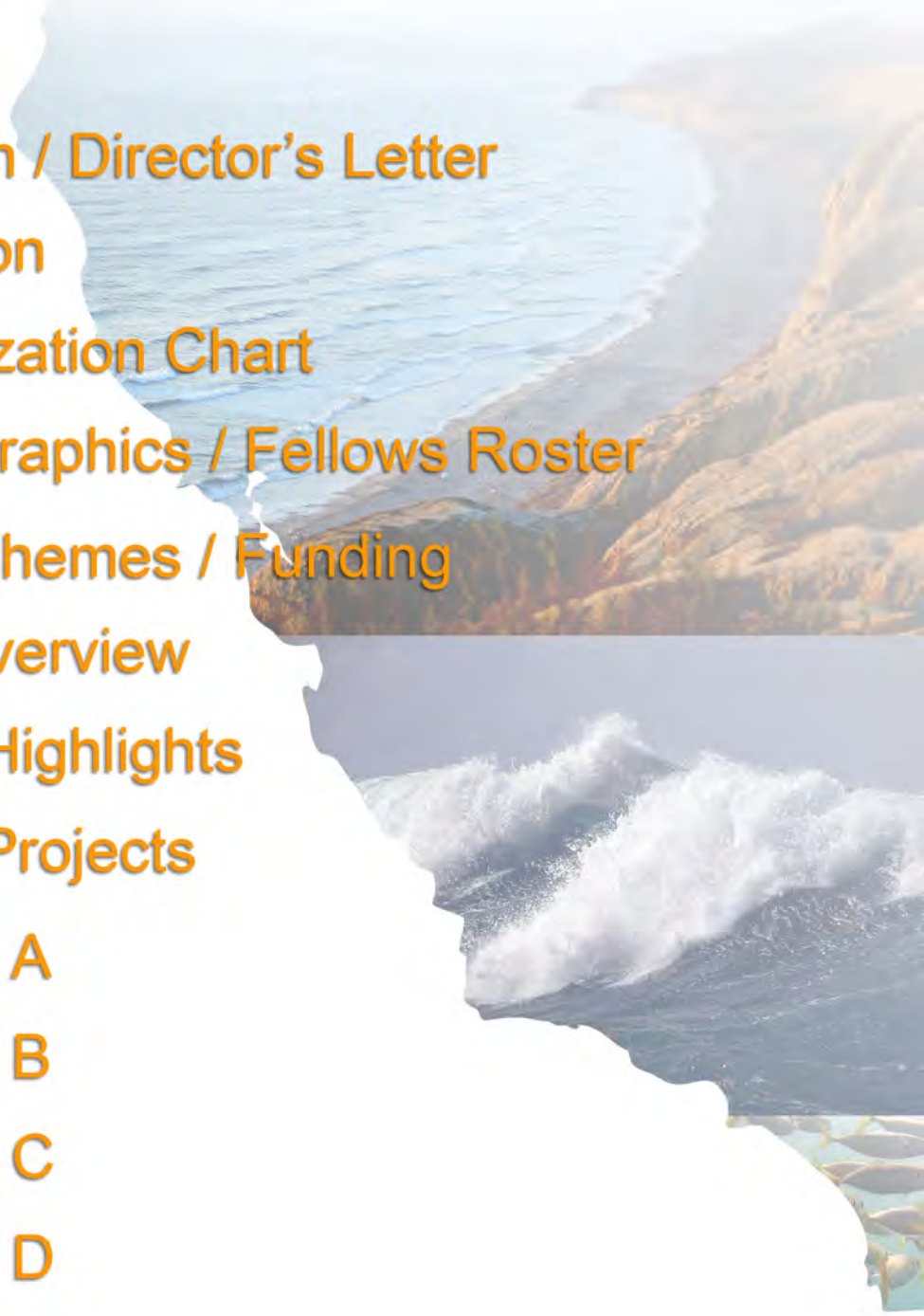

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INTRODUCTION

The Cooperative Institute for Marine Ecosystems and Climate (CIMEC) research and program activities for the first year (2012-2013) 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 (UCSD) 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, 2012 to March 31, 2013 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:

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

DIRECTOR'S LETTER

The Cooperative Institute of Marine Ecosystems and Climate continues to serve NOAA and the Nation through research and observing conducted 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 the training the next generation of scientists. Since its start on July 1, 2010 until March 31, 2013, CIMEC has received more than $36 million dollars from NOAA. CIMEC is proud to contribute valuably to NOAA's mission.

CIMEC continues to be active is a wide variety of areas of concern to NOAA. Fisheries research and training occurs at the UCSC, UCSD, and HSU. The Center for Stock Assessment Research has been joined by the Center for the Advancement of Population Methodology to contribute to NOAA's needs in fisheries management. The California Cooperative Oceanic Fisheries Investigations remains the longest physical/biological 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. The Argo Project characterizes the state of the upper ocean. Deep Argo floats were successfully tested. Standard Argo floats measure temperature in the upper two kilometers of the ocean. A complete energy budget requires temperature measurements to full ocean depth. Deep Argo will measure temperature and salinity to six kilometers, enabling assessment of the heat and freshwater content of the ocean. The Consortium on the Ocean's Role in Climate is designing and implementing boundary current observing systems. Two moorings in the California Current provide real-time observations of ocean physics, chemistry, and biology. And there is more.

Facilities continue to improve. The La Jolla Laboratory of the Southwest Fisheries Science Center recently occupied its new building, with a state-of-the-art test tank. The Marine Ecosystem Sensing, Observation, and Modeling Laboratory at SIO was dedicated in June 2013. The NOAA FRV Reuben Lasker will soon come to San Diego, and SIO's new global-class R/V Sally Ride, funded by the US Navy, is being constructed.

The CIMEC Executive Board met with the newly constituted Council of Fellows in May 2013. A challenge is enabling CIMEC's unfunded partners to contribute to NOAA's mission. CIMEC will undergo its fourth-year review early in 2014.

I continue to appreciate this expert administrative support provided to CIMEC by Rose Keuler, Anne Footer, and Garrett Eaton.

We look forward to continued service to NOAA in the coming year.

David M. Checkley, Jr.
CIMEC Director

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

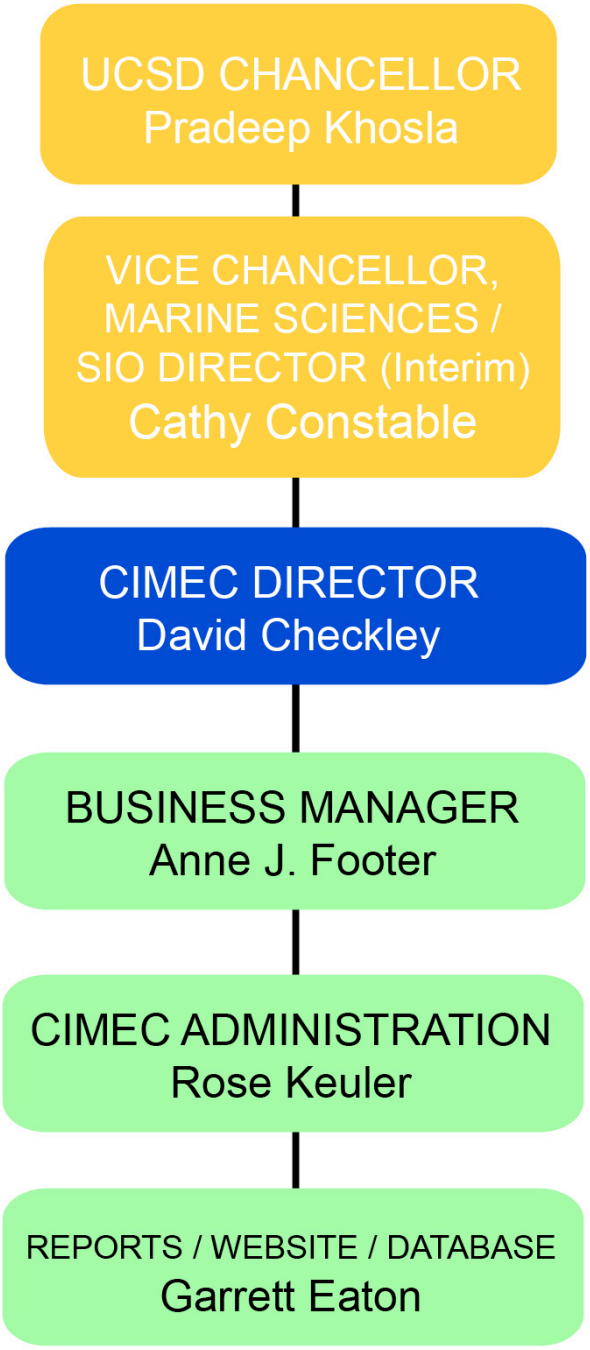
Director:

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 (April 1, 2012 – March 31, 2013)

Personnel Supported by NOAA/JIMO Funding				
Category	Number	B.S. / B.A.	M.S.	Ph.D.
Associate Professor	1			1
Assist. Professor	1			1
Project Scientist	2		1	1
Museum Scientist	1		1	
Postdoctoral Fellow	6			6
Research Specialist	8		3	3
Programmer Analyst	5	1	1	
Staff Research Assoc/Asst	9	5	2	
Assoc. Development Engr.	1	1		
Laboratory Asst	11	2		
Marine Technician	3	3		
Admin. Analyst	1	1		
Total (≥ 50% support)	**49**	**13**	**8**	**12**
Undergraduate Students	14			
Graduate Students	21			
Employees that receive < 50% NOAA Funding (not including students)	95			
Located at Lab (include name of lab)	40	NOAA/NMFS – Santa Cruz Laboratory		
Obtained NOAA employment within the last year	2	William Satterthwaite (SWFSC) and Andrew Ole Shelton (NWFSC)		
Sub-awards Postdoctoral Fellow Graduate Students Undergrad Student	 - 1 -			

CIMEC Fellows Roster (April 1, 2012 – March 31, 2013)

Jeffrey Abell (Humboldt State)	Baldo Marinovic (UC Santa Cruz)
Bruce Appelgate (SIO)	Eric Palkovacs (UC Santa Cruz)
Yehuda Bock (SIO)	V. Ramanathan (SIO)
Dan Cayan (SIO)	Dean Roemmich (SIO)
Luca Centurioni (SIO)	Brice Semmens (SIO)
Andrew Dickson (SIO)	Uwe Send (SIO)
John Hildebrand (SIO)	George Sugihara (SIO)
Ralph Keeling (SIO)	Eric Terrill (SIO)
J. Anthony Koslow (SIO)	Aaron Thode (SIO)
Marc Mangel (UC Santa Cruz)	Darren Ward (Humboldt State)

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 are relevant to the NOAA mission elements, particularly those of environmental assessment and prediction and environmental stewardship.

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.

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.

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.

D. Ecosystem-Based Management

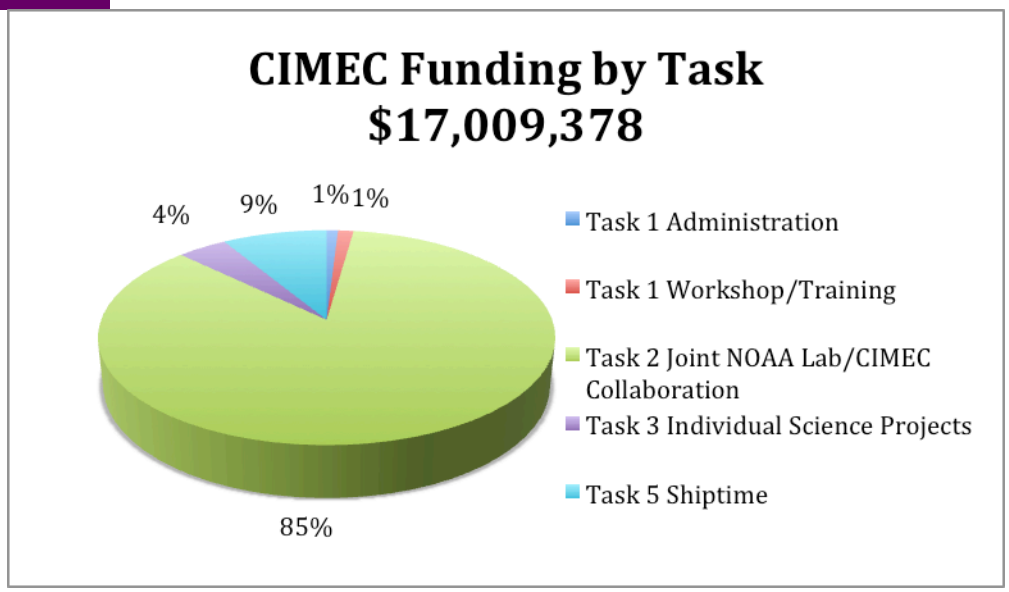
Fisheries management has undergone a paradigm shift in recent years from an exclusive focus on individual assessments of commercially-exploited stocks to maximize sustainable yield (or comparable metric) to a precautionary, ecosystem-based approach. Ecosystem-based management (EBM) explicitly considers 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.

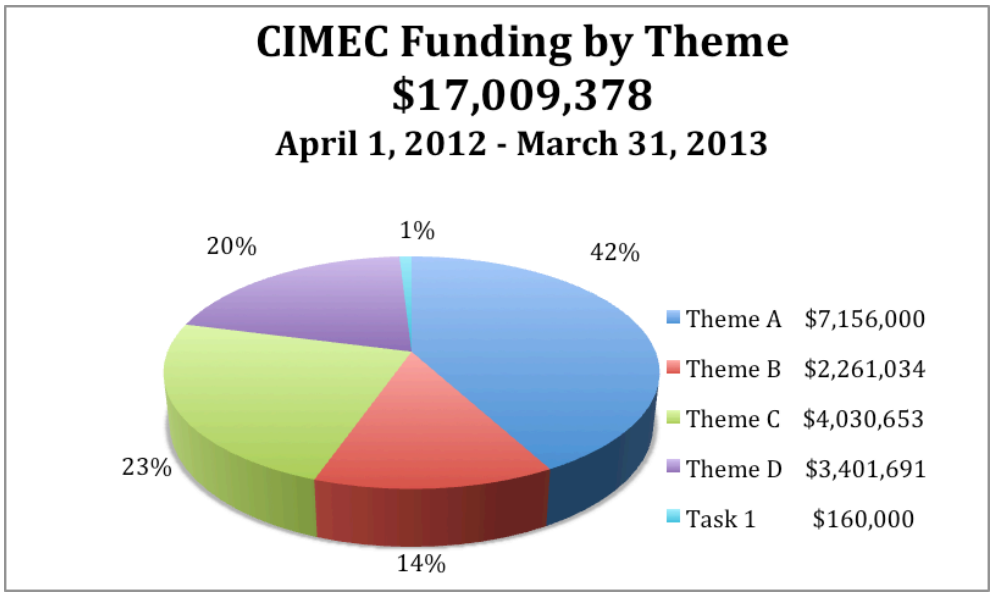
Integration of Marine Protection Areas (MPAs) and Conventional Fishery Management
More than 15 percent of the coast of California will soon be in MPAs implemented under California's Marine Life Protection Act. Modeling of the effects of these for decision makers has been done by Partner labs, and will 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."

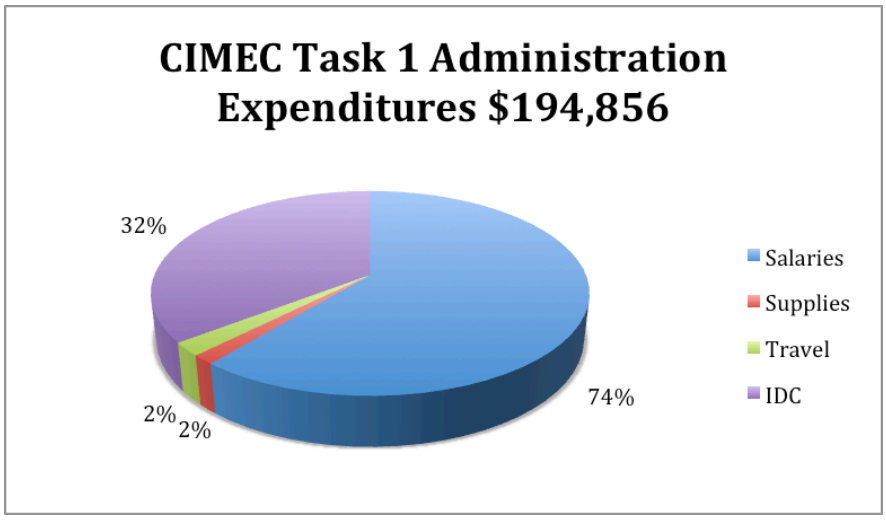
Funding Summary



Task 1: CIMEC Administration
Task 1: Workshop/Training
Task 2: Joint NOAA Lab/CIMEC Collaboration
Task 3: Individual Science Projects
Task 5: Shiptime

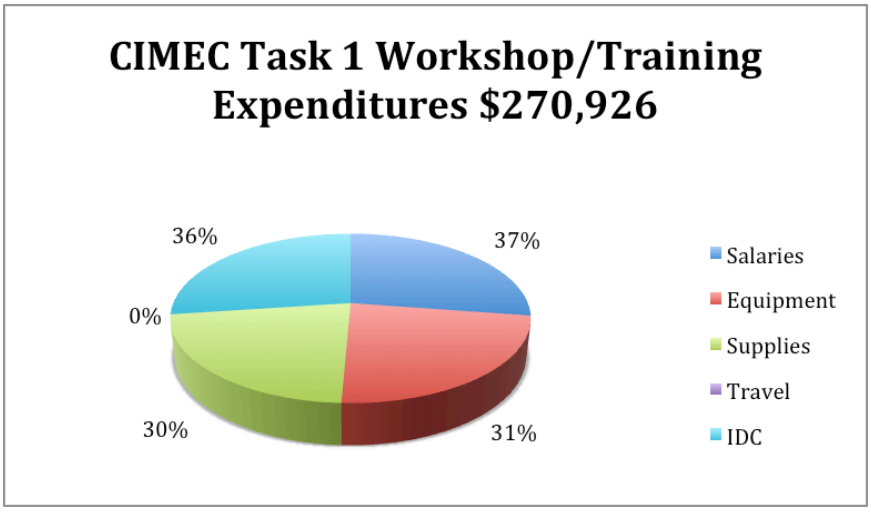


Theme A: Climate and Coastal Observations, Analysis and Prediction Research
Theme B: Climate Research and Impacts
Theme C: Marine Ecosystems
Theme D: Ecosystem-Based Management



Category	Awarded	Expensed
Salary and Benefits	$98,506	$118,806
Supplies	$2,346	$2,876
Travel	$2,374	$4,128
IDC	$56,774	$69,046
	$160,000	$194,856

Salary and Benefit expenditures are comprised of support for the CIMEC Director and Administrative staff. Supply expenditures comprise NGN costs (network support), and project specific supply costs. Travel expenses are for costs for the CIMEC Director and CIMEC Administrator to attend the Annual CI meeting held in Silver Spring, MD.



Category	Awarded	Expensed
Salary and Benefits	$34,621	$74,138
Equipment	$66,180	$63,153
Supplies	$51,576	$60,154
Travel	-	-
IDC	$47,623	$73,481
	$200,000	$270,926

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 in the tables below and are more fully developed in the body of this report.

A. Climate and Coastal Observations, Analysis and Prediction Research

Collection and Analysis of Seawater Samples from the California Coast [Andrew G. Dickson, SIO]	○ Have submitted a manuscript submitted to the Journal of Geophysical Research by Dr. Alin, and including our analyses (through 2011) as verification, was accepted and published in this reporting period
CO2/CLIVAR Repeat Hydrography Program CO2 Synthesis Science Team [Andrew G. Dickson, SIO]	○ Have submitted manuscript submitted to *Limology & Oceanography Methods* detailing our approach to making pH measurements was accepted and published ○ Have submitted manuscript submitted to *Global Biogeochemical Cycles* (together with other Science Team members) detailing decadal changes in calcite and aragonite saturation depths in the North Pacific was accepted and published
NOAA Ocean Acidification Program: Monitoring, Small Sample Analysis and AQ/AC Analytical Support [Andrew G. Dickson, SIO]	○ Reported data to Dr. Simone Alin at NOAA / PMEL as they are finalized ○ Observed that the quality of these small sample alkalinity measurements is very high, and within a factor of two of the best we can do on a much larger sample ○ Showed that a seawater reference material with a controlled high p(CO2) could be successfully prepared and that it was stable and could be used as a suitable test sample
HF Radar National Network Data Management Development [Eric Terrill, SIO]	○ Updated and supported ten data portals, systems designed for collecting HF radar site data and transferring to within the network for the participating Universities: Scripps Institution of Oceanography; Rutgers University; University of Southern Mississippi; University of California, Santa Cruz; University of California, Santa Barbara; San Francisco State University; California Polytechnic State University; University of Southern California, Oregon State University, University of Maine, and University of Miami. ○ Three new nodes, systems designed to act as data repositories and vector processing, have been purchased for the participating Institutions: SIO, NDBC, and Rutgers University. ○ Tested radial metric on three SIO sites ○ Maintained THREDDS server for near real-time RTV's ○ Maintained and updated HFRNET code repository ○ Deployed OI on HF Radar National Network and determined output needs further evaluation.

	○ New Codar sites were made available to all Nodes for RTV processing: ○ Westshore Coal Terminal, Tsawwassen (VCOL) (University of Victoria, BC) ○ http://cordc.ucsd.edu/projects/mapping/stats/?sta=VCOL&aff=UVIC ○ Upper Trestles, San Diego (SDUT) (Scripps Institution of Oceanography) ○ http://cordc.ucsd.edu/projects/mapping/stats/?sta=SDUT&aff=SIO ○ Port Monmouth, NJ (PORT) (Rutgers University) ○ http://cordc.ucsd.edu/projects/mapping/stats/?sta=PORT&aff=Rutgers ○ Hempstead, NY (HEMP) (Rutgers University) ○ http://cordc.ucsd.edu/projects/mapping/stats/?sta=HEMP&aff=Rutgers ○ Iona Wastewater Treatment Plant, Vancouver (VION) (University of Victoria, BC) ○ http://cordc.ucsd.edu/projects/mapping/stats/?sta=VION&aff=UVIC ○ The Exploratorium Museum, San Francisco, CA (EXPL) (San Francisco State University) ○ http://cordc.ucsd.edu/projects/mapping/stats/?sta=EXPL&aff=SFSU ○ Nicholas Canyon, CA (NIC1) (University of California, Santa Barbara) ○ http://cordc.ucsd.edu/projects/mapping/stats/?sta=NIC1&aff=UCSB ○ Brant Beach, NJ (BRNT) (Rutgers University) ○ http://cordc.ucsd.edu/projects/mapping/stats/?sta=BRNT&aff=Rutgers ○ Decommissioned Sites: SDSM San Mateo (Scripps Institution of Oceanography) – 7/01/2012 ○ 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 ○ The HF-Radar Network started as a prototype at SIO with a single portal and node and 4 sites in December 2003 that grew to an operational status produced by 112 sites from 30 participating institutions in 2007, is currently operating with 163 sites from 31 participating institutions. http://cordc.ucsd.edu/projects/mapping/maps/
Collaborative Scientific and Technical Support to the NOAA Earth System Research Laboratory [Yehuda Bock, SIO] [Peng Fang, SIO]	○ Maintained high reliability orbit solutions in terms of two global sub-networks in parallel with an automatic failover system ○ Continued using the latest global gravity model and most recent global reference frame, updated absolute antenna phase center model, most recent ocean tidal loading model, updated differential phase bias correction, and improved ambiguity resolution for long baselines ○ Continued comprehensive orbit quality control procedure to reduce the risk of contaminating the IPW estimates in the GPS/Met solutions ○ Implemented precise point positioning with ambiguity resolution as part of a hazard early warning system and estimated high-rate (once per second) troposphere zenith delays

B. Climate Research and Impacts

NOAA Support for CLIVAR and Hydrographic Data Office 2012 [Bruce Appelgate, SIO]	○ Increased US and non-US CTD profiles, both public and non-public, available for Argo reference data ○ Reconciled EXPOCODE expedition identifiers among US data centers ○ Improved data search capabilities and added bulk data download feature on CCHDO web site. Applications Programming Interface now in development to enable large data users (e.g., modelers) to directly download any/all data of interest ○ Added support for international GO-SHIP web site and related functions
NOAA Stratus Ocean Reference Station: Mooring, Mapping and in-situ Calibration Operations Aboard R/V Melville [Bruce Appelgate, SIO]	○ Recovered the Stratus 11 WHOI surface mooring that was the previous Stratus ORS ○ Deployed new WHOI surface mooring (Stratus 12) to take over as Stratus ORS ○ Conducted multibeam mapping of seafloor bathymetry at target mooring sites in the Stratus region ○ Performed in-situ calibration of the buoy meteorological and oceanographic sensors on Stratus 11 and Stratus 12 by comparison with each other and with instrumentation on the ship ○ Collected underway and on-station oceanographic and meteorological data to characterize the upper ocean in the stratus region ○ Serviced the NDC DART installation northwest of the Stratus site. Underway CTD (UCTD) profiles were collected during the transit from Valparaiso to the Stratus site. Surface drifters and subsurface floats were launched along the track in support of the NOAA Surface Drifter Program and the ARGO program
Global Drifter Program [Luca Centurioni, SIO] [Bruce Cornuelle, SIO]	○ Maintained a GDP array of over 1,000 drifters ○ 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 ○ Created Statistics of Drifter Performances ○ Tested and deployed of Hurricane Drifters ○ Reported GDP Activities ate various DBCP Meetings ○ Scientific Analysis of GDP data
Integrated Boundary Current Observations in the Global Climate System (CORC III) [Uwe Send, SIO]	○ Maintained continuous occupation of two CC sections with gliders, one CC section with moorings/PIES, one SS section with gliders, with 100% data return ○ Performed quarterly deployments of SVP drifters in the CCS ○ Identified summarizing indicators of Solomon Sea heat and mass transports. ○ Improved routine subsurface data retrieval via gliders, construction of modem gliders ○ Improved design of the Bottom Release Drifter ○ Performed first deployments of PIES and small moorings across the Solomon Sea ○ Incorporated more observations into assimilations (IES in particular) ○ Achieved better model fits to observations in general and eddy features in particular, including experiments with shorter assimilation windows

Meridional Overturning Variability Experiment (MOVE) **[Uwe Send, SIO]**	○ Recovered moorings, deployed fresh moorings/PIES; 13 years of data in hand now ○ Continuing joint analyses and presentations with RAPID community and modellers
Moored Climate, Carbon, Biogeochemical, and Ecosystem Observations in the Southern California Current (CCE) **[Uwe Send, SIO]**	○ Recovered and re-deployed two equivalent highly instrumented realtime moorings across the California Current ecosystem with physical, chemical, carbon, and ecosystem sensors ○ Conducted analyses of mixed-layer carbon (DIC) budgets ○ Conducted analyses of climate anomalies in subsurface oxygen ○ Quantified events in the carbon and oxygen conditions
Measurements of Atmospheric O2/N2, Ar/N2 and CO2 Abundances in Relation to Carbon Cycling, Ocean Biochemistry and Global Change **[Ralph Keeling, SIO]**	○ O_2 and CO_2 records from the Scripps O_2 program continue to provide estimates of the global uptake of CO_2 by the oceans and land biosphere. The data suggest that the land and ocean carbon sinks have both continued to grow over the past two decades ○ The data provide a new estimate of net community production in the Southern Ocean
Measurements System for Lightweight UAVs **[V. Ramanathan, SIO]**	○ Improved the quality with system modifications (a reduction in analogue noise; a redesigned gust probe mount; improved telemetry data) and reproducibility of flux data ○ Completed an iterative algorithm for airborne gust probe calibrations with positive outcomes on data quality, e.g. wind direction variability in a circle maneuver reduced from >13° to < 3° ○ Found that Maldivian data indicates system clearly determines different hydrometeorological regimes with linkages observed between boundary layer top and concurrent surface fluxes ○ Found that In-cloud instantaneous vertical velocities an water vapor concentration distributions are consistent with expected values
The Argo Project – Global Observations for Understanding and Prediction of Climate Variability **[Dean Roemmich]**	○ Deployed the first prototype Deep SOLO float, capable of profiling to 6000 m depth in January 2013 ○ 1250 research publications since 1998 have used Argo data (http://www.argo.ucsd.edu/Bibliography.html) ○ The Argo Program obtained its millionth temperature/salinity profile in November 2012 ○ The Argo Program has sustained its global coverage, with over 3500 Argo floats presently active ○ A comparison of Argo temperature measurements with those made by HMS Challenger in the 1870's, on oceanography's first global expedition, was published in Nature Climate Change in June 2012, showing that global ocean warming began at least a century ago

SIO High Resolution XBT/XCTD Transects **[Dean Roemmich]** **[Bruce Cornuelle]** **[Janet Sprintall]**	○ The mean and time-varying volume transport of all five subtropical gyre western boundary currents and the Antarctic Circumpolar Current are being observed regularly by the High Resolution XBT Network ○ Mass and heat budgets for the South Indian Ocean were analyzed by M. Pérez Hernández using the XBT transects, Argo data, and repeat hydrography ○ Characteristics and mechanisms responsible for Southern Ocean upper ocean heat content variability were examined by SIO graduate student Gordon Stephenson using XBT transects and remotely sensed data ○ Data from Scripps High Resolution XBT transects have been used in 9 PhD dissertations
California NIDIS Project **[Dan Cayan, SIO]**	○ Working with more than 100 stakeholders from agencies, industries, organizations, and tribes, the California NIDIS Pilot spans four Pilot Activities: Southern California, Russian River, Central Valley, and the Klamath. The Southern California NIDIS Pilot Activity focuses on drought issues in a metropolitan region heavily reliant on imported water. During the past year, three stakeholder meetings were held to develop applications of drought information for early warning, and to specify indicators for an experimental drought monitor. Resulting products and resources are designed to capture complexities of California droughts, and be transferable to other areas of the country ○ Conducted a survey of state drought managers in each of the 19 Western Governors' Association (WGA) states, investigating drought concerns and impacts, the use and value of drought plans, and the types of early warning information that could inform decisions and reduce drought damages. The survey found that all drought managers are concerned about drought, and expect droughts to become more frequent and severe. Drought damages averaged $1.1 billion per year, ranging from millions to tens of billions of dollars. All managers said that better early warning information could help reduce drought impacts, with an average reduction of 33%. Managers detailed types of "better" early information they needed, such "regionally relevant" indicators and "understandable" precipitation forecasts ○ Detailed highlights and results from the California Pilot, including summaries from stakeholder meetings and the four Pilot Activities, on the California NIDIS Pilot website: http://www.drought.gov/drought/regional-programs/california/california-home

C. Marine Ecosystems

The Center for Stock Assessment Research (CSTAR) **[Marc Mangel, UC Santa Cruz]**	○ CSTAR Almuni are repsented in 4 of the 8 research teams at the FED, and CSTAR members worked with colleagues in 5 of the 8 teams at the FED and with colleagues at US AMLR: ○ Salmon Assessment (CSTAR Alum Will Satterthwaite) ○ Landscape Ecology (CSTAR student Juan Lopez) ○ Groundfish Analysis (CSTAR Alum EJ Dick, CSTAR Post-doc Melissa Monk) ○ Fisheries Economics (CSTAR student Daniel Ladd) ○ Early Life History (CSTAR Alum Steve Munch, CSTAR Post-doc Carl Boettiger Santiago Salinas, CSTAR student Simon ○ Brown) ○ Salmon Ecology (CSTAR Alum Valerie Brown, CSTAR Researcher Jarrod Santora) ○ Molecular Ecology (CSTAR Visiting EU Marie Curie Fellow Simone Vincenzi) ○ US AMLR (CSTAR Student Kate Richerson)

	○ CSTAR student Kate Richerson participated in the first ever winter cruise of US AMLR ○ CSTAR student Daniel Ladd conducted an economic analysis of the elasticity of water release and employment in the Central Valley of California as part of his capstone project for the MSc in Statistics and Applied Mathematics ○ CSTAR student Juan Lopez conducted an analysis of the growth potential of steelhead in more than 60 streams in the Santa Ynez River system as part of his capstone project for the MSc in Statistics and Applied Mathematics ○ CSTAR student Braden Soper continued work with the Groundfish Team to analyze the recreational fishery database ○ CSTAR student Taal Levi published a paper in PLoS Biology on Ecosystem Based Fishery Management for salmon, taking into account indirect effects of fisheries on bear population dynamics ○ CSTAR post-doc Andew Ole Shelton started NOAA Fisheries employment at the Northwest Fisheries Science Center ○ CSTAR post-doc Melissa Monk developed new indices to be used in data moderate stock assessments ○ CSTAR post-doc Carl Boettiger received a NSF Postdoctoral Fellowship in Biology and Mathematics, to continue working on nonparametric methods for fishery management with CSTAR Director Mangel and member Dr. Stephan Munch (FED) ○ CSTAR post-doc Simone Vincenzi completed his work on kittiwakes and environmental change in the Bering Sea and began an EU International Outgoing Fellowship at the FED, working with Director Mangel and the Molecular Ecology and Genetic Analysis team. ○ CSTAR affiliate Mariah Boyle (FishWise staff member) published a second white paper on Illegal, Unreported, and Unregulated fishing ○ CSTAR Director Mangel gave the Keynote Address at the Symposium "In Honour of Dr. Colin Clark: Developments and Challenges in Fisheries Economics", the Distinguished Alumnus Lecture, Institute of Applied Mathematics, University of British Columbia and completed service on the Lenfest Forage Fish Task Force ○ CSTAR hosted two sabbatical visitors from the University of Bergen (Sigrunn Elliasen, March- August 2012; Hans Skaug, August 2012-April 2013 and continuing to the end of the academic year)
Operation of R/V Roger Revelle, Exploring one of Earth's Most Volcanically Active Plate Boundaries: The NE Lau Basin Between Arc and Back-Arc [Bruce Appelgate, SIO]	○ Completed successful fabrication of A-frame mounted Launch & Recovery (LRS) system for QUEST 4000 ○ Completed successful nonstop transmission of HD video broadcasts using satellite-based HiSeasNet communications system enabling remote viewing of all ROV dives in real time ○ Completed successful ship operations including Dynamic Positioning operations to maximize ROV uptime ○ Accomplished outstanding ship support for science mission
Shipboard Monitoring of the California Current System Off Central California [Baldo Marinovic, UCSC]	○ System modifications (a reduction in analogue noise; a redesigned gust probe mount; improved telemetry data) improved the quality and reproducibility of flux data ○ An iterative algorithm for airborne gust probe calibrations was completed with positive outcomes on data quality, e.g. wind direction variability in a circle maneuver reduced from >13° to < 3° ○ Maldivian data indicates system clearly determines different hydrometeorological regimes with linkages observed between boundary layer top and concurrent surface fluxes ○ In-cloud instantaneous vertical velocities an water vapor concentration distributions are consistent with expected values

Investigations in Fisheries Ecology [Eric Palkovacs, UC Santa Cruz]

- Developed aging criteria for analyzing Pacific sanddab otoliths, completed aging of over 6,500 specimens, and continued research on the reproductive ecology of Pacific sanddab, which will provide improved demographic data for stock assessments and life history studies
- Completed mapping and analysis of historical distribution of groundfish catches from catch reconstruction databases to determine the spatial development of California groundfish fisheries
- Completed second year of a stream restoration experiment to assess how stream communities, with steelhead and coho salmon as focal species, and physical habitat respond to the addition of large wood; completed first year of post-wood addition sampling of fish, stream invertebrates and algae, and habitat
- Completed analyses of deepsea coral communities from archived video surveys (1992-2010) and developed a comprehensive geospatial database of corals and associated habitats off central and southern California
- Developed predictive models and maps that relate distribution and abundance of deep-sea corals to ocean currents, water depth, and primary productivity throughout the Southern California Bight
- Conducted remotely operated vehicle (ROV) and autonomous underwater vehicle (AUV) surveys of Cobb Seamount, off the coast of Washington, to document the benthic ecosystem and potential impacts of bottom trawling
- Completed analysis of economic impacts of reduced water supply in the Sacramento-San Joaquin Delta and submitted manuscript to journal
- Developed ArcGIS methods for comparing vessel monitoring system (VMS) and logbook data regarding spatial distribution of groundfish trawl catches
- Expanded spatial coverage of a high-resolution stream temperature model to encompass the entire Sacramento River from Keswick Dam to Freeport, and began assembling data to apply the model to the Klamath River
- Developed a modeling framework based on Dynamic Energy Budget theory to link habitat conditions and fish performance across all life stages and habitats for Central Valley Chinook salmon
- Continued development of a life-cycle population model to evaluate the effects of large water projects and habitat restoration on Central Valley Chinook salmon
- Developed population and ecosystem models, risk assessments, and management strategy evaluation tools for use in the California Current Integrated Ecosystem Assessment and in management of Chinook salmon fisheries in California
- Expanded a study on juvenile Chinook salmon mortality associated with predation at large water intake structures on the Sacramento River from one site to three sites and completed second year of sampling
- Initiated a basin-wide study of survival of hatchery and wild Chinook salmon smolts in the Sacramento River using an extensive array of >100 JSAT acoustic receivers
- Completed summer ocean surveys to determine salmon distributions, diets, and age composition off the coast of central Oregon to central California and to tag adult Chinook salmon with acoustic telemetry tags to track movements in the coastal ocean and during spawning migrations
- Developed models to predicting changes in distributions of core

	habitats of 23 top predators and basin-scale patterns of biodiversity in the North Pacific under a global climate model to 2100 ○ Successful completion of genotyping and analysis of nearly 10,000 Chinook salmon sampled at-sea, as part of the West Coast Genetic Stock Identification Collaboration Project ○ Successful completion of genotyping and analysis for all fish used as broodstock in the four Central Valley steelhead hatchery programs in the 2011-12 spawning season, as well as all steelhead from Warm Springs Hatchery in the Russian River ○ Genotyping and evaluation of steelhead/rainbow trout from > 14 coastal basins in California and confirmation of strong correlation between a specific genomic region and life history strategy in the species ○ Production of short reports on the age structure of steelhead in the Russian River and differentiation of Chinook salmon in the Klamath/Trinity River
Freshwater Ecology Research Collaboration **[Eric Palkovacs, UC Santa Cruz]**	○ Presented at the Endangered Species Act Working Group for anadromous alewife and blueback herring ○ Organized a River Herring Recovery Working Group, held at the University of Maine ○ Published papers in The Quarterly Review of Biology and Evolutionary Ecology ○ Submitted papers to Evolutionary Appl and Biology Letters ○ Accepted an incoming PhD student (Gina Contolini) through the Dept. of Ecology and Evolutionary Biology ○ Working with the Seymour Marine Discovery Center to build the 'Evolution Around Us' program for K-12 education and outreach to the public including minority and underrepresented groups ○ Dave Fryxell (PhD student) obtained NSF Graduate Research Fellowship and NSF East Asia Pacific Summer Institute Fellowship ○ Dan Hasselman (Postdoc) published papers in Molecular Ecology and Transactions of the American Fisheries Society ○ Completed a research project on juvenile life history variation in ESA-listed coho salmon in a Northern California coastal stream; results are being used to develop population monitoring methods that account for diverse life histories ○ Completed data collection for a research project evaluating the growth and residence time of ESA-listed coho salmon in constructed off-channel habitats in Klamath River tributaries; data are being analyzed by graduate student Shari Anderson ○ Finalizing data collection and sample analysis for a research project on habitat-specific contribution of Chinook salmon to smolt production in the Shasta River, including a mark-recapture field study and otolith microchemistry ○ Thousands of scale samples mounted, digitized, and aged for analysis of relationships among freshwater growth, early marine growth, and survival of coho salmon from California coastal streams
Freshwater Fish Ecology Research Collaboration **[Darren Ward, Humboldt State University]**	○ Completed a research project on juvenile life history variation in ESA-listed coho salmon in a Northern California coastal stream; results are being used to develop population monitoring methods that account for diverse life histories ○ Completed data collection for a research project evaluating the growth and residence time of ESA-listed coho salmon in constructed off-channel habitats in Klamath River tributaries; data are being analyzed by graduate student Shari Anderson ○ Finalizing data collection and sample analysis for a research project on habitat-specific contribution of Chinook salmon to

	smolt production in the Shasta River, including a mark-recapture field study and otolith microchemistry ○ Mounted thousands of scale samples, digitized, and aged for analysis of relationships among freshwater growth, early marine growth, and survival of coho salmon from California coastal streams
Ocean Observing and Fisheries Oceanography Research of the Coastal Ocean off Northern California [Jeffrey Abell, Humboldt State University]	○ Successful completion of 14 ocean observing cruises along the Trinidad Head Line between April 2012 and March 2013 ○ Observations from coastal waters off Northern California contributed to State of the California Current Report (Bjorkstedt et al. 2012, Wells et al, in prep), and to quarterly and annual PaCOOS reports
Collaborative Studies of Cetaceans with the Southeast Fisheries Science Center [John Hildebrand, SIO]	○ Participated in cruises on the NOAA Ship Gordon Gunter ○ Collected broadband sound data on a range of cetacean species using both towed arrays and HARPs
Collaborative Studies of Cetaceans Using Passive Acoustic Monitoring with the Pacific Islands Fisheries Science Center [John Hildebrand, SIO]	○ Submitted manuscript on ambient noise in the Pacific for peer-review to the Journal of the Acoustical Society of America ○ Delivered longline HARP recorders to the PIFSC ○ Conducted research on echolocation click discrimination between false killer whales (*Pseudorca crassidens*) and short-finned pilot whales (*Globicephala macrorhynchus*)
Measurements of North Atlantic Ambient Noise [John Hildebrand, SIO]	○ Prepared High-frequency Acoustic Recording Package for deployment ○ Obtained Permit for marine scientific research from the Bermuda Department of Environmental Protection
Using Combined Video Acoustic Recordings of Marine Mammals/Fishing Gear Interactions to Evaluate Utility of Passive Acoustic Monitoring [Aaron Thode, SIO]	○ Camera pressure housing built ○ Acoustic acquisition software modified to operate camera module as a slave ○ Ten deployments of system so far off longlining vessel in Prince William Sound, AK ○ Acoustic data of vessel hauls collected during camera acquisition
D. Ecosystem-based Management	
California Cooperative Fisheries Investigations (CalCOFI), an Ocean Observation Program for the Southern California Current, FY 2011 [J. Anthony "Tony" Koslow, SIO] [Ralf Goericke, SIO]	○ CalCOFI featured in ~ 35 peer-reviewed papers and 5 book chapters published this past year, including papers in *Science* and *PNAS*. CalCOFI featured in regional, national and international conferences and symposia, including ASLO, AGU, and PICES, as well as many workshops, seminars, and symposia. Studies ranged from the plankton to whales, from fisheries to the biogeochemical and ecological implications of climate variability and change. The wide-ranging use and dissemination of CalCOFI data are arguably the best measures of the value of the CalCOFI program to the marine scientific, conservation, and management communities. The length, breadth, and quality of the CalCOFI time series make it indispensable to address the most difficult and contentious issues confronting marine scientists and managers ○ Linked studies published in *Science* and *Proceedings of the National Academy of Sciences* examined how complex time series, such as for the Pacific sardine, may be analyzed when relationships with environmental predictors are non-linear and potentially changing through time ○ A study published in the *Proceedings of the National Academy of Sciences* used the CalCOFI krill time series to show how apparent large-amplitude ecological phase

	transitions (i.e. 'regime shifts') can be generated statistically from atmospheric time series characterized by white noise. This study provides a new base hypothesis for understanding the mechanisms underlying these state shifts ○ Spatial modeling studies continue to be successfully applied to CalCOFI data to elucidate pelagic habitat features conducive to reproductive success in key pelagic fishes, such as bocaccio rockfish and sardine and to demonstrate how data on the scale of the CalCOFI sampling area was required to understand fish assemblage dynamics within a marine reserve off southern California ○ CalCOFI data continued to be used extensively in conjunction with mooring, glider, and satellite data to assess ocean dynamics across a range of spatial and temporal scales
Studies in Anadromous Fisheries [Darren Ward, Humboldt State]	○ Completed mark-recapture field study of juvenile Chinook salmon in the Shasta River; over 1000 juvenile Chinook were marked with PIT tags from two natal habitats, then tracked through the freshwater rearing period and smolt outmigration. ○ Otolith samples from an archive maintained by California Department of Fish and Wildlife mounted and prepared for laser-ablation analysis of microchemistry
Advancement of Population Assessment Methodologies (CAPAM) [Brice Semmens, SIO]	○ Implemented the first CAPAM Selecivity Workshop, attracting over 70 participants from around the world ○ Hired postdoctoral researcher Juan Valero to develop the *Good Practices Guide* and mentor graduate student Lynn Waterhouse
Training the Next Generation of Marine Population Dynamics Scientists [Brice Semmens, SIO]	○ Published 4 peer-reviewed manuscripts and taught a 'Statistical Methods in Marine Biolology' undergraduate course ○ Established a new Center for the Advancement of Population Assessment Methodology (CAPAM) in collaboration with Paul Crone (NOAA) and Mark Maunder (IATTC) ○ Implemented the first CAPAM Selecivity Workshop, attracting over 70 participants from around the world ○ Recruitment of postdoctoral researcher Darren Johnson for an assistant professorship by Cal State Long Beach as a result of his research focusing on stock-recruit relationships in marine fish ○ Collaborated with recreational anglers to successfully tag 3,493 fish as part of the *Paralabrax* Floy tagging program ○ Installed 40 acoustic receivers in the kelp beds off the coast of La Jolla, California ○ Developed a project website and cell phone application to facilitate reporting of recaptured tagged fish ○ Continued mentorship of graduate student Lyall Bellquist and his work on tagging *Paralabrax* in Southern California ○ Enlisted four new graduate students: Brian Stock, Lynn Waterhouse, Joshua Stewart, and Sierra Joy Stevens-McGeever ○ Hired programmer/analyst Brian Stock to develop an open-source GUI, MixSIAR ○ Hired lab manager Devon O'Meara to develop the Catch Reporter™ program and assist with day to day lab operations ○ Initiated the development of a citizen science program "Catch Reporter™" allowing recreational anglers to participate research by reporting their catches to a SIO database

Workshop on Application of Non-Linear Time Series Analysis [George Sugihara, SIO]	○ Explained and promoteds nonlinear state-space reconstruction techniques for time series forecasting ○ Introduced NMFS scientists to tools for nonlinear time series analysis with a series of hands-on examples ○ Discussed differences between the nonlinear time series analysis approach and conventional biomass-based models ○ Examined successfully specific case studies where classical fisheries methods failed with NLTS ○ Recruitment dynamics of altantic menhaden and pacific hake were found not to be random, but were amenable to forecasting with SSR/NLTS methods. ○ Presented applications and extensions of the method for identifying causal interactions, comparing ecosystem structure, optimizing fisheries yield, and ecosystem-based management

Collection and Analysis of Seawater Samples from the California Coast

Andrew G. Dickson (SIO)

NOAA Technical Contact: L. Jewett (CPO)
Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: 8, 30

Research Objectives and Specific Plans to Achieve Them

The goal of this work is to provide information that can be used to test an algorithm developed by Dr. Richard Feely (NOAA/PMEL) and his colleagues for predicting aragonite saturation state in the upper water column of waters off the California coast. This algorithm (which is specific to a particular geographic region) is based on measurements of salinity, temperature, depth, and oxygen concentration.

We thus collect water samples from cruises off the coast of California where the appropriate ancillary measurements (in particular oxygen concentrations) are also made. Examples of such cruises are the quarterly CalCOFI cruises (California Cooperative Oceanic Fisheries Investigations) and cruises off Northern California performed by Dr. Jeff Abell of Humboldt State University. These water samples are returned to the Scripps Institution of Oceanography, where they are analyzed for total dissolved inorganic carbon, total alkalinity, and salinity. Once the analyses are complete, and the data have been evaluated, they are reported to Drs. Feely & Alin at NOAA/PMEL where they are used to compare with the proposed algorithms.

Research Accomplishments

In the portion of the reporting period supported by this grant (April 1, – June 30, 2012). We collected a further set of samples from the April 2012 CalCOFI cruise, and completed the analysis of these samples and the samples from the earlier January 2012 cruise. This brings the total number of samples to around 520 for the completed project.

The analysis results have been sent to Dr. Simone Alin at NOAA/PMEL to incorporate into her algorithm development. In addition, the data for CalCOFI have been provided to the CalCOFI group (and are available through their data system), and those for Northern California to Prof. Jeff Abell at Humboldt State University.

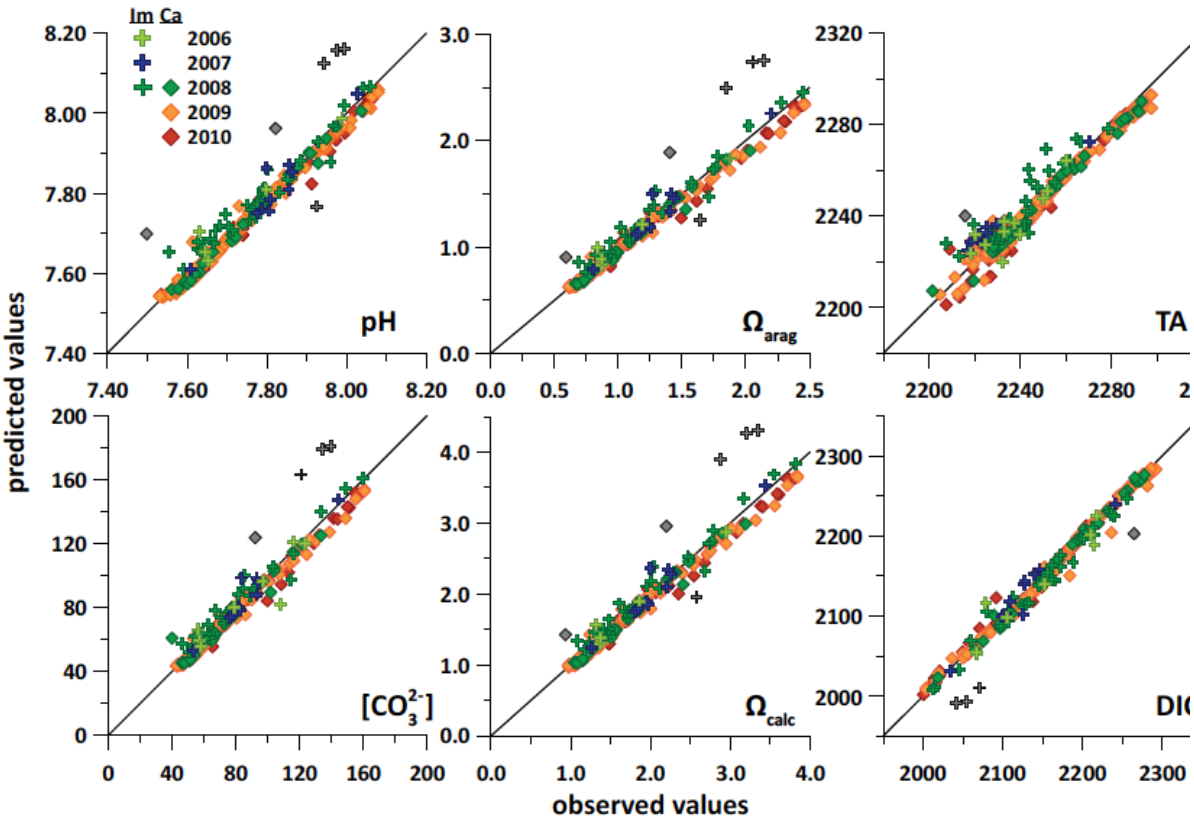


Fig. 1 Comparison of modeled aragonite saturation states (based on an MLR fit to data from August 2007 (Feely *et al*. 2008a) with those predicted from direct CO_2 measurements. The diamonds are data that were collected on a number of CalCOFI cruises and analyzed in the Dickson laboratory at UCSD. (Alin *et al*, 2012).

CO2/CLIVAR Repeat Hydrography Program CO2 Synthesis Science Team

Andrew G. Dickson (SIO)

NOAA Technical Contact: Joel Levy (CPO)
Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: 17

Research Objectives and Specific Plans to Achieve Them

The NOAA/NSF Repeat Hydrography CO2/tracer Program is a component of the Carbon Cycle Science Program (CCSP) and is a collaborative effort between NOAA and NSF to conduct a global decadal time-scale sampling of ocean transports and inventories of climatically significant parameters. It provides a core set of carbon and tracer measurements and anticipates that additional carbon/CLIVAR measurements will be added to the cruises on an "as required" basis. The sequence and timing for the sections takes into consideration the CCSP objectives, and considers the timing of national and international programs. The new data from this program needs to be synthesized into a globally consistent data set (e.g., corrected for analytical errors and

systematic biases) and combined with similar data sets from our international partners working on this same problem.

The CO2 Science Team has been formed to meet these goals. It usually meets once a year, and corresponds in between meetings working to ensure that the surveys are carried out in an efficient manner, and that the data obtained are consistent and correct.

Research Accomplishments

The Science Team funded by this grant (Project Director, Dr. C. Sabine, NOAA/PMEL) did not meet in this time period. During this reporting period, we continued to work on finalizing data from the various CLIVAR cruises we participated in.

- Alkalinity data from our I08S (2007) cruise was finalized and submitted.
- pH data from our I05 (2009) cruise was finalized and submitted.
- pH data from our A13.5 (2010) cruise was finalized and submitted.
- Alkalinity and pH data from our A20 (2012) cruise was finalized and submitted.

NOAA Ocean Acidification Program: Monitoring, Small Sample Analysis and AQ/AC Analytic Support

Andrew G. Dickson (SIO)

NOAA Technical Contact: L. Jewett (CPO)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management;
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: 44

Research Objectives and Specific Plans to Achieve Them

This project comprises three independent activities:

(1) Collection and Analysis of Samples from the California Coast;

The primary goal of this work is to provide information that can be used to test algorithms developed by Dr. Richard Feely (NOAA/PMEL) and his 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.

(2) Evaluation of Measurement Quality for Analysis of Small Samples

The goal of this activity is to assess just what the uncertainty will be when using state of the art analysis techniques on small seawater samples (*e.g.*, 50 mL for measurement of both total alkalinity and total dissolved inorganic carbon).

(3) QA/QC for CO_2-Related Measurements in NOAA OA Laboratories

The goal of this activity is to provide advice to various NOAA OA laboratories that will enable them to improve their ability to make effective CO2-realted measurements in support of NOAA's Ocean Acidification program..

Research Accomplishments

Activity 1: Samples were collected on the following CalCOFI cruises: CalCOFI 1207OS (9 Jul 9 – 26 Jul 2012); CalCOFI 1210NH (19 Oct – 05 Nov 2012); CalCOFI 1301SH (10 Jan - 02 Feb 2013). The analyses have been completed and finalized for the 2012 cruises, analyses for the 2013 cruise are still in progress.

Activity 2: We have demonstrated that it is practical to titrate total alkalinity on a 20 mL sample with a reproducibility of around 1.5 μmol kg^{-1}. The overall uncertainty of the measurement is probably about 2.0 μmol kg^{-1}. Our approach is based on the method we use to certify seawater CO2 reference materials. We have also shown that it is possible to determine total dissolved inorganic carbon using a Marianda Airica system with a precision of around 3 μmol kg^{-1}, and are now working to estimate the uncertainty in that estimate.

Activity 3: Dr. Dickson made two trips to visit NOAA laboratories. The first in July 2012 was to laboratories in Alaska, the second (in September 2012) was to laboratories in the US North East. Each of these trips was made together with a program officer from the NOAA OA Program: Libby Jewett in Alaska, Dwight Gledhill in the North East, and reports based on these visits were submitted to the NOAA OA Program officers. In addition, my laboratory made two CO2-in-seawater test materials – one with a "normal" and one with a "high" p(CO2) – and distributed these samples in January 2013 as blind samples to all the laboratories affiliated with the NOAA OA Program. The results have now been received and a report is being prepared.

HF Radar National Data Management Development

Eric Terrill (SIO)

NOAA Technical Contact: Jack Harlan (NOAA/IOOS) and Richard Crout (NOAA/NWS/NDBC)

Links to NOAA Strategic Plan:

NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
NOAA Goal 3: Serve Society's Needs for Weather and Water Information
NOAA Goal 4: Support the Nation's Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation
NOAA Goal 5: Provide Critical Support for NOAA's Mission

Amendment No.: 2, 23, 39

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 primary focus on preparing the data for integration into the United States Coast Guard (USCG) Search and Rescue Optimal Planning System (SAROPS).

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 includes a tech refresh year to devote to new hardware for continued operations. CORDC programmers will replace site aggregators operating for four years or more; SQL database management and diagnostics will be implemented on CORDC node; migrate radial file formats to NetCDF for distribution; analyze DOA metric implementation in real-time operations. Personnel will continue to support system maintenance including portal/node growth from previous years, network administration, software upgrades and license renewals, and deployment of full nationwide optimal interpolation for gap free products and improved coverage.

Research Accomplishments

Research and implementation efforts for this project met expectations during this reporting period. Throughout this reporting period, efforts focused on continued operations, maintenance, and expansion as well as evaluation of optimal interpolation output and the Direction of Arrival (DOA) metric. As background, the HF-

Radar Network architecture is comprised of two hardware building blocks, aggregators and nodes with distinct roles. Aggregators serve as 'point of entry' machines by acquiring and serving radial data from any number of HF-Radar sites. Nodes serve as data concentrators by collecting radial data from any number of portals (or nodes). This design minimizes data requests through sometimes unstable network connections to individual sites by serving data through portals while maintaining a high degree of network flexibility through selective data collection at nodes.

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 3 sites on the West coast and 3 sites on the East coast.

The optimal interpolation (OI) method is a biased estimator and assumes a (continuous) spatial covariance function, derived from the observed spatial scale and structure. It improves both baseline consistency and the uncertainty definition in the estimates [e.g., Kim et al. "Mapping surface currents from HF radar radial velocity measurements using optimal interpolation" (2008), Kim(2010)]. Optimal Interpolation (OI) was implemented on the national network for both U.S. West Coast (USWC) and U.S. East and Gulf Coast (USEGC). Following implementation of OI programmers determined additional quality control of the data output was necessary based on anomalies and differences with un-weighted least-squares fitting (UWLS). CORDC programmers hope to continue this evaluation in FY13.

HF Radar radial metrics were collected from three sites within the SIO network (Border Field State Park; Point Loma; and Coronado Island). The goal was to research possible performance enhancements of system baseline vectors by filtering out data outliers in 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)

Results included:

1. Bad radial vectors, often large in magnitude and going in the opposite direction, were eliminated
2. Variance decreased, making a more consistent set of baseline vectors
3. Variance along baseline decreased by up to 5 cm/s

Programmers implemented a program called 'db2sql' which monitors the database for all relevant changes and translates the data to a MySQL server on the SIO node. This allows web applications for metadata to rely on the more familiar, widespread, and sometimes faster MySQL database for serving the collected near real-time radial data and metadata. Future diagnostic features will utilize this database for web queries

CORDC programmers maintained a THREDDS server for hosting the near real-time vectors (RTV). Radar derived surface currents are now available through the following protocols:

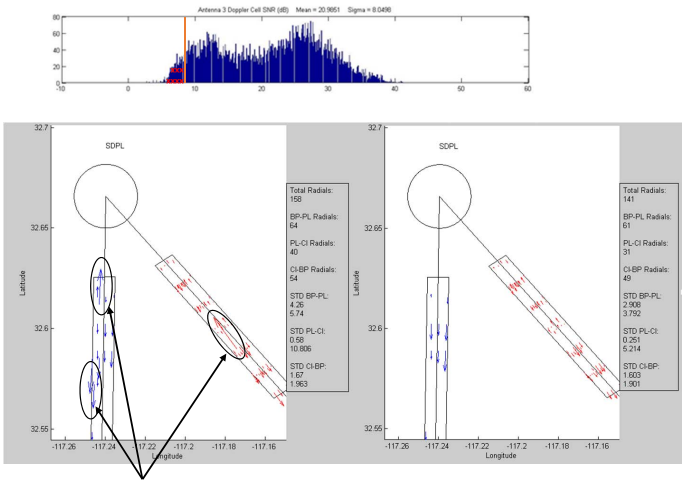
- Data Access via CORDC THREDDS Server
- Data Access via FTP (3 day rolling archive)
- Shapefile Access (California) via FTP (3 day rolling archive)
- Shapefile Access (Gulf Coast) via FTP (3 day rolling archive)

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

Monopole SNR (SNR3) Example

Log(SNR3) Distribution – μ = 21.0 dB, σ = 8 dB



Unfiltered with bad radial vectors

Filtered

Strategy:

1. Compute unfiltered variance of baseline radial vectors between San Diego sites
2. Remove all radials more than 2σ below the mean for SNR3 and then re-computing the hourly mean.
3. Re-compute filtered variance of remaining radial vectors

Result:

1. Bad radial vectors, often large in magnitude and going in the opposite direction, are eliminated
2. Variance goes down, making a more consistent set of baseline vectors
3. Variance along baseline decreases by up to 5 cm/s

Fig. 1 HF Radar Radial Metric analysis conducted at sites along baselines at Scripps Institution of Oceanography

FBK1 [+more data]	12.1496	01:48 RDL_m_SLO_FBK1_2013_04_23_1800.hfrss10lluv	2830 (measured)	90.40 (measured)	0 W /6 W
LUIS [+more data]	0.0000	OLD			W / W
PTC1 [+more data]	12.1496	01:48 RDL_i_SLO_PTC1_2013_04_23_1800.hfrss10lluv	1633 (ideal)	59.30 / 128.99 (ideal)	0 W /255 W
RAGG [+more data]	4.5500	01:48 RDL_i_SLO_RAGG_2013_04_23_1800.hfrss10lluv RDL_m_SLO_RAGG_2013_04_23_1800.hfrss10lluv	1464 (ideal) 802 (measured)	198.20 / 244.81 (ideal) 209.80 (measured)	46 W /0 W

Point Conception, CA (34.448300 -120.471700)

Voltages	Value	Temperatures	Value
RX +12 VDC		RX chassis	25
RX +5 VDC	5.160000	AWG module	35
RX -5 VDC	-5.050000		
RX +24 VDC	0.000000		
TX +28 VDC	0.000000	TX chassis	0
TX +5 VDC	0.000000	TX Amplifier	0

	NoiseFloor	SNR	Amplitude	Phase (Calculated)	Phase (Corrected)
Loop1	-147.000000	23.000000	1.66900000	46.90000000	100.0000
Loop2	-150.000000	32.000000	0.73100000	128.10000000	103.0000
Monopole	-146.000000	32.000000			

Fig. 2 HF radar national network example hardware diagnostics utility which will expand in out year programming

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

Yehuda Bock and Peng Fang (SIO)

NOAA Technical Contact: Seth Gutman (ESRL/GRD)
Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: 10, 56

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. We constantly introduce the latest error modeling techniques in order to provide more robust and timely GPS satellite orbits. These include realizing the latest global gravity mode and global reference frame, incorporating the absolute antenna phase center model, applying improved tidal loading model and differential code bias correction, adding more evenly distributed raw data from global GPS tracking stations, and developing redundant and more robust quality control mechanisms. The Co-PI (Peng Fang) interacted closely with our sponsor at NOAA (Seth Gutman, his staff, and their international contacts) to enhance their systems for GPS Meteorology, providing scientific and technical consultations. In addition, he computed, upon requests, numerous special solutions for the Northern America region as well as places of global interest.

Research Accomplishments

High quality orbits are now delivered hourly with better than 99.2% (3 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. A redundant processing system has been implemented to improve the reliability of GPS orbit support at SOPAC for NOAA. EGM08, a new global gravity model, and ITRF2008, a new reference frame, have been adopted. A few improved error modeling schemes have been incorporated into the data processing system. This research directly contributes to atmospheric sounding research in general and directly contributes to operational weather forecasting by NOAA in the U.S. Techniques developed for this system can support other applications in geodynamics and surveying/navigation.

NOAA Support for CLIVAR and Hydrographic Data Office 2012

Bruce Appelgate (SIO)

NOAA Technical Contact: David Legler (CPO)

Links to NOAA Strategic Plan:

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

Amendment No.: 65

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). 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. CCHDO continues to work with NOAA to assemble and incorporate into NOAA-related holdings select cruise data sets. [For example, over 6500 HOT and BATS profiles were submitted to OceanSITES, and a large number of new profiles from US and non-US cruises were added to the Argo reference CTD data set. The CCHDO negotiated with the GOA National Institute of Oceanography to receive synthetic profiles within the Indian EEZ and actual data outside it (still, however, awaiting first delivery of data and products); CCHDO will be SOOS data center for the type of data the CCHOD handles.]

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. [Also, acquired the GO-SHIP web site, assisted the new GO-SHIP technical manager with start-up; held 2-day meeting with GO-SHIP and US HYDRO leadership.]

ii. Working with NODC to improve efficiency of transfer of data and to make CCHDO data more "archive ready". [Developing an Application Programming Interface for CCHDO and Argo. Working with Tim Boyer (NODC) to better synchronize data holdings.]

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

[For example, and EXPOCODE reconciliation has taken place between the CCHDO, BCO-DMO, and CDIAC (this also reconciles GO-SHIP EXPOCODES since the CCHDO is the data assembly center for GO-SHIP.]

c. CCHDO holdings are of great value to a wide audience of climate researchers and other users (e.g. modelers). The CCHDO is preparing to implement 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), for example via an Application Programming Interface. [Data search based on available parameters now available and can be combined with other search features; "OR" function available in data searches; data cart now enables bulk download of selected files.

NOAA Stratus Ocean Reference Station: Mooring, Mapping and in-situ Calibration Operations Aboard R/V Melville

Bruce Appelgate (SIO)

NOAA Technical Contact: D. Stanitski (CPO)

Links to NOAA Strategic Plan:

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

Amendment No.: 51

Research Objectives and Specific Plans to Achieve Them

This grant funded the cost of operating the Research Vessel Melville to recover and deploy deep-sea moorings in the equatorial eastern Pacific Ocean. 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 eastern Pacific. Shipping agents were retained in Bahia de Valparaiso (Chile) and Puerto Ayora (Galapagos Ecuador) to handle pre-and post- cruise mobilization and demobilization (respectively), and all port logistics were arranged by the Scripps Nimitz Marine Facility staff. Foreign clearances to work in the waters of Chile and Ecuador were 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, including heavy-lift capabilities required to overboard these large deep-sea moorings and associated scientific instrumentation.

Research Accomplishments

The Stratus Ocean Reference Station (ORS) at 20°S, 85°W under the stratus clouds west of northern Chile is being maintained to provide ongoing climate-quality records of surface meteorology, air-sea fluxes of heat, freshwater, and momentum, and of upper ocean temperature, salinity, and velocity variability. The Stratus Ocean Reference Station (ORS Stratus) is supported by the National Oceanic and Atmospheric Administration's (NOAA) Climate Observation Division. This program achieved its scientific objectives including recovering the old Stratus mooring and replacing it with a new, upgraded version, routine technical servicing of the NOAA DART mooring north of the Stratus site, and acquisition of underway meteorological, oceanographic and multibeam bathymetric data in support of the time-series data collected by each of the moorings.

The Global Drifter Program

Luca Centurioni (SIO) and Bruce Cornuelle (SIO)

NOAA Technical Contact: Candyce Clarke (CPO)

Links to NOAA Strategic Plan:

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

Amendment No.: 19, 27, 59

Research Objectives and Specific Plans to Achieve Them

1) Provide to the Global Telecommunication System (GTS) a near-operational, near-real time data stream of drifter position, SST, Sea Level Air Pressure (SLAP). 2) observe the 15m depth velocity on a global basis with a nominal 5.0° resolution and, jointly with satellite altimeter data, produce circulation charts of the world ocean at 0.5º 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. In collaboration with AOML we maintained an array of 1100 drifters (average) to chart 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 the processes, such as wind-driven Ekman currents and spatial patterns of the seasonal circulation in ocean climate models.

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 instrumental observations of daily average SST (+/- 0.10C) over the global ocean at a 5º resolution, or the spatial scale of the error covariance function of operational NOAA satellite infrared SST sensors, sufficient to keep the potential SST satellite bias error smaller than 0.5ºC [. Surface pressure sensors are also supported 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 24% smaller than its nominal size due to a variety of issues).
Thirty-seven salinity drifters were deployed in the tropical Atlantic in support of NASA's SPURS experiment. The experiment is underway and the deployment of the full array should complete in FY13. See also http://spurs.jpl.nasa.gov/SPURS/ .
Four drifters were sent to the National Aquatic Resources Research and Development Agency of Sri-Lanka and deployed starting from August 2012.
Several drifters were also deployed in support of CalCoFi cruises, specifically CalCoFi cruise of March 2012 (14 drifters), CC-LTER (August 2012, 8 drifters), and CalCoFi/Ocean Starr cruise (September 2012, 9 drifters).
The GDP worked in synergy with the ONR funded experiment OKMC with the goal to map the seasonal surface circulation in the South Philippines Sea and to understand the seasonal migration of the separation point in the western boundary of the North Equatorial Current. To enhance the historical near surface current data in the study area, deployments of surface drifters from the merchant vessels from Kaohsiung to eastern Australia were performed. Professor Ruo-Shan Tseng at National Sun Yat-Sen University is a local contact point in

Taiwan to store, prepare and deliver the drifters to the ship. The deployments continued in 2011 and six deployment cruises (9 drifters for each deployment) have been made successfully. The Hyundai Shipping Co. cancelled the regular route from Kaohsiung to Australia, in February 2012 because of global recession and five deployments were skipped starting from February, 2012. Fortunately drifter deployments by the Global Drifter Program supplemented this study. We deployed a total of 54 drifters since October, 2011 and 8 drifters failed on deployment.

Several technical issues were addressed (i.e. battery packs) to improve the endurance of the drifters.

The enhanced drifter dataset was updated quarterly. Dr. Dong-Kyu Lee has downloaded the archived data from AOML with success. There were 13 requests from scientists for drifter data during the funding cycle reported here. This is on top of the data distributed by AOML and available in real time or near-real time though the GTS.

The PI organized the deployment of 10 drifters ahead of tropical storm/hurricane Isaac. Of the 10 drifters deployed, 5 were equipped with thermistor chains. The deployment was coordinated with CARCAH and performed by the 53rd WRX "Hurricane Hunters" (figure 2). All data (SST, air pressure, sea-level wind and subsurface temperature was posted to the GTS as well as made available through a SIO ftp server and in graphic form through a SIO website.

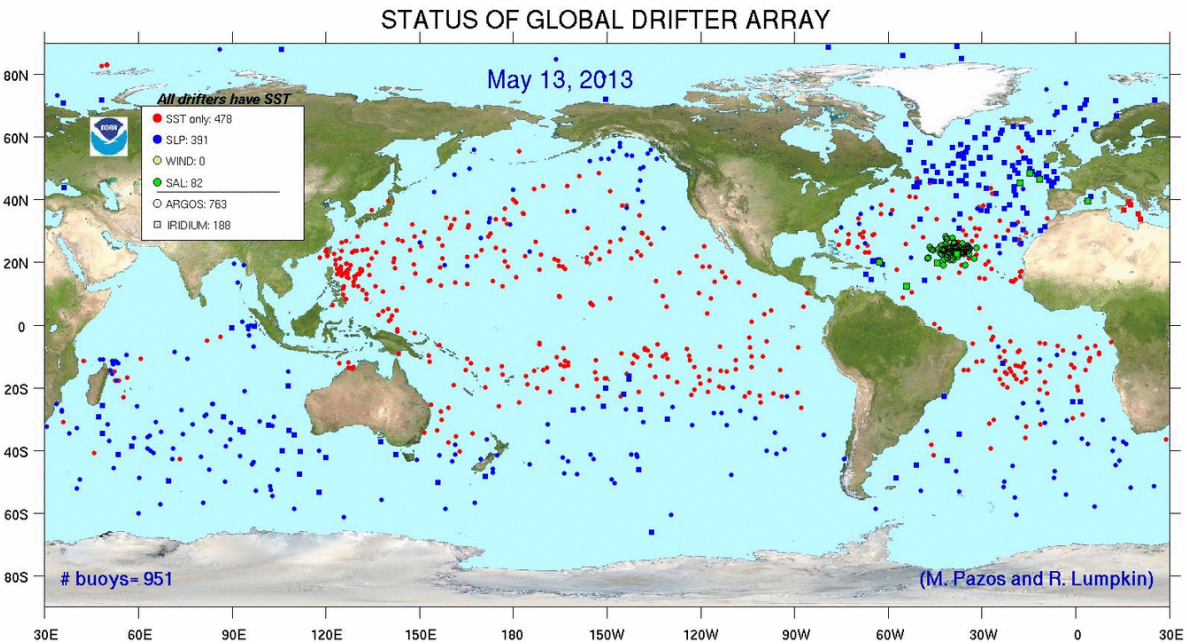


Fig 1 Global drifter population as of May 13, 2013

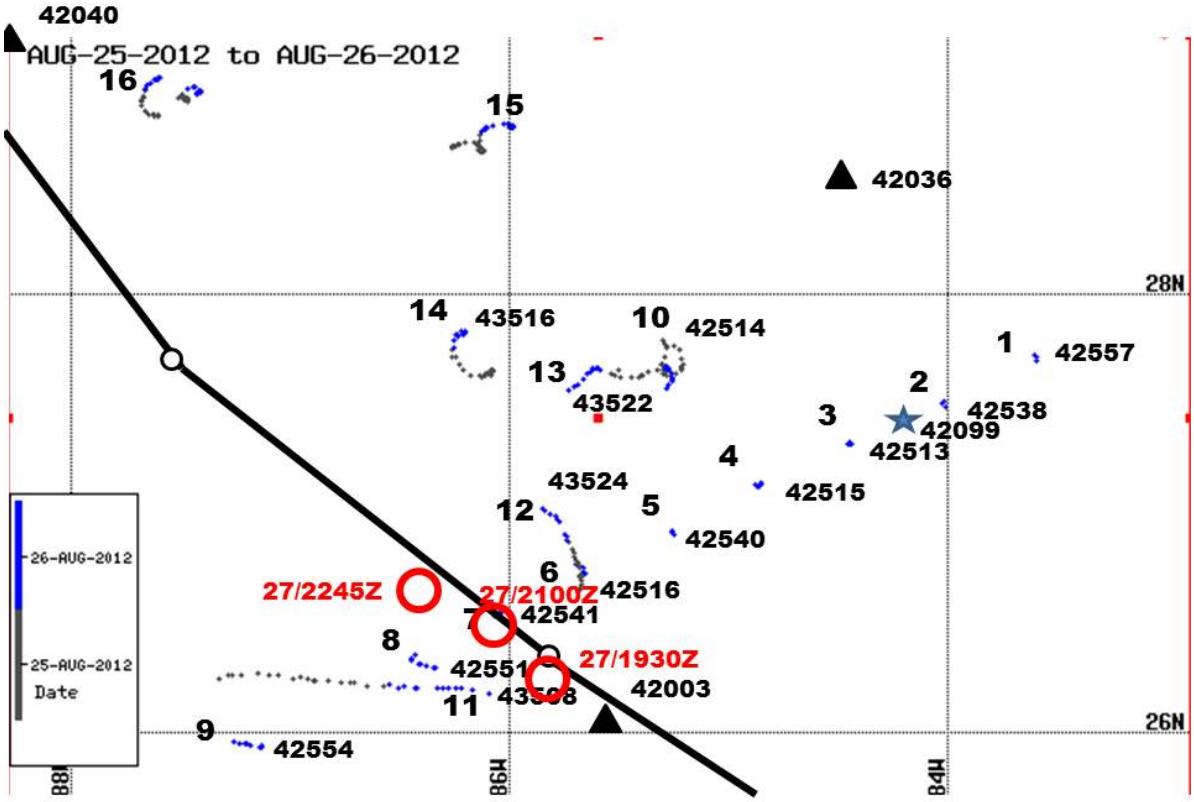
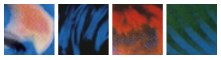


Fig 2 Drifter deployments ahead of tropical cyclone Isaac



Integrated Boundary Current Observations in the Global Climate System (CORC III)

Uwe Send (SIO)

NOAA Technical Contact: Diane Stanitski (CPO)
Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: 24, 64

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. To form a SoCal Niño Index, we average temperature anomaly inshore of 200 km, and filter with a 3-month running mean. The SoCal Niño Index is remarkably correlated with the Oceanic Niño Index (Nino 3.4 filtered with a 3-month running mean), figure 1. This immediate response implicates an atmospheric teleconnection between the CCS and the equator. The CORC moorings and PIES on line 90 were reconfigured in September 2012 to capture more fully the cross-shelf circulation on shorter timescales, and now form an approximately rectangular box with the two CCE moorings off Pt. Conception. We are also testing to what extent stationary gliders can replace a simple mooring in some cases. Drifter deployments continued in the CCS (subcontract to Dr. Carter Ohlmann, UCSB) and the third generation of bottom-release drifters (BRD) has been constructed.

In FY2012 we continued the time series of Solomon Sea (SS) transport above 700 m begun in 2007. An additional ten transects of the southern SS were completed with 100% data return. These observations are the only repeated indicator of the subsurface western boundary current in the tropical South Pacific. The 6+ year glider and Argo time series show transport variability in the interior and the WBC to be well correlated to each other and to equatorial SST on ENSO scales (figure 2). The time series from shows a typical equatorward transport of 15 Sv above 700 m varying from zero to 25 Sv in synchronism with the two La Niñas and one El Niño in the period. The transports and heat contents of the two layers have been tentatively identified as the best indicators of equatorial transport through the Solomon Sea. In order to provide more complete temporal sampling, an end-point component across the Solomon Sea has been added during the reporting year, consisting of a simple small mooring plus a PIES on each side of the Solomon Sea.

Argo data in the ocean interior east of the Solomon Islands and in the Solomon Sea, provide basin-integrated estimates of the mean and time-varying transport of the of the South Pacific's shallow overturning circulation. Zilberman, Roemmich, and Gille (2012a) found that the ENSO fluctuations in the ocean interior transport (about

11 Sv per unit of Nino 3.4 index for annual mean values) were larger than those in the Solomon Sea (4 Sv per unit of Nino 3.4 index), and that the ocean interior and WBC ENSO fluctuations were oppositely phased. A comparison is made of the consistency of Argo-based and glider-based transport in the western boundary region. In this work, the ocean's mean and time-varying mass and heat budgets are closed for the region north of 7.5°S, including the Indonesian Throughflow transport as a residual of geostrophic and Ekman flow across 7.5°S.

In the state estimation component of the CORC project we have achieved the original goal of technology development to allow for regional assimilation at eddy-permitting resolution with long duration windows. This has included development of refined open boundary adjustment methods, better treatment of altimeter means and anomalies, and incorporation of new data types, including IES. Mesoscale eddies modulate much of the alongshore and cross-shore flows, and the model is now converging to reproduce the variability including eddy signals. We have developed complementary Ensemble Kalman Filter (EnKF) tools for the MITgcm and used them for some short-term experiments. We have compared with ROMS runs by HaJoon Song for the same region, on short timescales, and compared and contrasted the ROMS vs MITgcm assimilation system. We have tested our reanalysis heat flux adjustments against independent estimates using high-resolution cloud images.

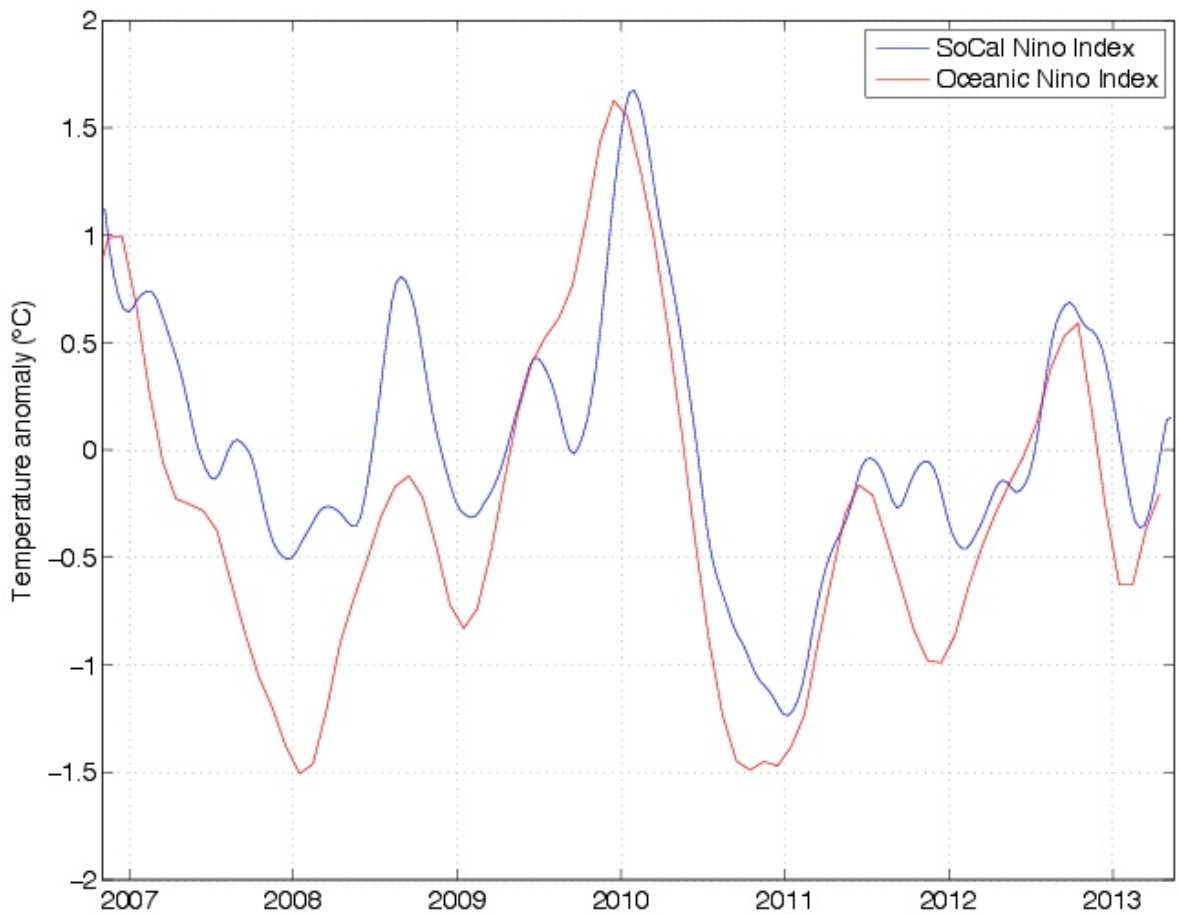


Fig. 1 Comparison the SoCal Nino Index derived from the gliders (blue) with the "Oceanic Niño Index" published by NOAA is SST in the Niño 3.4 region (The Niño 3.4 region spans the east-central equatorial Pacific between 5N-5S, 170W-120W), with a 3-month running mean (red). The indices are remarkably correlated

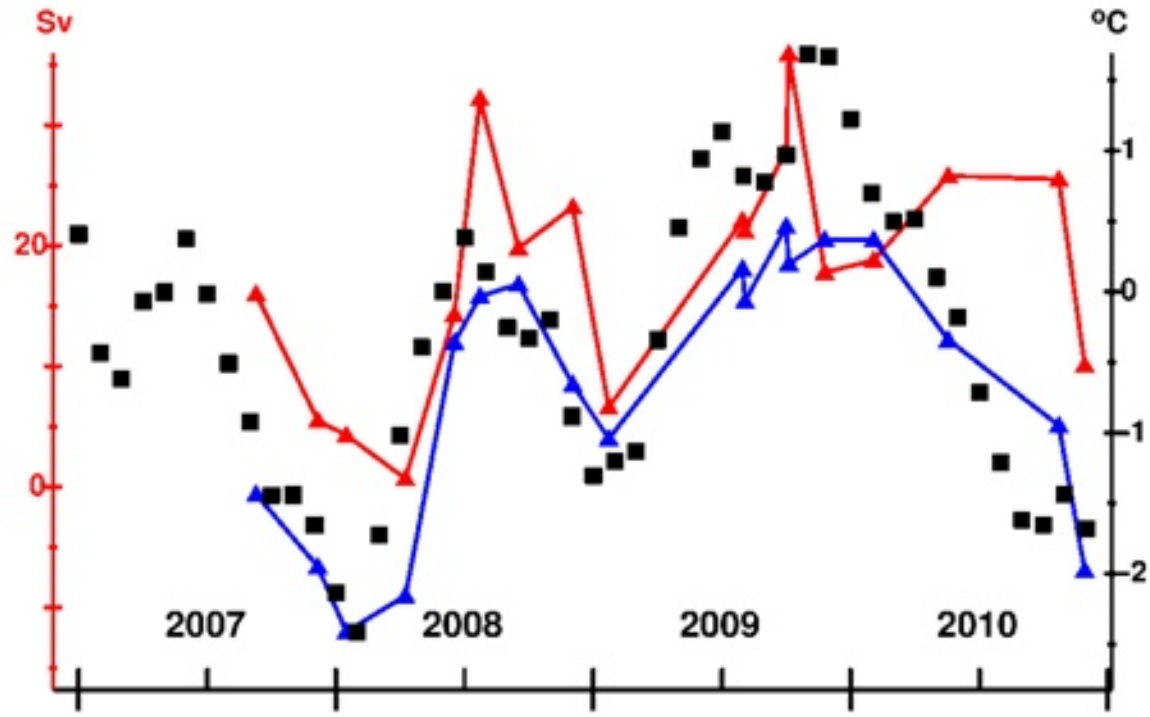


Fig. 2 Time series of total equatorward transport (Sv) through the Solomon Sea (red), the transport by shear referenced to 700 m depth (blue), and the Niño 3.4 surface temperature index (black squares). The measured series continues but analysis of 2011-2012 is incomplete

Meridional Overturning Variability Experiment (MOVE)

Uwe Send (SIO)

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

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 and vertically 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, and routine delivery of indicators about the state of the thermohaline overturning circulation at this latitude will be enabled. The moorings and PIES have recently been equipped with acoustic modems, allowing data retrieval from research vessels or via gliders.

Research Accomplishments

Much of the effort in the year reported here was dedicated to acquiring and building new instrumentation and hardware, and fabricating new moorings and PIES. A major MOVE array service was then carried out in May 2013 from the German RV “Meteor” cruise where the MOVE team had the opportunity to participate in the leg from Guadeloupe to the Cape Verde Islands.
During this cruise, all three moorings were recovered, serviced, and redeployed, and two additional PIES were added to the existing ones in order to finally reach the staggered 4-year deployments with 2-year overlaps at each site. All new moorings and PIES now carry acoustic modems, using the technology developed under CORC, to allow data retrieval with gliders.

On the science side, with the newly recovered data, we now have a 13-year long data set in hand. The weakening trend over the first 9-1/2 which we had published in the previously reported GRL paper, had appeared to weaken or cease when we had expted the data set to 11 years after the last instrument recovery. We were wondering at that time whether we were witnessing the reversal of a decadal timescale fluctuation. The new 13-year record just in hand, after preliminary analysis on board the ship, does indeed seem to suggest a reversal of the weakening trend from the first 9-1/2 years (see figure 1).

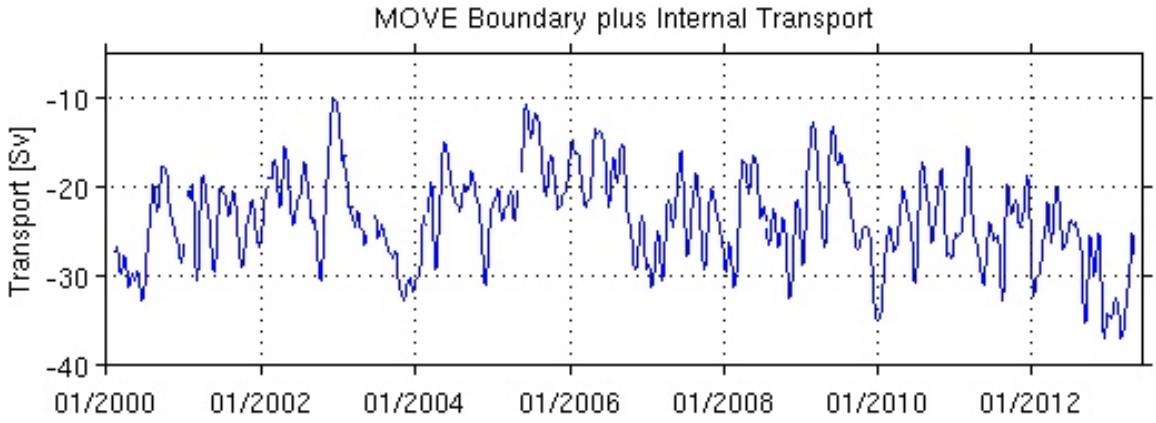


Fig. 1 Thirteen years of North Atlantic Deep Water MOC transport (southward therefore negative), showing first a weakening and then a strengthening trend

Moored Climate, Carbon, Biogeochemical, and Ecosystem Observations in the Southern California Current (CCE)

Uwe Send (SIO)

NOAA Technical Contact: Diane Stanitski (CPO)
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

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 will establish 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 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 FY2012 funding was used for the first recovery and redployment of two nearly identical moorings CCE1 and CCE2 along CalCOFI line 80 in March 2011, 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 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 sensor 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 allow the characterization of periods and events that are believed to have an impact on the ecosystem. These include hypoxic periods, and events with sufficiently low pH that the aragonite saturation levels drops below 1 (which means that calcium-forming organisms would be seriously affected). The latter so-called "corrosive" conditions have been found over wide shelf areas along the US west coast in the NOAA OA acidification surveys. Our moorings now allow to collect temporal information about such events. We are also working on constructing carbon budgets in the mixed layer, and using both the pH and oxygen data, we can estimate net community production in two different ways, and the agreement between these which we have found so far is encouraging (figure 1). Even though our timeseries at CCE are still short, we have covered part of the recent El Nino/La Nina events and we can start to analyze impacts of these climate processes on the biogeochemical system and ecosystem conditions at the moorings. This is still in the early stages, but some first steps can be shown (figure 2)

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

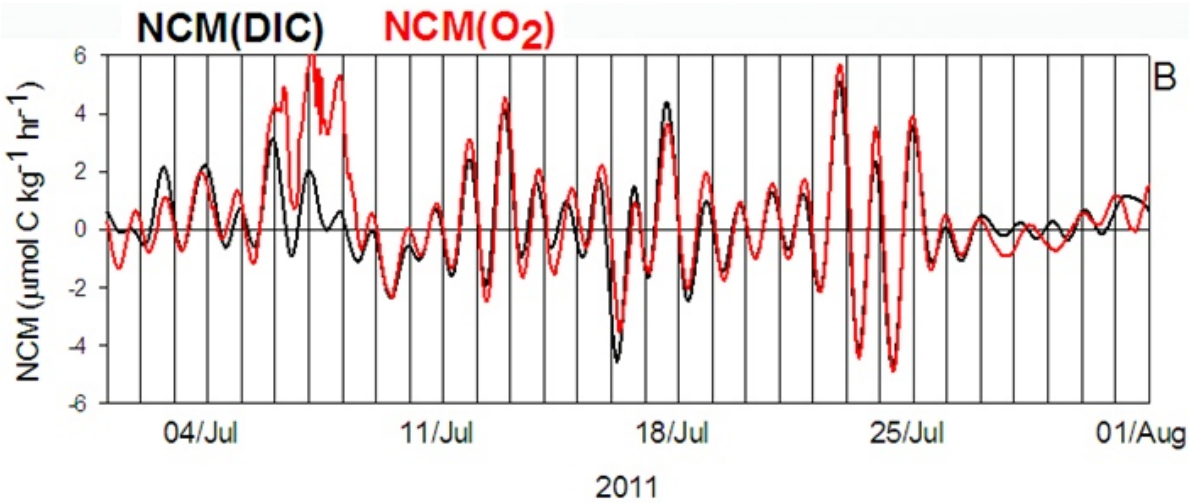


Fig. 1 Diel-band estimates of net community production at CCE2 using the DIC balance (domimated by advection) and the O2 balance (dominated by air-sea flux). The agreement suggests that on short timescales, NCM can be estimated from O2 and then be used in the DIC balance

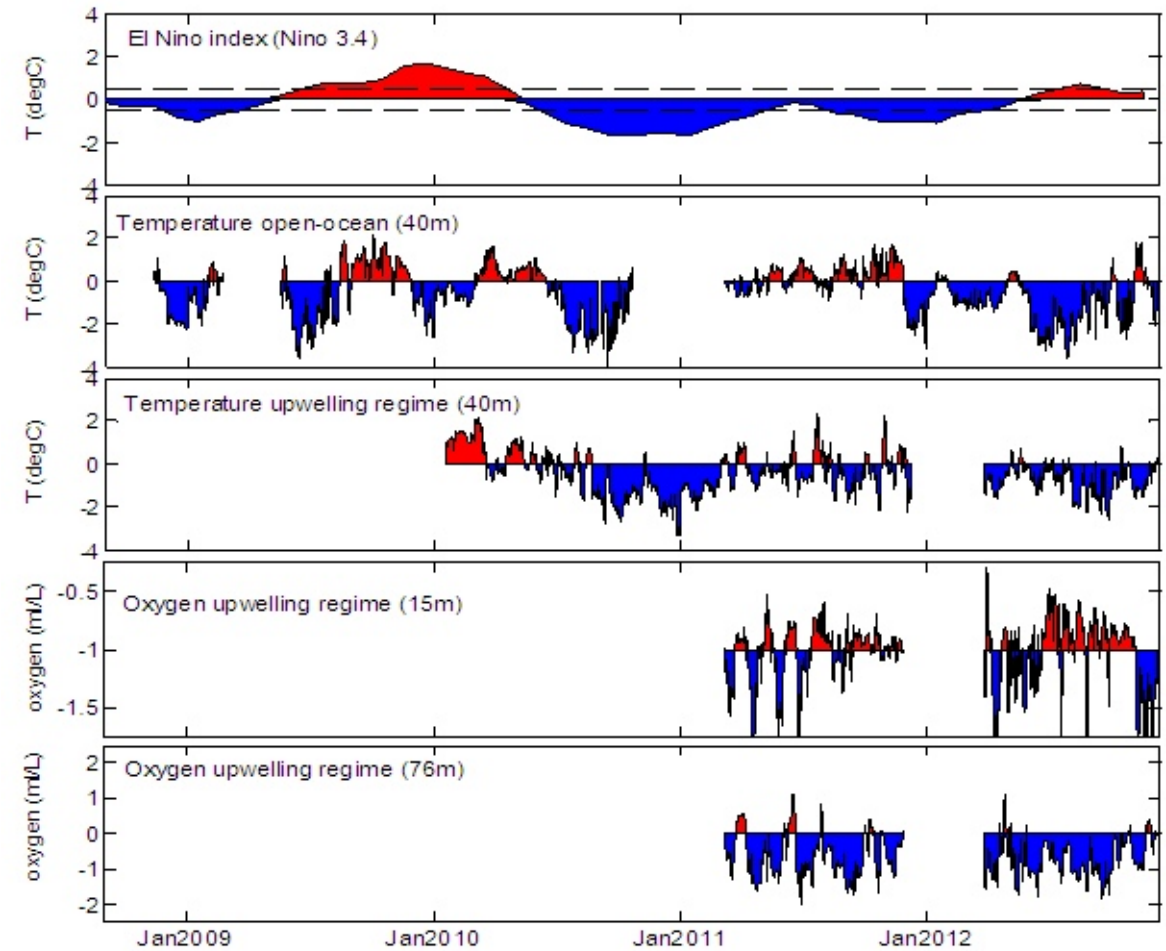


Fig. 2 El Nino index as a measure of El Nino/La Nina activity, and CCE mooring anomalies for temperature and oxygen, relative to the long CALCOFI records at the same locations and depths. Large and significant anomalies in oxygen are observed at the moorings, which will be analyzed to understand their forcing and their impact

Measurements of Atmospheric O2/N2, Ar/N2 and CO2 Abundances in Relation to Carbon Cycling, Ocean Biochemistry and Global Change

Ralph Keeling (SIO)

NOAA Technical Contact: Ken Mooney (CPO)

Links to NOAA Strategic Plan:

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

Amendment No.: 16, 40

Research Objectives and Specific Plans to Achieve Them

This project continues and expands time series measurements of O_2/N_2 and Ar/N_2 ratios and CO_2 concentration at background air stations by the Scripps O_2 project (Figure 1). These measurements enable refined estimates to be made of land and ocean carbon sinks and provide benchmark tests for models depicting the response of ocean biogeochemistry to changing climate on a range of time scales, extending from seasonal, El Nino, to multi-decadal. The measurements are also relevant for quantifying the global loss of O_2 from the oceans, or "deoxygenation" and for detecting changes in ocean ventilation and production associated with warming-induced stratification that may influence future deoxygenation. The measurement may enable improved atmospheric inversions that take account of processes internal to the ocean influencing carbon dioxide. The measurements have strong synergistic relationship to measurements by the carbon cycle group of the NOAA Global Monitoring Division, the Argo float program, to measurements made as part of the HIAPERS Pole-to-Pole (HIPPO) mission to survey the distribution of long-lived atmospheric tracers related to carbon dioxide, and to the Scripps CO_2 program.

The primary proposed activity involves sustaining ongoing time series at a global array of nine stations extending from the Arctic to the Antarctic along a (mostly) Pacific transect. One new site, Barrow, Alaska, has been added to the flask network during this three-year grant period in order to sustain the Barrow time series initiated by the Princeton atmospheric O_2 program (Figure 2).

An integrally related activity involves the assessment and reduction of systematic errors which may impact the ongoing measurements or the merging with these measurements with measurements of other programs. The project supports interpretive activities related to detecting and reporting such errors. It support activities to reduce errors, and it enables the Scripps O_2 program to continue its central role in an international intercalibration effort for O_2 measurements, as endorsed by the World Meteorological Organization.

The proposal support collaborative interpretive activities with investigators at other institutions to develop methods for incorporating O_2/N_2 measurements into atmosphere/ocean inversions for detecting trends in land and ocean sinks on decadal time scales.

Research Accomplishments

Flask collections and analyses have proceeded without disruption at eight of the nine primary long-term stations in the Scripps O_2 network.

Sampling at Cold Bay, Alaska station was compromised starting in October 2012 due to inability to obtain adequate flow through the sampling line. Troubleshooting via station staff proved to be very slow. This disruption caused a hiatus in obtaining adequate samples until May 2013 when a station visit by Scripps staff to the site identified and corrected the problem. The problem was traced to the sampling line being crushed near

the intake due to a dangling safety chain that was free to swing in the wind. A new 3/8" line intake line was installed while the original 1/4" line was repaired to serve as a back-up. Sampling was resumed from the second week of May, 2013.

At our request, staff at the South Pole station installed a new intake to allow sampling from a 30m tower in Jan 2012. We have continued to sample both at the new and old location to establish overlap. The comparison generally shows very good agreement.

At Palmer Station, we moved the tower on the Tera Lab building (which has been in use for some years) to a cleaner side of the building. We expect this will help reduce contamination especially in the summer, when there are more activities around the building (e.g. power equipment, deliveries, etc.).

Work is ongoing to investigate the potential for improving the stability of the O_2/N_2 and Ar/N_2 ratios delivered from high pressure cylinders by placing a ball in the cylinder and rocking the cylinder to force the ball to role. The approach has the potential to reduce thermal and gravitational fractionation in the cylinders.

The PI is continuing a collaboration with Bruce Cornuelle of Scripps to assess trends in the amplitude of the seasonal cycles in APO (weighted sum of O_2/N_2 ratio and CO_2 mole fraction which is insensitive to land exchanges), as discussed in last year's report, although progress has been slow owing to the competing demands on the O_2 projects chief programmer (Stephen Walker).

A manuscript is in press by the PI and Dr. Andrew Manning of U. East Anglia summarizing the main value of atmospheric O_2 measurements to global change research. Entitled, "Studies of recent changes in atmospheric O_2 concentration", the draft describes motivation and methods for measuring changes in O_2/N_2 abundance, the relation to atmospheric oxygen, an overview of basic phenomena, including seasonal cycles, secular and interannual trends, and provides updated estimated of global land and ocean carbon sinks, as summarized in Table 1 below.

A draft is in preparation by the PI in collaboration with Manfredi Manizza (of Scripps) and Cindy Nevison (of CU Boulder) to compare observed cycles in Ar/N_2 and APO with results from a high resolution biological ocean model. The ratio of the amplitudes of the seasonal cycles of APO and Ar/N_2 appear to be well measured, and provides a measure of the seasonal biological response of the ocean biota (via APO) to the seasonal physical forcing of the upper ocean (via Ar/N_2). A correct depiction of the processes influencing the seasonal exchange of O_2 is critical also for accurate depiction of the seasonal controls on surface water pCO_2. The purpose of the paper is to illustrate the power of the Ar/N_2 and APO constraints for challenging ocean models used for assessing ocean biological and carbon cycle processes.

The O_2/N_2 and Ar/N_2 data from the Scripps program have figured prominently in a collaborative study led by Dr. Cindy Nevison of the University of Colorado and including the PI to decompose the seasonal cycles in APO into the three main components: (1) photosynthesis, (2) ventilation, and (3) warming/cooling induced solubility changes. The study leads to a new estimate of marine net community production for the oceans south of 50S of ~1 Pg C yr^{-1}, and illustrates how O_2 measurements can be reconciled with satellite estimates of ocean productivity. This study was published in Global Biogeochemical Cycles (Nevison et al., 2012).

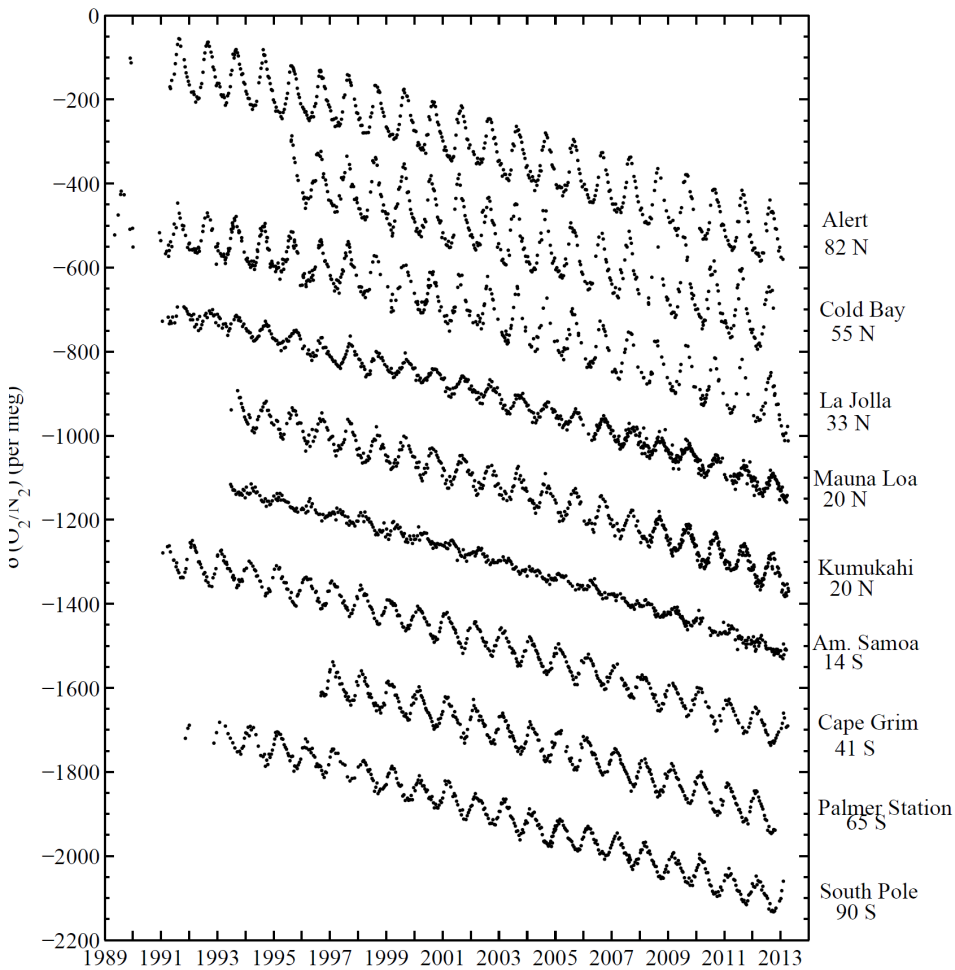


Figure 1. Time series of O_2/N_2 ratio at sites in the Scripps O_2 program. Data from Alert are shown on the Scripps Institution of Oceanography reference scale. The scales of all other stations are offset from the station above by −200 per meg

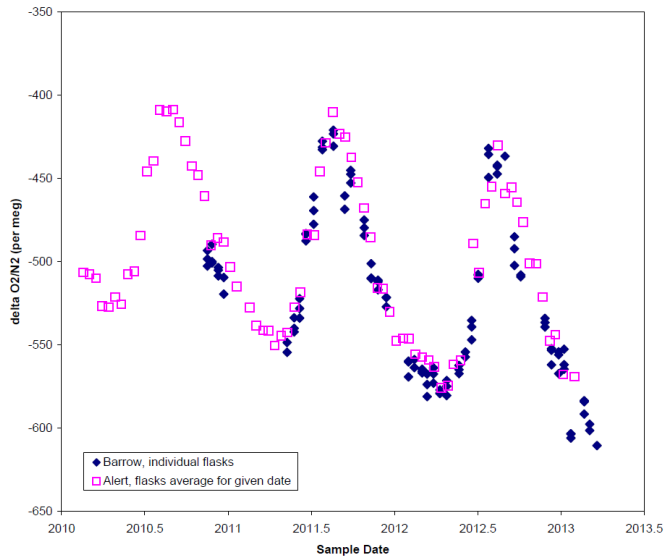


Figure 2. O_2/N_2 meaurements at Barrow and Alert Stations. The agreement is generally very good, but perfect agreement is not expected due to site-specific differences. The spring-time decrease appears to occur slightly earlier at Barrow

Time frame	ΔδAPO per meg yr^{-1}	ΔCO_2 ppm yr^{-1}	Z_{eff} 10^{14} mol yr^{-1}	α_F	Fossil-fuel Pg C yr^{-1}	Atm. CO_2. Pg C yr^{-1}	Ocean sink Pg C yr^{-1}	Land Sink Pg C yr^{-1}
1990-2000	7.79 (0.72)	1.52 (0.02)	0.34 (0.40)	1.391 (0.03)	6.39 (0.38)	3.23 (0.04)	1.83 (0.57)	1.33 (0.75)
1993-2003	8.60 (0.50)	1.74 (0.02)	0.34 (0.40)	1.393 (0.03)	6.60 (0.40)	3.70 (0.04)	2.10 (0.53)	0.80 (0.72)
2000-2010	10.41 (0.52)	1.90 (0.02)	0.34 (0.40)	1.378 (0.03)	7.81 (0.47)	4.04 (0.04)	2.61 (0.55)	1.16 (0.80)
1991.5-2011	9.49 (0.42)	1.76 (0.01)	0.34 (0.40)	1.384 (0.03)	7.24 (0.43)	3.74 (0.02)	2.34 (0.52)	1.16 (0.75)

Table 1. Oxygen based carbon budget over different time periods from data from the Scripps O2 Program. ΔδAPO is the observed change in atmospheric potential oxygen, which is the key observed input from the Scripps O2 program. ΔCO_2 is the change in CO2 concentration from the NOAA GMD program. Z_{eff} is a correction term allowing for warming-induced ocean outgassing of O_2. The remaining columns detail the main terms in the global carbon budget, with the atmospheric increase, ocean sink and land sink summing to equal the fossil-fuel emissions. Estimated uncertainties (1σ) are in parenthesis

Measurements System for Lightweight UAVs

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NOAA Technical Contact: Gary Wick (ESRL)

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

Amendment No.: 11

Research Objectives and Specific Plans to Achieve Them

The main objective of this project is to develop a lightweight UAV based system for the measurement of water vapor fluxes to complement existing NOAA field programs and satellite observations in the eastern Pacific region for the observation of atmospheric rivers (ARs), with the ultimate goal of improving understanding and forecasts of such events. These ribbon-like structures, extending 1000s of Km, are contained within the lowest 3km of the troposphere and are a critical pathway for meridional moisture transport. In California, AR systems play a key role in flooding events.

By providing localized, targeted sampling of the turbulent wind field and the water vapor content, UAVs can provide data on ARs on temporal and spatial resolutions not possible with satellites or easily obtainable with manned aircraft. In order to properly resolve the key components of an atmospheric river, any flux system needs to adequately distinguish between latent heat flux (λE) ranges expected within the hydrometeorological regimes typical of an AR system.

Research Accomplishments

In the 2012-2013 reporting period we have analyzed data from the 38 hours flown during a scientific field campaign in the Maldives and a NOAA led deployment on San Nicolas Island in June 2012.

System improvements from the previous year have proved very useful in the field; the redesigned gust probe mount enabled rapid, repeatable positioning of the gust probe relative to the airframe; and the improved telemetry allowed for targeted placement in the atmospheric layer of interest.

An algorithm was developed to automate the gust probe calibrations from airborne data. These calibrations are necessary to determine i) alignment offsets between the inertial navigation sensor and the gust probe, ii) offsets induced in measured angles of attack and sideslip due to airframe influences on sampled air, and iii) pressure correction offsets relating to probe orientation into the ambient wind field. These 8 parameters are interrelated through via the ambient wind derivation equations, therefore a series of maneuvers are undertaken in quiescent air designed to isolate each as much as possible and a recursive algorithm was developed to calculated converged values. These corrections greatly improved the data quality, e.g. wind direction variability in a circle maneuver reduced from >13° to < 3°.

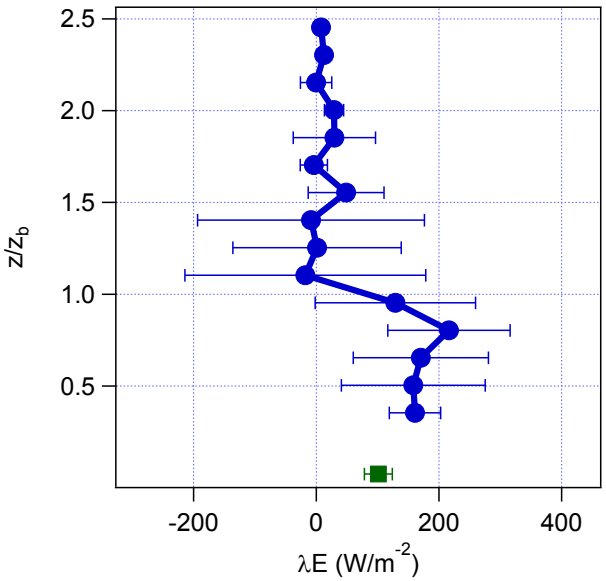
Mean results from each flux flight (excluding runs which partially included cloud penetration) during the 38 hours flown as part of a scientific measurement campaign (CARDEX) conducted in the Maldivian maritime environment are given in Figure 1a. Aircraft altitude (z) is normalized to the boundary layer height (z_b) derived from UAV soundings. There is a clear distinction between latent heat fluxes measured above the boundary layer ($z/z_b>1$) than below, with an entrainment zone transition layer seen in between. The mean value from fluxes concurrently measured at a surface tower (green square) are seen to be consistently lower than the UAV BL fluxes, but not outwith 1-σ in natural variability indicated by the bars. In fact, the linear relationship between hourly averaged UAV BL fluxes and concurrent surface data (Figure 1b) implies a flux of <30 Wm^{-2} at z_b for surface fluxes <100 Wm^{-2}, rising to >200 Wm^{-2} at z_b when surface fluxes rise above 100 Wm^{-2}. This implied inertia of the system is being investigated further in the data.

Whilst flux data from runs penetrating clouds cannot be easily derived, the instantaneous vertical wind velocity velocities (w) are valid and can be used to give an indication of the w distribution within encountered clouds. Using video data and image analysis techniques, w and water vapor (q) data is segregated into cloud/non-cloud

periods. Figure 2 (a) demonstrates this for 20th March 2012. In-cloud w values peak at approximately 0.2 m/s and are skewed towards positive w. Non-cloud samples are normally distributed with a much lower peak (0.067 m/s). Water vapor Figure 2 (b) segregates cleanly into wetter cloud and drier non-cloud portions, the tri-modal distribution in the non-cloud histogram reflects the three measurement altitudes.

Operationally the San Nicolas Island flights were a success, with demonstrable collaboration between the Navy, NOAA and Scripps. Two science flights were achieved despite a throttle issue on the Manta required a rapid engine refit and a short campaign window. Wind direction and speed results from these flights demonstrated good agreement with sonde data, but the low boundary layer height coupled with reduced flight times due to base operations were not conducive to flights low enough to penetrate the surface layer.

(a)



(b)

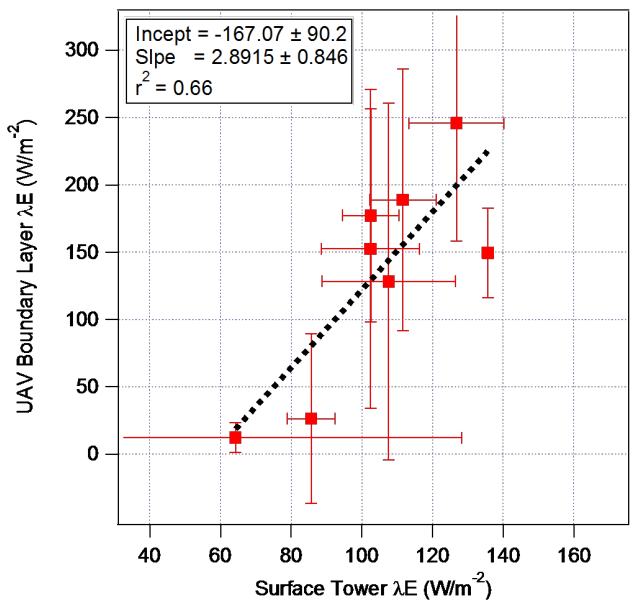


Fig. 1 (a) Latent heat profile for all UAV flux flights excluding runs which partially included cloud penetration. Aircraft altitude (*z*) is normalized to the boundary layer height (z_b) derived from UAV soundings. Surface tower derived fluxes for the same period is shown (green square). Bars represent 1-σ of all runs at that altitude. (b) : Hourly UAV means of flux runs performed in the boundary layer (BL) against and corresponding surface tower data bars indicate 1-σ. The majority of UAV fluxes were collected in the upper 50% of the BL. Linear fit is shown as a black dashed line

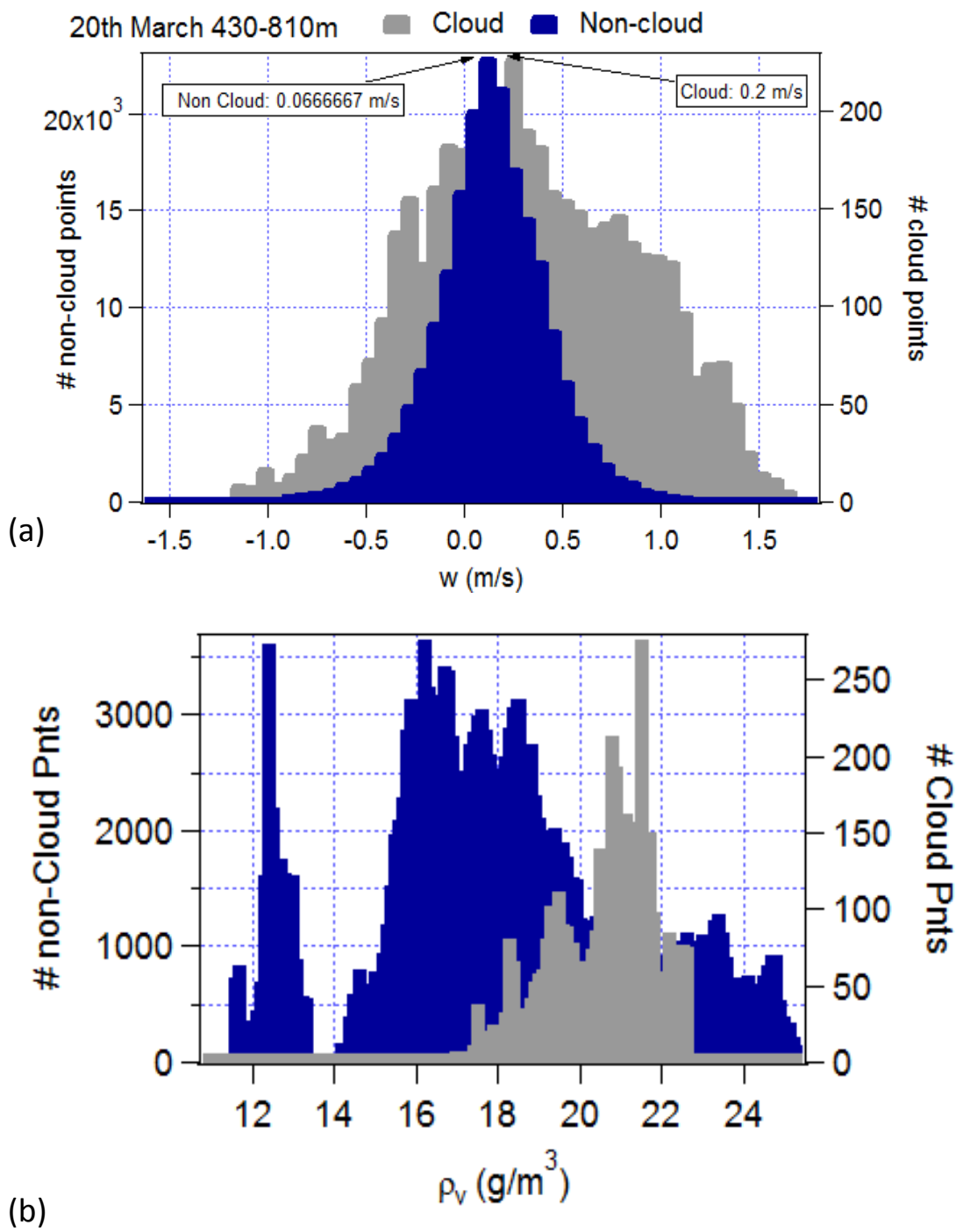


Fig. 2 (a) vertical wind velocity and (b) water vapor distribution in trade-cumulus measured on 20th March 2012, between altitudes of 430-810m

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

Dean Roemmich (SIO)

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

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 3500 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 large initiative for oceanography, merging research and operational objectives to provide a uniquely valuable global dataset for climate science, ocean state estimation, seasonal-to-decadal forecasting, 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 (04/2012 – 03/2013), 74 SIO Argo floats were built, shipped, and deployed. An additional 45 will be shipped in early June. Deployments included 11 floats by RV Melville in the tropical North Pacific, 51 floats by RV Kaharoa in the subtropical South Pacific, and 12 floats by RV Tangaroa in the Southern Ocean. In addition to these Argo-funded floats, our lab also built 17 floats for the OKMC project. These were deployed by RV Mirai in the tropical North Pacific and their data are provided gratis to the Argo Program.

The total number of active SIO Argo floats is now 476. 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 newly designed SOLO-II float have been successful, including both SOLO-II floats built at Scripps and SOLO-II floats produced under commercial license by MRV Systems LLC. The SOLO-II design provides greater buoyancy adjustment, more robust operation, and increased lifetime relative to all existing Argo floats.

During this reporting period the design and development of Deep SOLO floats, capable of more than 100 cycles to full ocean depth (6000 m), was continued. A prototype Deep SOLO float was built and deployed off Central California on January 24, 2013 by RV Bell Shimada on a CalCOFI cruise. This prototype instrument has now completed 37 dives to 4000 m depth. It is planned to be recovered after 75 cycles in early August. This instrument will then be reconditioned and, along with a second prototype Deep SOLO float will be deployed in late 2013 in water depth greater than 5000 m.

Scientific quality control of all SIO Argo profile data has been carried out by J. Gilson 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 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 New Zealand's National Institute of Water and Atmospheric Research (NIWA) in its March 2013 meeting. The meeting report for AST-14 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

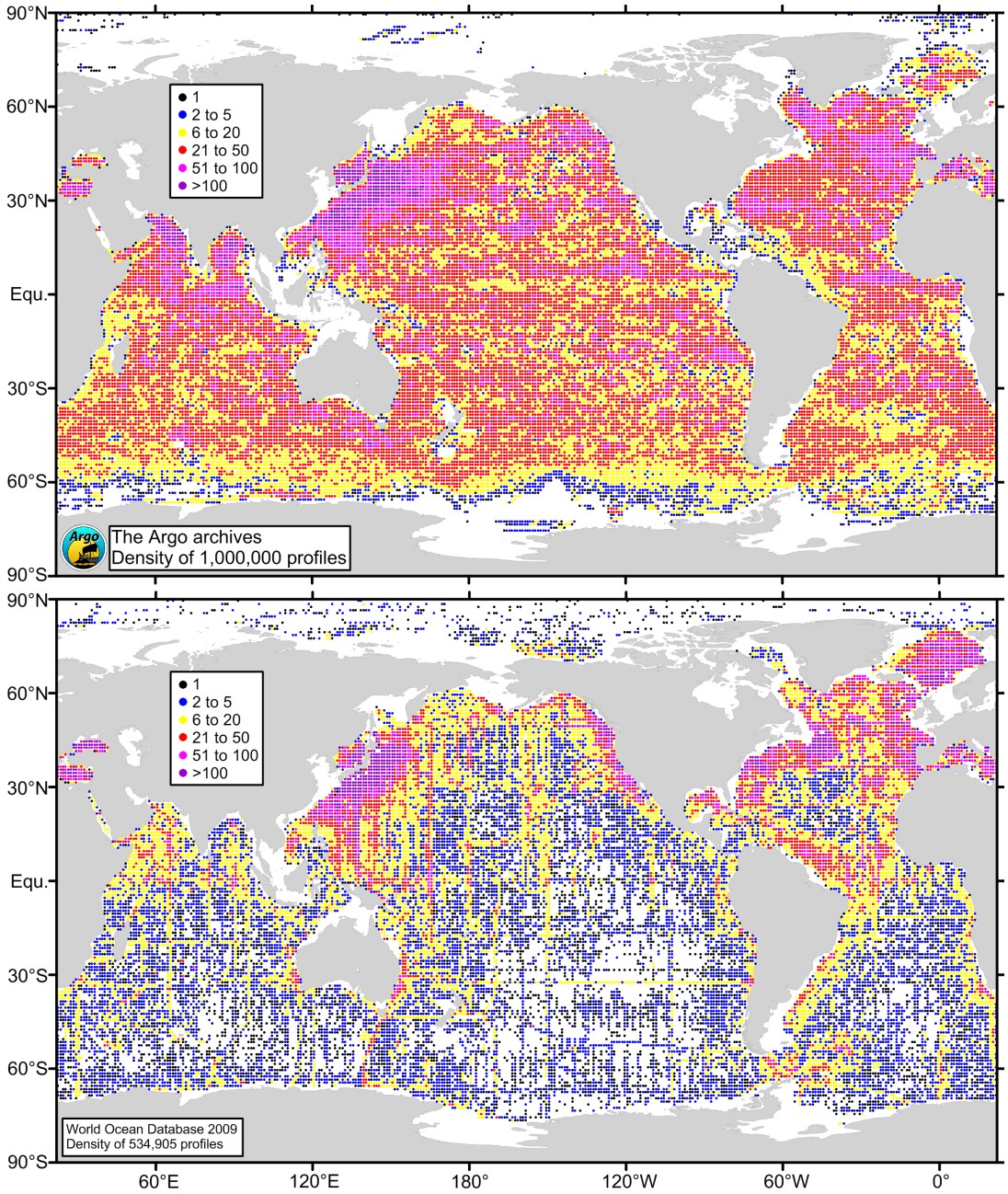


Fig. 1 Argo obtained its millionth Temperature/Salinity profile in November 2012. The number of Argo Temperature/Salinity (T/S) profiles per 1° square of ocean is displayed in the upper panel. For comparison the number of historical (non-Argo) T/S profiles per 1° square, to depth greater than 1000 m, is shown in the lower panel. Argo has collected twice as many T/S profiles as in the entire pre-Argo history of oceanography

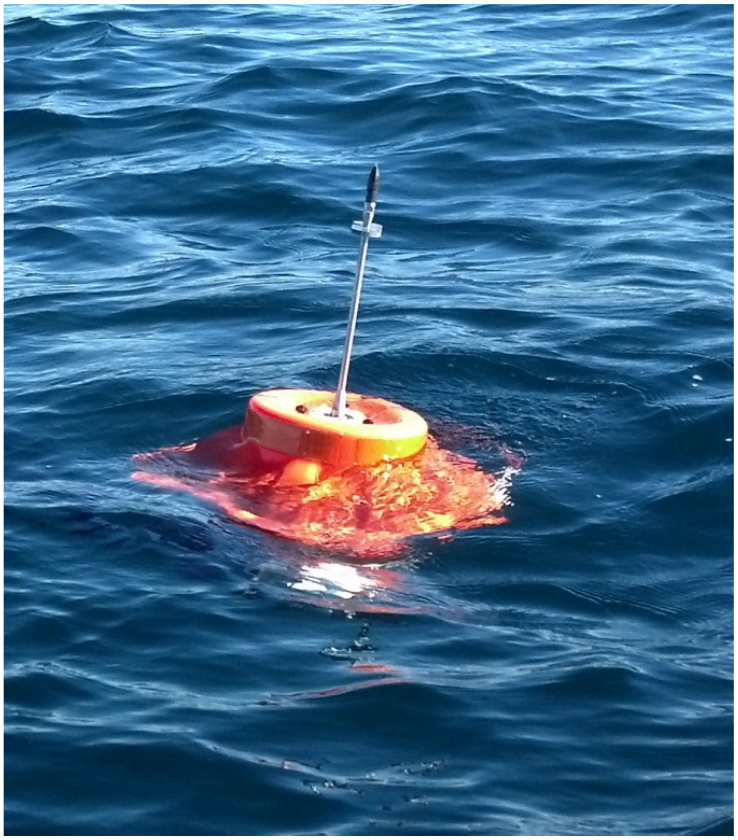


Fig. 2 A prototype Deep SOLO Argo float, capable of profiling to 6000 m depth, is deployed off Central California

SIO High Resolution XBT/XCTD Transects

Dean Roemmich, Bruce Cornuelle and Janet Sprintall (SIO)

NOAA Technical Contact: Candyce Clark (CPO)

Links to NOAA Strategic Plan:

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

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

Amendment No.: 20, 47

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 basin-spanning routes (Fig 1) that include:

- PX37/40 (North Pacific – Los Angeles to Hawaii to Yokohama)
- PX38 (North Pacific – Hawaii to Alaska)
- PX05 (Western Pacific – Brisbane to Yokohama)
- PX06/31 (Central Pacific – Auckland to Fiji to San Francisco)
- PX30 (South Pacific – Brisbane to Fiji, joint with CSIRO Australia)
- IX15/21 (South Indian –Durban to Mauritius to Fremantle)

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. D. Roemmich and HRX colleagues showed that 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. Absolute geostrophic transports for the upper 800 m are estimated using 800 m reference velocity observations from the Argo Program, and compared with measurements from moored arrays in the boundary current regions.

California NIDIS Project

Dan Cayan (SIO)

NOAA Technical Contact: C. McNutt (NIDIS)

Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
NOAA Goal 3: Serve Society's Needs for Weather and Water Information

Amendment No.: 62

Research Objectives and Specific Plans to Achieve Them

The National Integrated Drought Information System (NIDIS) aims to provide an effective drought early warning system that develops and communicates drought information to improve decision-making and thereby reduce impacts and costs. The NIDIS Pilots provide a major mechanism to explore and demonstrate a variety of early warning strategies, in partnership with stakeholders and agencies. This work, in this third year of the California NIDIS Pilot, will be to provide coordination and guidance in the design, implementation, and evaluation of the overall California Pilot and individual Pilot Activities, while maintaining close collaboration with the NIDIS Program Office, the leaders of the Pilot Activities, and stakeholders. Three major aims of this work are the following: (1) Implementation of California NIDIS Pilot and Coordination of Pilot Activities; (2) Evaluation of California NIDIS Pilot and Overall Process; (3) Design of Drought Indicators, Triggers, and Early Warning System. Work will be conducted throughout the State of California and, in particular, in the four Pilot Activity regions: Klamath Basin, Russian River, Southern California, and Central Valley. Results of this work will contribute not only to California, but also to the larger NIDIS effort, ensuring innovations through the California Pilot that can be transferable to the nation.

Research Accomplishments

1. Design of California NIDIS Pilot and Implementation Strategy

- Assisted in development of process for elicitation of potential NIDIS Pilot projects. Four Pilot Activities were selected through group processes and criteria developed during planning meetings.

- Communicated with personnel in other NIDIS Pilots and the NIDIS Program Office to obtain insights, experiences, and lessons. Coordinated with other Pilot Activity leaders to determine objectives and processes for the Pilot. Ensure that the four Pilot Activities will generate synergies and opportunities for cross-learning, with lessons and resources that can be transferred to other regions and states.

- Provided coordination for the meetings and the selection process. Designed roundtable discussions, including questions to be asked, format for eliciting input, intended outcomes from meetings, and follow-up procedures. Identified participants to be included at meetings and in NIDIS Pilot activities, and communicated with participants. More than one hundred stakeholders have been involved in the California NIDIS Pilot, with about half in the Southern California Pilot Activity.

- Assisted in development of criteria for NIDIS Pilot and Pilot Activities. Synthesized stakeholder input and refine list of criteria. Presented revised list of criteria to stakeholders, and incorporated additional feedback.

- Identified critical drought issues for focus of NIDIS Pilot Activities. Identified stakeholders to be involved, along with goals, processes, and expected outcomes. Together with Pilot Activity leaders, determined objectives for Pilot, and ways to develop results and resources that would be useful to the rest of the county.

2. Evaluation of California NIDIS Pilot and Process

- Developed protocols to document activities in each stage of implementation. Developed evaluation criteria, metrics, and methods for data collection and analysis. Currently collecting data on the use and potential value of NIDIS Pilot Activities and information. A primary finding is that stakeholders can identify specific and

needed applications of NIDIS drought early warning information, and the economic and societal benefits of using that information.

- Performed first-phase evaluation of NIDIS Pilot. Dimensions include the following: What would make a successful pilot? How do the Pilot Activities each contribute to that success? How would NIDIS drought information be used and integrated into decision-making? What are the net benefits of the use of that information to reduce drought impacts and costs? What can NIDIS provide decision-makers that wouldn't otherwise be possible? What resources and lessons can be transferred from California to the rest of the county? Stakeholders indicated that NIDIS offers a valuable and needed resource that doesn't otherwise exist, and it could provide a centralized, authoritative, integrated, and usable source of drought information.

- Performed first-phase evaluation of NIDIS Process. Dimensions include the following: What is a successful process for the NIDIS Pilot Activities? What are criteria for evaluation? Were the processes fair, efficient, participatory, and support? What do stakeholders think? What recommendations can we provide for future NIDIS Pilot efforts? Stakeholders indicated that the NIDIS Pilot Activity processes and meetings have been inclusive and valuable, and cite specific benefits of the meetings and the overall NIDIS process and goals.

3. Evaluation of Drought Indicators, Triggers, and Early Warning System

- Compiled and compared the range of drought indicators used by decision-makers (e.g., water managers) in each of the pilots, and links with drought decisions. Nearly half of the agencies rely on the U.S. Drought Monitor for assessing and triggering drought, even though they note its limitations for regional and local drought assessment.

- Developed criteria for drought indicator evaluation. For instance, what is a "good" drought indicator and early warning system? In the absence of a gold standard for drought, design ways to assess indicator performance. For instance, one set of criteria relate to an indicator providing early warning, without false alarm or false assurance.

- Determined possible indicators for integrated NIDIS drought information resources, including indicators for varying types of decisions and early warning time frames, drought supplies, drought demands, temporal and spatial scales, historic analogs, climatologies, and formats. Stakeholders indicated the value of a percentile-based system, which can be used to compare different indicators and varying temporal and spatial scales, and for messaging to the public in a way that is understandable and useful.

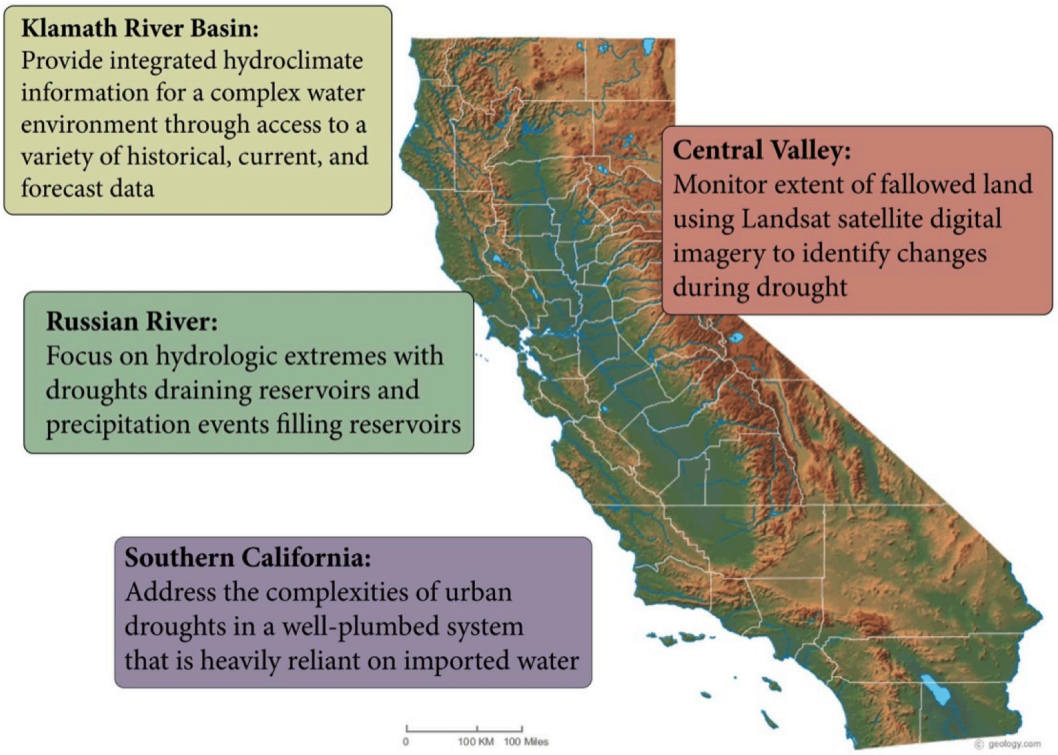


Fig. 1 California NIDIS Pilot, and Pilot Activities

The Center for Stock Assessment Research (CSTAR)

Marc Mangel (UC Santa Cruz)

NOAA Technical Contact: Steve Ralston (NMFS)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: 1, 35, 54

Research Objectives and Specific Plans to Achieve Them

The objective of CSTAR is 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.

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
Eric Anderson (Staff Member, NMFS Santa Cruz Laboratory)
Carl Boettiger (Postdoctoral Scholar)
Christie Boone (PhD Anthropology, June 2012)
Mariah Boyle (Assistant Project Director, FishWise)
Edward (EJ) Dick (Staff member, NMFS Santa Cruz Laboratory)
Chris Edwards (Faculty, UCSC)
Sigrunn Eliassen (sabbatical visitor from the Theoretical Ecology Group, University of Bergen, 2011-12)
John Field (Staff Member, NMFS Santa Cruz Laboratory, co-Director)
Xi He (Staff member, NMFS Santa Cruz Laboratory)
Meisha Key (Staff member, California Department of Fish and Wildlife)
Thanassis Kottas (Faculty, UCSC)
Daniel Ladd (MSc Student, Statistics and Applied Mathematics)
Taal Levi (PhD Environmental Studies, June 2012)
Juan Lopez (PhD student, Applied Mathematics)

Alec MacCall (Staff member, NMFS Santa Cruz Laboratory)
Marc Mangel (Faculty UCSC, Co-director)
Melissa Hedges Monk (Postdoctoral Scholar)
Steve Munch (Staff member, NMFS Santa Cruz Laboratory)
Roxanna Pourzand (Undergraduate research fellow)
Steve Ralston (Staff member, NMFS Santa Cruz Laboratory)
Kate Richerson (PhD student, Ecology and Evolutionary Biology)
Santiago Salinas (Postdoctoral Scholar)
Jarrod Santora (Independent AMLR contractor)
Hans Skaug (sabbatical visitor from the Department of Mathematics, University of Bergen, 2012-13)
Braden Soper (PhD student, Applied Mathematics)
Will Satterthwaite (Staff member, NMFS Sants Cruz Laboratory)
Simone Vincenzi (Research scientist, MRAG Americas and EU Marie Curie Outgoing Fellow)
Brian Wells (Staff member, NMFS Santa Cruz Laboratory)
Justin Yeakel (PhD Ecology and Evolutionary Biology, June 2012)

Research Accomplishments

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. Undergraduate student Roxnna Pourzand completed her research project on steepness and life history variables, graduated with honors, and accepted employment at Oracle Corporation. Graduate students Christie Boone, Taal Levi, and Justin Yeakel completed PhDs (in Anthropology, Environmental Studies, and Ecology and Evolutionary Biology respectively). Boone is currently on maternity leave, Levi holds a NSF Postdoctoral Fellowship, and Yeakel is a post-doctoral scholar with Jonathan Moore at Simon Fraser University. Student Daniel Ladd completed a MSc project in Statistics and Applied Mathematics that included work with members of the FED Economics Team estimating the elasticity of labor with respect to water in the Central Valley of California, student Juan Lopez began a collaboration with members of the Landscape Ecology team on steelhead in the Santa Ynez mountains and on the Carmel River, student Kate Richerson continued her close collaboration with US AMLR, including participating in the first ever AMLR Austral winter cruise, and student Braden Soper continued his work with the Groundfish team on the analysis of recreational catch data as it is relevant to stock assessments. Post-doc Simone Vincenzi completed work on kittiwakes and environmental change in the Bering Sea and transitioned to his own funding with an EU Marie Curie International Outgoing Fellowship, which will allow him to spend 2 calendar years at CSTAR, working with the Molecular Ecology and Genetic Analysis team and CSTAR Director Mangel on climate change, life history and genetics of marbled trout. Melissa Monk and Carl Boettiger joined CSTAR as post-docs; Monk began work with the Groundfish team on the determination of habitat and abundance indicates for rockfish fisheries Boettiger began work combining non-parametric models of stock dynamics and stochastic dynamic programming models for fishery management, working with the Salmon Ecology team. CSTAR affiliate Mariah Boyle (FishWise) continued her outstanding work on IUU (Illegal, Unreported, and Unregulared) fishing and wrote two high profile white papers on the subject and CSTAR affiliate Jarrod Santora continued his work with US AMLR and with the Salmon Ecology team on Integrated Ecosystem Assessment. CSTAR Director Mangel completed service on the Lenfest Forage Fish Task Force. CSTAR sabbatical visitors from the University of Bergen were Sigrunn Elliasen (Department of Biology), working directly with Director Mangel, and Hans Skaug (Department of Mathematics) working with Eric Andersen and the Salmon Genetics Team.

Operation of R/V Roger Revelle, Exploring one of Earth's Most Volcanically Active Plate Boundaries: The NE Lau Basin Between Arc and Back-Arc

Bruce Appelgate (SIO)

NOAA Technical Contact: D. Simon (PMEL)

Links to NOAA Strategic Plan:

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

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

Amendment No.: 61

Research Objectives and Specific Plans to Achieve Them

This grant funded the cost of operating the Research Vessel Roger Revelle to deploy an ambitious ROV-based exploration and sampling program of active submarine volcanic and hydrothermal fields in the northeast Lau Basin (south of Fiji). To fulfill this objective, Scripps Insitution 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 Fiji and Samoa to handle pre-and post- cruise mobilization and demobilization (respectively), and all port logistics were arranged by the Scripps Nimitz Marine Facility staff. Foreign clearances to work in the waters of Fiji, Samoa and Tonga were 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, including establishment of satellite transmission of HD-quality video and audio in real time as ROV observations were made on the seafloor.

Research Accomplishments

This program supported ship time and shipboard technical services to carry out the second year of a two-year program to explore active volcanic and hydrothermal systems in the northeast Lau basin using water column surveys, a towed camera, and a remotely operated vehicle (ROV). Ship operations would commenced on 07 September 2012 with the mobilization in Suva, Fiji of a third-party remotely-operated vehicle (QUEST 4000, operated by University of Bremen, Germany) as well as ancillary power and handling machinery including modification of the ship's A-frame.

During twenty operational days at sea the science party successfully met its objectives to map out hydrothermal sites and their deposits, to retrieve fluid, biology, and rock/mineral samples for immediate shipboard and later shore-side laboratory analyses, and characterize these ecosystems based on their geology, chemistry, and macro- and micro- biology. Secondary objectives were also met, including 1) examination of hydrothermal output and exploration for new hydrothermal sites using the shipboard CTD system for vertical and towed hydrocasts, 2) understanding the regional geomorphology and the geophysical drivers by using the EM122 multibeam system and a towed magnetometer, and 3) measuring local and regional water currents using the ship board ADCP and Hydrographic Doppler sonar system.

These explorations follow the 2008 discovery of plumes emanating from two ongoing eruptions and several additional hydrothermal sources. A 2009 research survey explored the eruption sites using the JASON-2 remotely-operated vehicle. The West Mata volcano was found to be erupting lava at two summit sites at ~1200 m depth. We now realize that the NE Lau basin is a locus of particularly diverse volcanic and hydrothermal activity over a large depth range (~1000- 2000 m) within a small geographic area, making this area a uniquely rich exploration site.

Shipboard Monitoring of the California Current System Off Central California

Baldo Marinovic (UC Santa Cruz)

NOAA Technical Contact: Steve Miller (NMFS)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: 4, 32, 50

Research Objectives and Specific Plans to Achieve Them

In cooperation with the NMFS, we propose to continue shipboard measurements along CalCOFI Lines 67 and possibly 60 through September 2013. Personnel will be provided to assist in the collection of data during the NMFS run Winter and Spring cruises of 2013. Additional surveys along Lines 67 and 60 will be conducted in the Fall of 2012 and the Summer of 2013, pending the availability of opportunistic shiptime. Potential measurements in Fall 2012 and Summer 2013 will consist of CTD/rosette casts, plankton tows, VMADCP current observations, and continuous underway measurements of sea surface and meteorological parameters. Seawater will be assayed for nutrients (nitrate, nitrite, phophase and silicate). Water samples in the upper 200 m will also be assayed for chlorophyll-a, primary production, phytoplankton taxonomy and cell counts. Zooplankton sampling will include standard bongo oblique tows to 210 m depth. Samples will be preserved in 10% buffered formalin/seawater and processed post-cruise in the laboratory. Biovolume displacements will be initially determined and then samples will be archived at NMFS-La Jolla where taxon specific processing will be conducted by various research groups. All data collected on the fall and potential summer cruises will be made available as soon as possible to other researchers via web based archives and technical reports, e.g. Rago et al., 2012.

Research Accomplishments

Accomplishments during the reporting period can be broken up into 3 major categories

1) Data Analysis of the hydrographic and biological data collected from the March 2012 survey have been completed. This includes thorough work up of all CTD data and water samples (nutrients, chlorophyll, phytoplankton) as well as zooplankton samples (biovolume displacements, euphausiid abundance/size structure).
2) Physical data have been utilized in a number of larger scale studies including

- a comparison of the geostrophic shear between station 67-90 and the Aloha site north of Oahu (which is close to the surface center of the subtropical gyre). The data show weak poleward geostrophic flow below about 700 m
-Characterization of an enhanced oxygen minimum off Monterey Bay, likely caused by tidal mixing
-investigation of long term trends of oxygen on isopycnal surfaces, the results of which do not really show a significant long term trend

3) Providing personnel for hydrographic sampling on the northern legs of the 3013 Winter and Spring CalCOFI surveys conducting by NMFS.

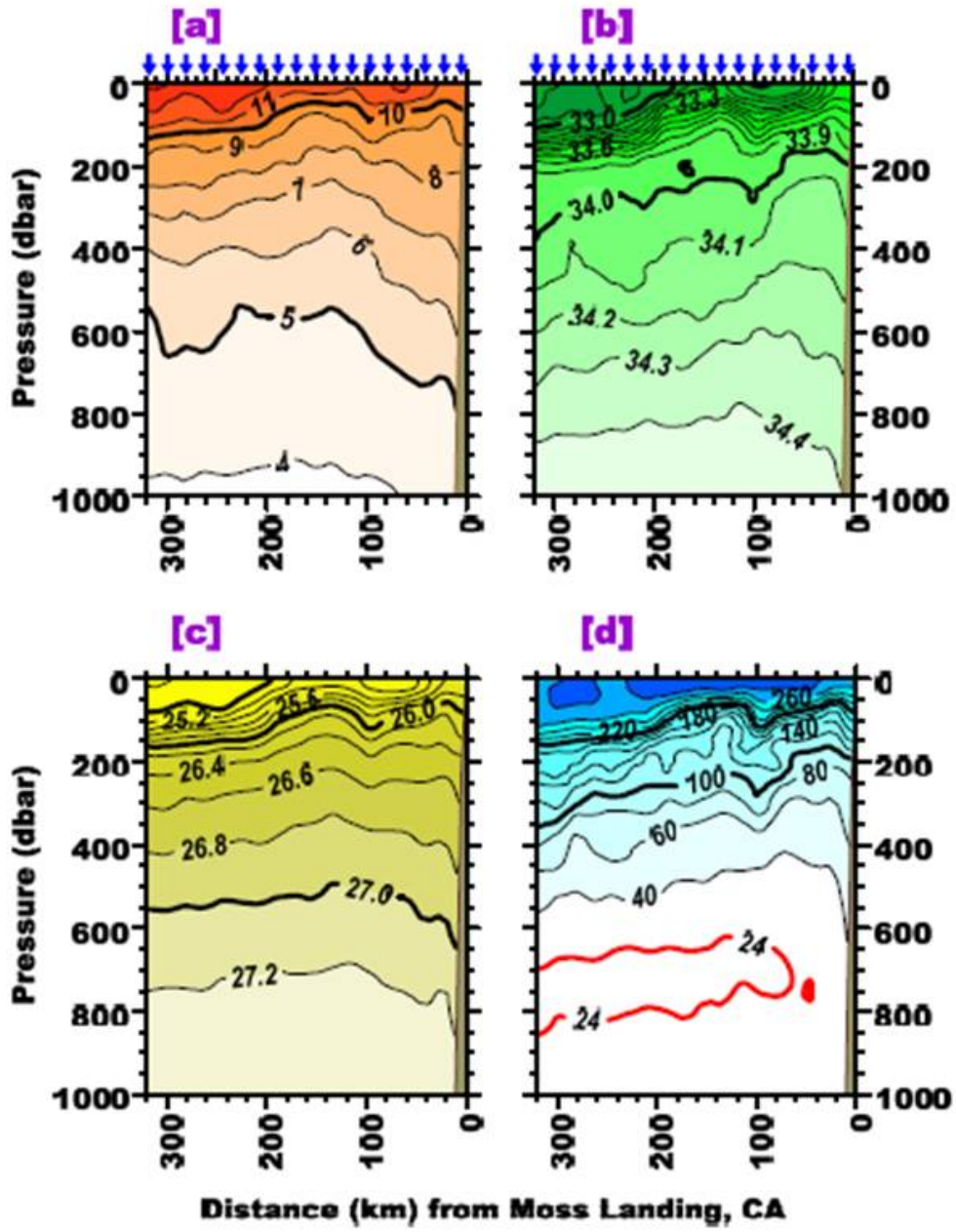


Fig. 1 Contours of **(a)** temperature (^{o}C), **(b)** salinity, **(c)** density anomaly (kg m-3), and **(d)** oxygen (mmol kg-1) fields along the line of hydrographic stations from Moss Landing, California, (on the right) to CalCOFI station 67-90 (on the left). The blue arrows along the top axes in the upper two panels indicate the locations of CTD casts. Contour intervals for panels a-d are 1oC, 0.1, 0.2 kg m-3, and 20 mmol kg-1, respectively, except that the (nearly) oxygen minimum contour of 24 mmol kg-1 is highlighted in red in panel d. Other highlighted contours are 5o and 10oC (upper left), 33 and 34 (upper right), 25, 26, and 27 kg m-3 (lower left), and 100 and 200 mmol kg-1 (lower right)

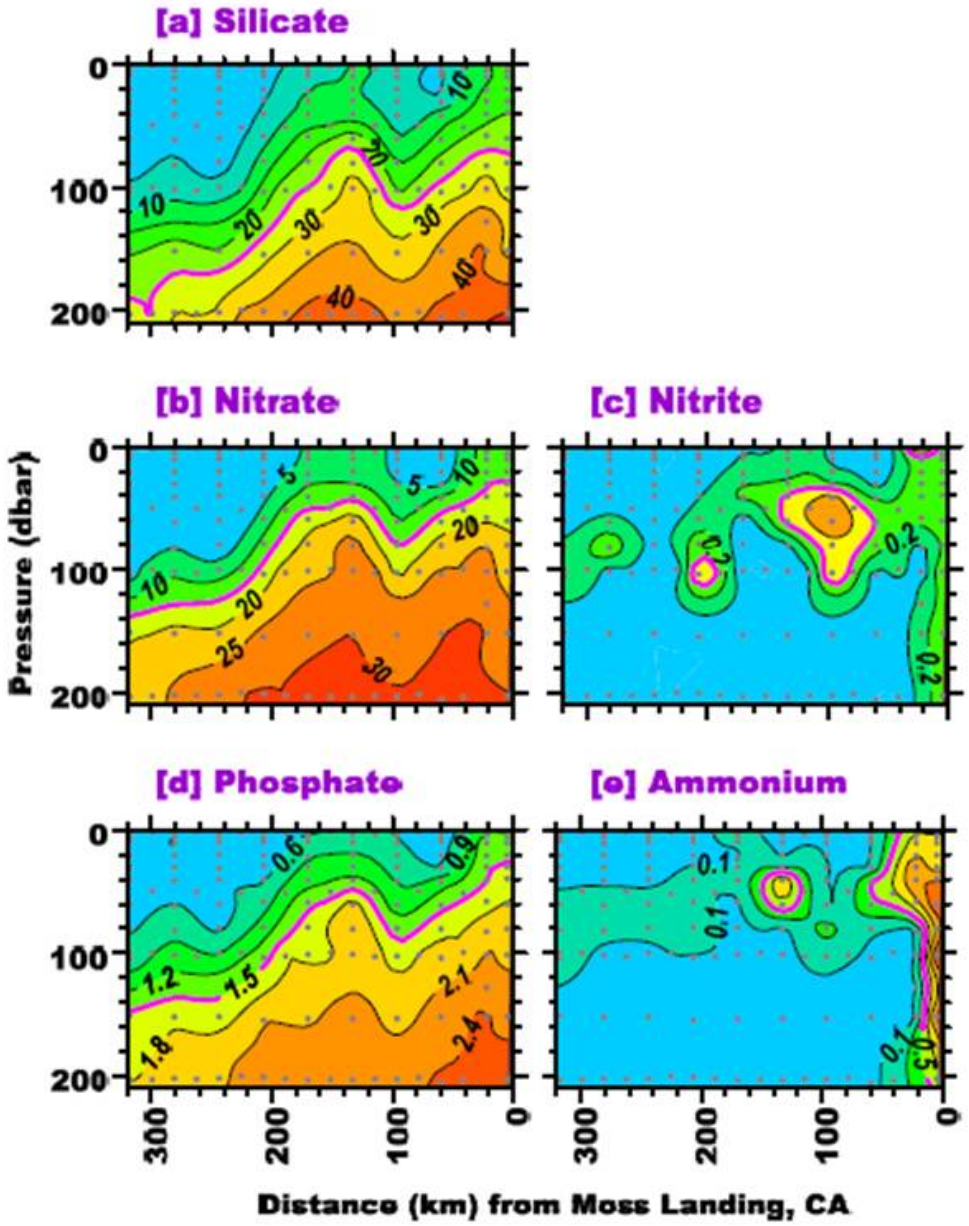


Fig. 2 Contours of **(a)** silicate (mM), **(b)** nitrate (mM), **(c)** nitrite (mM), **(d)** phosphate (mM), and **(e)** ammonium (mM) fields along the line of hydrographic stations from Moss Landing, California, (on the right) to CalCOFI station 67-90 (on the left). The dots indicate the water sample locations. Contour intervals for panels a-e are 5 mM, 5 mM, 0.1 mM, 0.3mM, and 0.2mM, respectively. Highlighted contours are 25mM, 15 mM, 0.3mM, 1.5 mM, and 0.5mM for panels a-e, respectively

Investigations in Fisheries Ecology

Eric Palkovacs (UC Santa Cruz)

NOAA Technical Contact: Steve Miller (NMFS)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management
Amendment No.: 6, 22, 63

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 11 objectives: (1) develop improved historical catch statistics and demographic data for commercially important groundfish; (2) examine effects of habitat complexity and productivity on growth and production of juvenile salmonids in the context of habitat restoration; (3) conduct surveys and analyses of deep-sea coral communities off the West Coast to assess the distribution and habitat of these communities; (4) expand habitat-based predictive models and maps of distribution and abundance of demersal fishes in southern California; (5) evaluate the economic effects of salmon restoration activities on affected human uses and the effects of groundfish regulations on the spatial behavior of commercial groundfish vessels; (6) develop an integrated genetic monitoring and evaluation program for salmon and steelhead in California; (7) develop physical and biological models and decision support tools to aid fisheries and water management and habitat restoration for listed salmonids; (8) develop ecosystem indicators, risk assessments, and management strategy evaluation tools to guide management of anadromous species as part of an Integrated Ecosystem Assessment for the California Current; (9) develop mathematical and statistical tools to improve salmon stock assessments and population dynamics models; (10) conduct comparative studies of salmon ecology and life history across small and large rivers and estuaries; and (11) assess climate-ecosystem linkages at interannual to decadal time scales in the North Pacific Ocean and disseminate satellite-derived oceanographic data. 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 each of the 11 projects described above, which addressed a wide range of topics on biology, analytical methods, and economics related to the management of groundfish, salmon, sturgeon, and the California Current ecosystem. 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 research staff, developing research plans and protocols, and beginning data collection or model development. Results were published in 24 journal articles and 16 reports, and an additional 18 articles were in press or submitted. Project scientists engaged in more than 29 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.

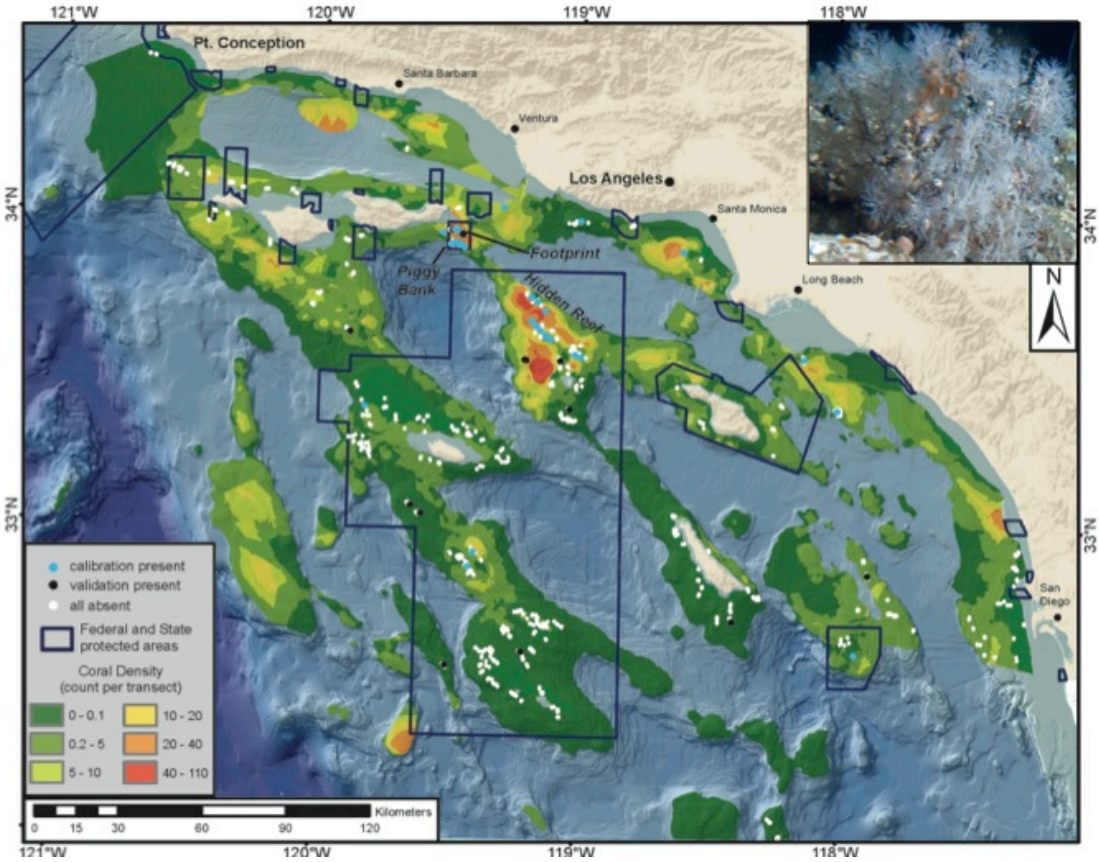
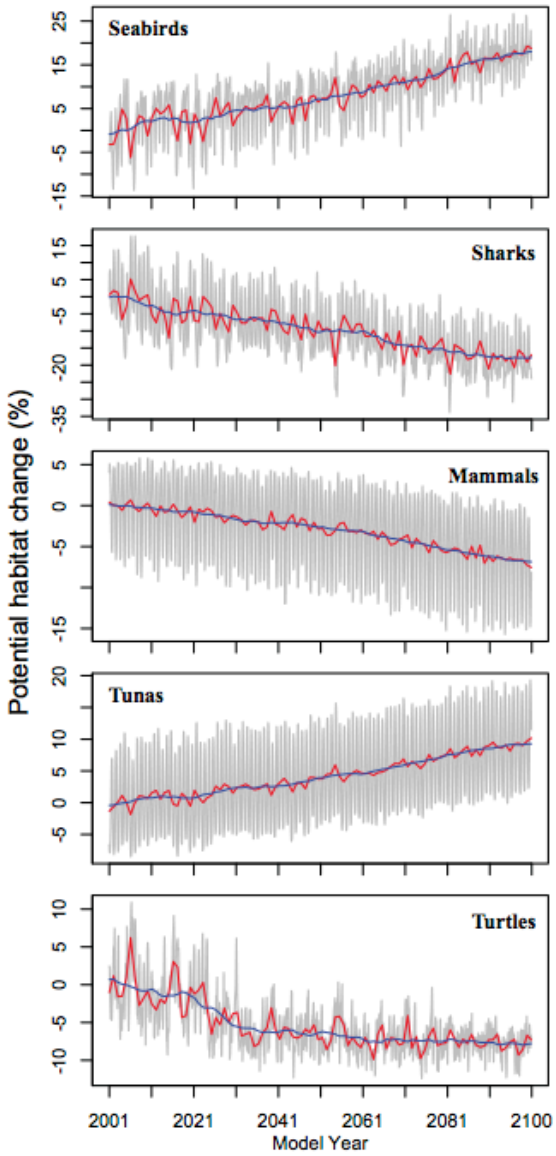


Fig. 1 Distribution and density of deep-water Christmas tree corals predicted from environmental factors, along with boundaries of areas closed to fishing, throughout the Southern California Bight. Inset: In situ image of a coral colony



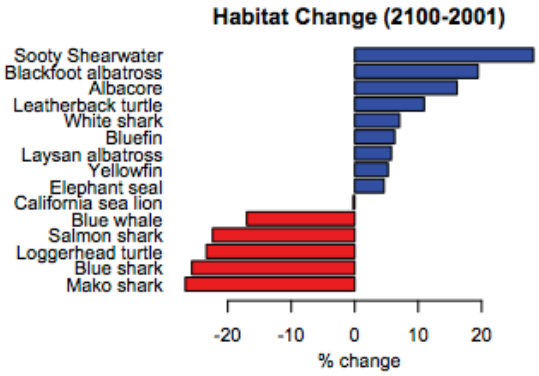


Fig. 2 Predicted changes in top predator core habitat by guild. (Left panels) Top predator core habitat area by guild from 2000 to 2100 shown as monthly (grey), yearly (red) and 5-year filtered (blue) time series with 1 standard deviation marked by dashed lines. (Right panel) Total predicted mean habitat change from 2001 to 2100 for each of the 15 top predator species with 1 standard deviation error bars. From Hazen et al. (2013)

Freshwater Ecology Research Collaboration

Eric Palkovacs (UC Santa Cruz)

NOAA Technical Contact: Steve Miller (NMFS)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management
Amendment No.: 9, 21, 52

Research Objectives and Specific Plans to Achieve Them

A faculty member will be selected to be the Project Leader for the Freshwater Ecology Research Collaboration. The individual will develop a research program with primary components of population dynamics, evolutionary development and environmental dynamics that complements ongoing and future science needs of NMFS. This work is relevant to improved understanding of ecological factors influencing anadromous fishes utilizing California freshwater ecosystems. Also, he/she will be the faculty adviser and mentor of students conducting research relevant to NMFS interests, through which means he/she is able to direct students to potential collaborations with NMFS researchers. In addition, the faculty member will be expected to teach graduate and undergraduate classes, adding elements of environmental resource analysis and management to the curriculum, incorporating the Marine Ecosystems theme of CIMEC and support fostering the public understanding of NOAA and its programs.

Dr. Eric Palkovacs was selected this year as this new faculty member. His primary objectives were 1) to establish the Palkovacs Laboratory at UCSC, 2) continue to make progress on existing projects, and 3) establish and fund new projects and collaborations in California. To accomplish these goals, he hired a postdoc (Dr. Daniel Hasselman), a research technician (Emily Argo), and took on one PhD student (David Fryxell). All have been extremely productive. This year, the Palkovacs Lab has published 4 peer-reviewed papers and has 3 more in review. He has organized and contributed to several working groups, established numerous research collaborations, and initiated connections for K-16 education and outreach.

Research Accomplishments

Continuing projects:

1) River herring population genetic structure and demography – presented at Endangered Species Act Working Group; paper submitted to Evolutionary Applications (EP Palkovacs first author)
2) River herring bycatch assignment using microsatellites – data collection complete, analysis underway by Dr. Daniel Hasselman (Palkovacs Lab Postdoc)
3) Alewife landocking and rate of evolution – paper submitted to Biology Letters (EP Palkovacs first author)
4) Alewife and blueback herring hybridization – analysis complete, manuscript preparation in progress (DJ Hasselman first author)

New projects:

5) Ecological effects of temperature adaptation in Gambusia – Dave Fryxell (Palkovacs Lab PhD Student) obtained NSF Graduate Research Fellowship and NSF East Asia Pacific Summer Institute Fellowship to pursue this project in California and New Zealand (with Dr. Kevin Simon, University of Auckland)
6) Ecological causes and consequences of chromosome 5 variation in Steelhead Trout – obtained funding to analyze existing chromosome 5 data in the context of environmental variables (with Dr. Devon Pearse, NMFS SWFSC)
7) Trait variation among Golden Trout populations in the Sierra Nevada – selected lakes to examine for trait variation (with Dr. Stephanie Carlson, UC Berkeley and Dr. Roland Knapp, Sierra Nevada Aquatic Research Laboratory)
8) Pupfish extinction risk due to climate change – began collecting data for extinction modeling (with Dr. Barry Sinervo and Dave Fryxell, UCSC)
9) Testing eco-evolutionary trophic cascades in aquatic ecosystems – submitted NSF proposal (with Dr. Mike Kinnison, University of Maine)

10) Selection on anadromous fishes driven by fishways – began analysis of Connecticut River fishway selectivity on size and body shape variation in American Shad (with Ted Castro-Santos, USGS).

Fig. 1 Alewives at Damariscotta Mills, Maine (Photo by Peter Stetson). Anadromous alewife (*Alosa pseudoharengus*) is being considered for Endangered Species Act listing. Population genetic analysis indicates three distinct genetic stocks (Northern New England, Southern New England, Mid-Atlantic). Analysis of demographic trends show that all stocks have declined, but that the Southern New England Stock has declined most dramatically over recent decades.

Freshwater Fish Ecology Research Collaboration

Darren Ward (Humboldt State University)

NOAA Technical Contact: Steve Miller (NMFS)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management
Amendment No.: 3, 29, 49

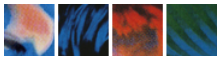
Research Objectives and Specific Plans to Achieve Them

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 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 research proposals. In the 2012-2013 project period, the first finishing graduate student from the Ward laboratory at Humboldt State defended her thesis. Jennifer Hauer's graduate work quantified variation in juvenile life history of ESA-listed coho salmon in Freshwater Creek, a tributary of Humboldt Bay in Northern California. Her work is already being applied to guide improved population monitoring techniques in coastal salmonid monitoring programs. Two additional research projects are in the final stages. Graduate student Shari Anderson, a NOAA Advanced Studies student, has completed an intensive field study to evaluate the growth and habitat use of ESA-listed juvenile coho salmon using natural off-channel ponds and ponds constructed for habitat enhancement in tributaries of the Klamath River. Graduate student Meiling Roddam is wrapping up data collection on a study that combines mark-recapture and otolith microchemistry to evaluate Chinook salmon smolt production from discrete spawning and rearing areas in the Shasta River, a large Klamath River tributary. Part of the research cost for Meiling's work is funded through a separate CIMEC project (Studies in Anadromous Fisheries). Meiling Roddam and Shari Anderson plan to complete analyses and writing and defend their theses in Fall 2013. Projects in progress include graduate student Sean Cochran's analysis of time-series data and archived scale samples from coho salmon monitoring projects all along the California coast to identify links among freshwater growth, early marine growth, and marine survival. Two new students are coming into the Ward laboratory this coming fall to continue work on coho salmon in the Klamath River in support of NMFS salmon conservation objectives.



Ocean Observing and Fisheries Oceanography Research of the Coastal Ocean off Northern California

Jeffrey Abell (Humboldt State University)

NOAA Technical Contact: Steve Miller (NMFS)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management
Amendment No.: 34

Research Objectives and Specific Plans to Achieve Them

The 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 was hired to fill the technician position supported under this grant and has proven to be a tremendous asset to the program. She has coordinated and led 14 successful cruises along the Trinidad Head Line, processed hydrographic data, overseen 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. Results from these surveys indicate that despite hydrographic evidence of upwelling, phytoplankton stocks (as indexed by concentrations of chl a) did not

develop normally, and remained low throughout summer 2012 following unusually strong storms late in Spring 2012 (see Figure).

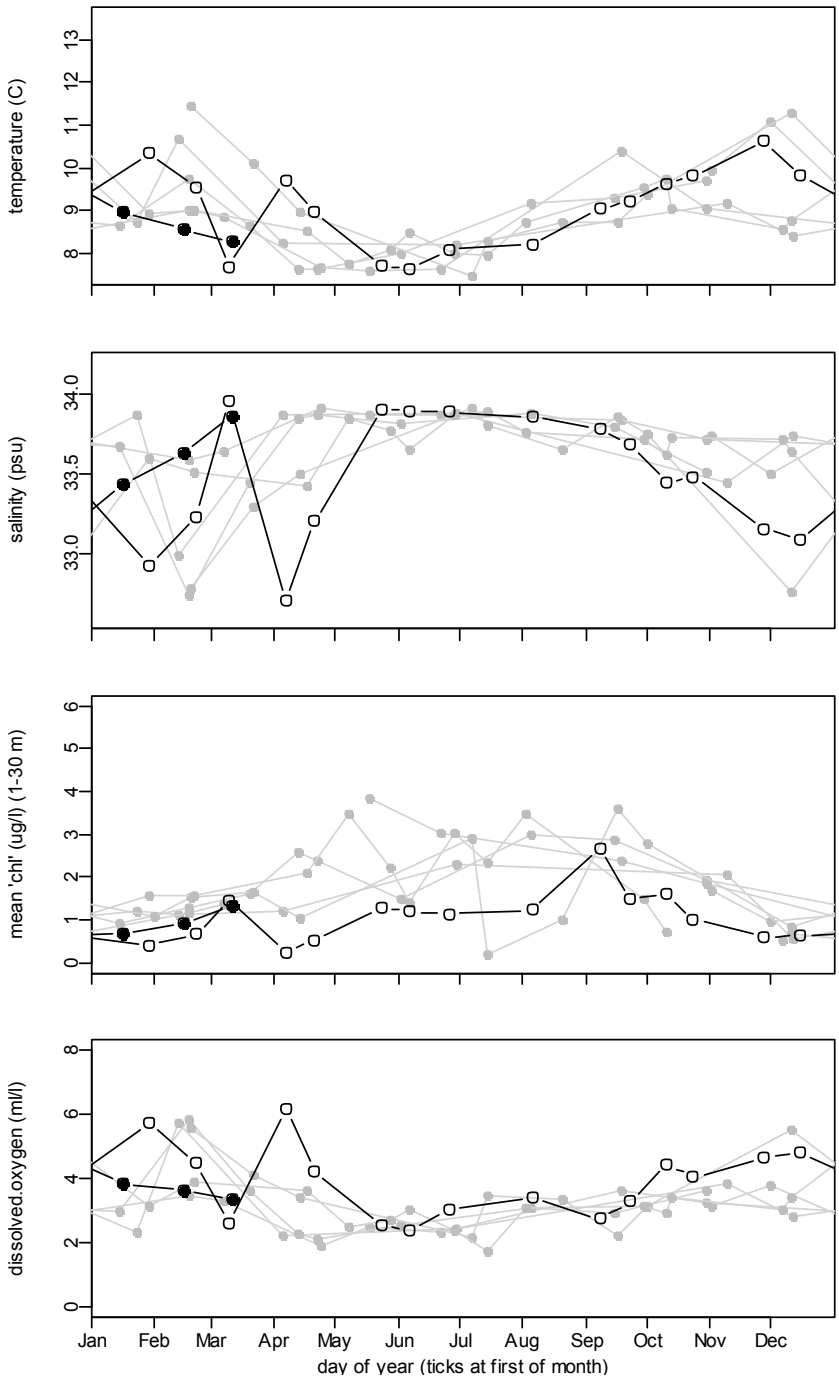


Fig. 1 Ocean observations at station TH02 (approximately mid-shelf, 41° 03.5' N, 124° 16' W, 75m depth) along the Trinidad Head Line by calendar year. From top to bottom: temperature at 60 m, salinity at 60 m, mean 'chlorophyll' concentration (ug/l based on fluorometer) over the upper 30 m of the water column, and dissolved oxygen at 50 m. Dark lines indicate observations over 2012 (open black circles) and early 2013 (solid black circles); grey lines and symbols indicate observations over previous years (late 2006-2011)

Collaborative Studies of Cetaceans with the Southeast Fisheries Science

John Hildebrand (SIO)

NOAA Technical Contact: L. Garrison (NMFS/SEFSC)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management
Amendment No.: 13, 55

Research Objectives and Specific Plans to Achieve Them

The goal of this project is to conduct acoustic observations of cetaceans during the Gulf of Mexico Sperm Whale Cruise (GMSWC) on the NOAA Ship Gordon Gunter and using High-frequency Acoustic Recording Packages (HARPs) deployed in the southeastern Gulf of Mexico. A broadband towed hydrophone array was sent to the Gulf of Mexico, along with personnel to operate the array, during a three leg cruise (total 55 days at sea). Recordings of cetacean sounds were collected to aid in characterization of sounds by species. Two HARPs were deployed in the southeastern Gulf of Mexico, and their acoustic data analyzed for marine mammal sounds to better understand the distribution of marine mammal populations in the Gulf of Mexico.

Research Accomplishments

SIO provided personnel and support for conducting towed array acoustic measurement on the NOAA Ship Gordon Gunter during cruises in summer 2012. SIO provided an acoustic array and personnel to collect data on cetacean presence and sound production on these cruises. The array provided broadband (1 kHz – 200 kHz) frequency response to provide characterization of the full bandwidth of cetacean sounds. The array also provided the direction to calling cetaceans. The acoustic array information will be used to better characterize the acoustic repertoire of cetacean populations in the Gulf of Mexico. In addition, two HARPs were deployed in the Gulf of Mexico to collect long-term passive acoustic monitoring for cetaceans.

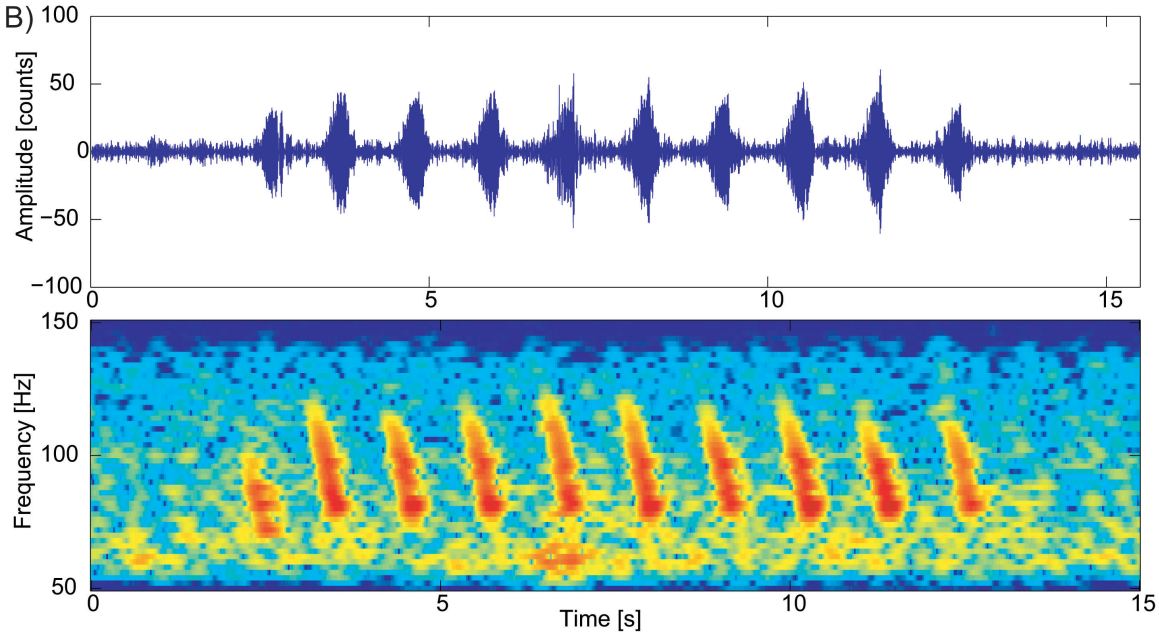


Fig. 1 Waveform (top) and spectrogram (bottom) of Brydes whale calls recorded in the Gulf of Mexico

Collaborative Studies of Cetaceans Using Passive Acoustic Monitoring with the Pacific Islands Fisheries Science Center

John Hildebrand (SIO)

NOAA Technical Contact: E. Oleson (NMFS/PIFSC)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management
Amendment No.: 14, 46

Research Objectives and Specific Plans to Achieve Them

The goal of this project is to collaborate with the NOAA Pacific Island Fisheries Science Center (PIFSC) to conduct analysis of acoustic data focusing on cetaceans and noise recorded through the central and western Pacific Ocean. Scripps Institution of Oceanography (SIO) will conduct three studies: (1) examine the interaction of false killer whales and long-line fisheries; (2) characterize local and regional ocean noise from data collected in the Pacific Islands region; and (3) describe echolocation clicks from false killer whales and short-finned pilot whales to enable easier acoustic classification.

Research Accomplishments

SIO characterized monthly and daily low frequency noise, from 15 Hz to 1 kHz, from data collected at seven sites across the central and western Pacific Ocean. Sounds at these lower frequencies propagate over long distances and thus have contributions from shipping and other distant sources, as well as nearby anthropogenic sources. Noise at higher frequencies (>1 kHz) is usually dominated by local sea conditions (sea state, precipitation). We found that the contributions to the sound field can be attributed to anthropogenic, environmental, and cetacean sources. Interestingly, noise levels from distant shipping were commonly lower during 2009 than 2010, possibly a reflection of the change in shipping levels in the Pacific as the recession eased in 2010, resulting in increasing shipping. However, there was no direct relationship between shipping indices as obtained from AIS data and local shipping noise. Other anthropogenic sources of sounds across the Pacific include low-frequency sonar (recorded off Saipan) and Navy underwater communication modem signals. Cetacean contributions to background noise were seasonal and we detected substantial contributions from blue whales, fin whales, humpback whales, and Bryde's whale calls during parts of the year. Manuscript on this work has been submitted for review to the Journal of the Acoustical Society of America.
SIO also constructed a small, acoustic recorder for attaching to longline fishing gear. Ocean tests have been conducted with NMFS-PIFSC and the recorders have been deployed and recovered from longline fishing gear near Hawaii. Multiple longline HARPs have been delivered to the PIFSC. SIO is also finishing the analysis on classification of echolocation clicks from false killer whales and short-finned pilot whales to enable easier acoustic classification. A manuscript will be prepared describing the approach used for this method.

Measurements of North Atlantic Ambient Noise

John Hildebrand (SIO)

NOAA Technical Contact: J. Gedamke (MED)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management
Amendment No.: 53

Research Objectives and Specific Plans to Achieve Them

This project will examine changes in North Atlantic ocean ambient noise by comparing measurements conducted south of Bermuda in 1966 with current noise levels. An autonomous acoustic recorder will be deployed at a previously studied location south of Bermuda. Data will be compared for shipping and other anthropogenic noise sources as well as environmental contributions (wind and waves). A year-long study of ambient noise was conducted during 1966 southwest of Bermuda. We propose to place an autonomous seafloor recorder at the site of the 1966 recordings so that direct comparison can be made without the need to correct for site dependency. The bandwidth of the new recordings (100 kHz) will be greater than the bandwidth used in 1966 (400 Hz), allowing a baseline to be established for mid-frequency as well as low-frequency noise. We expect to find an increase (3 dB/decade) in shipping noise at the Bermuda site.

Research Accomplishments

We have obtained a permit from the Bermuda Department of Environmental Protection to conduct marine scientific research in Bermuda. We have also shipped the autonomous acoustic recorder to Bermuda and anticipate deploying it sometime in June 2013.

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

Aaron Thode (SIO)

NOAA Technical Contact: D. Orner (NMFS/OHC)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management
Amendment No.: NA12NMF472053 (Competed)

Research Objectives and Specific Plans to Achieve Them

The overriding objective is to simultaneously deploy cameras and acoustic recorders from fishing gear, to determine whether visually-documented interactions of killer and false killer whales are accompanied by distinctive acoustic cues, such as echolocation sounds by the species of interest.

Specific subobjectives include the following:
(1) Expanding two existing autonomous acoustic recorders to incorporate a long-endurance natural-lighting camera capability (between 24 hours to 7 day coverage, depending on picture frame acquisition rate);
(2) Testing the system on sperm and killer whales in Alaska and false killer whales in Hawaii.
(3) Using visually-documented encounters to determine the probability that killer and false killer whales generate sounds during fishing gear interaction during daylight hours, as a function of gear depth.

(4) Exploiting opportunistic visual records of other bycatch events to determine whether acoustic cues are generated by entanglement with the fishing gear.

Research Accomplishments

The first of two combined camera/acoustic system has been built and has been deployed in the field in Prince Williams Sound, AK, between May 4 and May 10, in an attempt to document orcas depredating longline gear off the F/V Babkin. The system consists of a previously-developed passive acoustic monitoring system (built with support from the Alaska Longline Fishermen's Association) with a 100 kHz sampling rate. The base system has been extended with a camera module, using a Canon EOS Rebel T3i (EOS 600) camera, enclosed in an aluminum/acrylic pressure case that can survive deployments to 1 km depth. After a timed sleep period, both the recorder and camera wake up and begin acquiring data, with the camera acquiring 3 frames per sec, constantly adjusting the f-stop, aperture, and ISO to maintain a fixed depth-of-field goal. The system was deployed ten times off the F/B Babkin with 90% success rate (an improper flash memory card formatting accounted for the one failure). No orcas were encountered, but the system concept was demonstrated and some software bugs identified and fixed. Ideas for a more rapid attachment system were developed and are being implemented. The first camera system is presently in Sitka AK were it is planned to be deployed from longlining fishing vessels in the presence of sperm whales. The second camera system is being assembled.

Fieldwork is scheduled throughout the summer in Alaska.

Fig. 1 Camera and acoustic system on deck of F/V Babkin, Prince William Sound, May 8 2013. The white pressure case contains the rechargable battery pack and acoustic acquisition system. The long camera cable is intended for situations where depredating animals may shy away from a large object on the line.

Fig. 2 Image of halibut caught on longline, 21 feet away from camera, during a haul to the surface on May 9 2013 under good weather conditions, at around 60 m depth. The camera has been hauled from a 915 m deployment depth.

California Cooperative Fisheries Investigations (CalCOFI), an Ocean Observation Program for the Southern California Current, FY 2011

J. Anthony Koslow and Ralf Goericke (SIO)

NOAA Technical Contact: Roger Hewitt (NMFS)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: 28, 58

Research Objectives and Specific Plans to Achieve Them

CalCOFI's primary objectives are 1) to continue its 60+ year time-series of comprehensive, high-quality physical, chemical and biological observations of the California Current ecosystem, 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.

CalCOFI successfully carried out its quarterly 2011-2012 cruises aboard Scripps and NOAA vessels, processing the physical, chemical and biological data, exercising quality control, and making the data publicly available through the web. Ancillary projects based on partnerships and external funding continue to be fostered and expanded to provide 'end-to-end' ecosystem observations of regional biogeochemistry (NSF-funded California Current Ecosystem Long-Term Ecological Research (CCE-LTER) project), seabirds (W. Sydeman, Farallon Institute), marine mammals (J. Hildebrand, SIO with ONR funding), and acoustic/trawl observations of micronekton (Koslow, SIO). There were approximately 35 peer-reviewed papers published in this reporting period based on CalCOFI data on various aspects of fisheries, conservation, climate, and ecosystem dynamics in the California Current, as well as a book that reviewed CalCOFI's role in the development of fisheries oceanography, contributions to other books, theses, reports and numerous presentations at conferences, workshops, and seminars.

Research Accomplishments

The four quarterly CalCOFI cruises were completed successfully. The cruises continue to be used as a platform for ancillary research programs: the NSF-funded CCE-LTER studies of biogeochemical and lower trophic level processes, ONR-funded marine mammal observations, and independently funded observations of Lagrangian currents, nitrogen biogeochemistry, seabirds, and acoustic and trawl sampling of krill and other micronekton. Pacific sardine is one of the few US species managed with reference to environmental conditions and their influence on stock productivity and sustainability. This year, the Sardine Harvest Parameters Workshop recommended to the Pacific Fishery Management Council that the environmental input be based on the mean sea temperature at 10 m depth from CalCOFI cruises, which was shown to be superior to the previous index based on the Scripps Pier temperature.

A fishery-independent time series was published for spiny lobster (*Panulirus interruptus*), a key California invertebrate fishery. The time series, based on the abundance of the early phyllosoma larval stages in CalCOFI ichthyoplankton samples, provides an index of spawning stock biomass. Abundance appears to be related to ENSO cycles, local SST, and the PDO. This study will contribute to the stock assessment and management of the species.

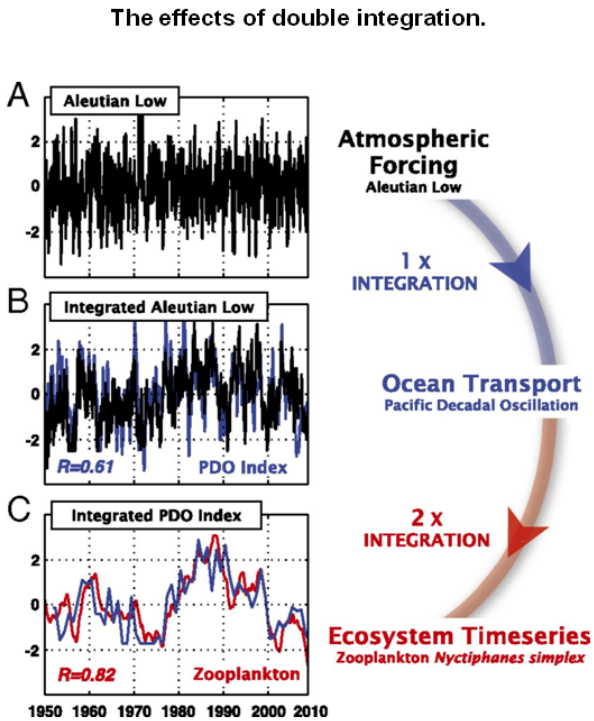
Several studies published this year demonstrated the utility of CalCOFI ichthyoplankton sampling for Marine Protected Area (MPA) management. CalCOFI station spacing and limited inshore sampling are not ideal for MPA monitoring, but the length of the CalCOFI time series and the ability to examine nearshore communities within the context of offshore forcing enable CalCOFI to provide unique contributions to marine spatial management in the California Current.

This year saw the publication of several papers in high-impact journals (*Science, PNAS*) that used CalCOFI time series to propose fundamental advances in the way fishery-environment time series are analyzed or in understanding how physical processes, whose time series are dominated by white noise, translate to driving biological time series in the ocean, characterized by low-frequency variability. The length and range of variables covered by CalCOFI time series render them particularly well-suited for such ground-breaking studies. Following on from a series of similar studies in recent years, several further studies this past year made use of the spatial coverage of CalCOFI sampling to model the suitability of spawning habitat for Pacific sardine and other small pelagics, and for bocaccio rockfish (*Sebastes paucispinis*).

Moorings and glider lines coinciding with CalCOFI lines now provide high resolution temporal and spatial data that complement CalCOFI sampling. The mooring data reveal considerable high-frequency variability of acidic and hypoxic conditions, particularly nearshore in relation to upwelling events. CalCOFI spatial coverage also enhances its use to calibrate and complement satellite data, for example in examining regional trends in chlorophyll and frontal dynamics. A number of studies this year made use of these time series with complementary temporal and spatial resolution and coverage to examine climate patterns and their dynamics in the California Current System.

The first book-length review of the role of CalCOFI in the development of fisheries research and management in the California Current, written by Sam McClatchie (NOAA), was submitted for publication with Springer.

Fig. 1 (Left to right) Dr. Sinjae Yoo (PICES Science Board Chairman) and Dr. Bocharov (PICES Chairman) presenting the PICES Ocean Monitoring Service Award (POMA) to Tony Koslow and Steve Bograd (NOAA) at the 2012 PICES Symposium in Hiroshima, Japan



Di Lorenzo E , and Ohman M D PNAS 2013;110:2496-2499

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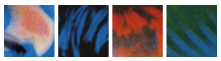
PNAS

Fig. 2 Di Lorenzo and Ohman (2013) use a linear autoregressive model in combination with long-term zooplankton observations off California to show that cumulative integrations of whitenoise atmospheric forcing (th Aleutian Low index) can generate marine population responses that are characterized by strong transitions and prolonged apparent state changes. (*A*) Aleutian Low index. (*B*) Integrated Aleutian Low index (black) and PDO index (blue). (*C*) Integrated PDO index (blue) and zooplankton time series of *Nyctiphanes simplex* from CalCOFI in the California Current System (red)



Studies in Anadromous Fisheries

Darren Ward (HSU)

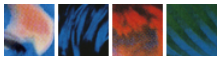
NOAA Technical Contact: Steve Miller (NMFS)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management
Amendment No.: 33

Research Objectives and Specific Plans to Achieve Them

This project provides support for research activities at Humboldt State University that provide information for restoration and conservation of anadromous salmonids in Northern California and the Klamath basin. Current research emphasizes ecological studies of species and habitats of conservation concern, evaluation of restoration effectiveness, and assessment of issues relating to improvement and restoration of salmon production in the northern California and the Klamath River system.

Research Accomplishments

In the 2012-2013 project period, this project supported the thesis research of a graduate student in the Ward lab, Meiling Roddam. Roddam's research focuses on evaluating the relative productivity of the two primary rearing areas for Chinook salmon in the Shasta River terms of numbers of outmigrating smolts and the characteristics of the smolts. The project includes both a field component of current conditions using a mark-recapture demographic study and a long-term analysis using archived otolith samples collected over the past five years. This ongoing work will provide insight into the population dynamics of the Chinook salmon population in this key Klamath River tributary and into the effects of habitat restoration activities recently implemented at one of the rearing locations. Roddam has completed data collection for the field part of the study and all of the otolith samples are mounted and prepared for analysis. Her anticipated completion date is December 2013.



Advancement of Population Assessment Methodologies (CAPAM)

Brice Semmens (SIO)

NOAA Technical Contact: J. McDaniels (NMFS/SWFSC)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management
Amendment No.: 66

Research Objectives and Specific Plans to Achieve Them

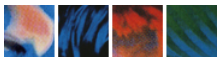
The goals of the new Center for the Advancement of Population Assessment Methodology (CAPAM) are to improve quantitative methods generally used in stock assessment modeling efforts, provide guidance regarding good practices in stock assessment methods, and afford the educational opportunities necessary 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

Since April 2012, we published the first peer-reviewed publication under CAPAM titled “A stock-recruitment model for highly fecund species based on temporal and spatial extent of spawning”. We held the first CAPAM workshop on the topic of “Selectivity: theory, estimation, and application in fishery stock assessment models” in March, 2013. We are in the process of publishing a special issue in the Journal of Fish Biology detailing the results of the CAPAM Selectivity Workshop, which is scheduled for release this summer.

Fig. 1 Fishery Researchers Gather for Inaugural CAPAM Workshop on Modeling Selectivity in Fish Stock Assessments - La Jolla, CA (March 11-14th, 2013) — Over 70 fishery researchers from around the world gathered recently at a Fisheries Workshop for purposes of evaluating an important phenomenon related to underlying fishing processes and theory, ‘selectivity’ (probabilities associated with fish being captured, or not). Selectivity considerations, as part of formal stock assessments, can be very influential to bottom-line results generated from stock assessment models, including critical statistics important to fishery management and the overriding goal to develop and maintain sustainable fishing practices for marine resources. The 4-day Workshop, held at the Southwest Fisheries Science Center (SWFSC, NOAA Fisheries) and the Scripps Institution of Oceanography (SIO, UCSD), was the first organized by the newly established Center for Advancement of Population Assessment Methodology (CAPAM)



Training the Next Generation of Marine Population Dynamics Scientists

Brice Semmens (SIO)

NOAA Technical Contact: S. Murawski (NMFS)

Links to NOAA Strategic Plan:

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

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

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

Amendment No.: 5, 31, 45

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

Since April 2012, I reinforced my connections with other scientists through the establishment of a new Center for the Advancement of Population Assessment Methodology (CAPAM) in collaboration with Paul Crone (NOAA) and Mark Maunder (IATTC). We held the first CAPAM workshop on the topic of "Selecivity: theory, estimation, and application in fishery stock assessment models" in March, 2013. A special issue of the Journal of Fish Biology detailing the results of the CAPAM Selectivity Workshop is scheduled for release later this summer.

I also enlisted 4 new graduate students and hired 2 employees. Graduate student Joshua Stewart and I are processing pelagic manta ray tissue samples using stable isotope analysis to identify differences in foraging behavior, food sources and trophic levels between sampling locations which, when paired with satellite telemetry and population genetics data will provide further insight into critical habitat use and regional population structuring. Additionally, my graduate student (Lyall Belquist) and I began implementing a large scale tagging program for basses (genus *Paralabrax*) targeted by recreational anglers in southern California. This program was partially funded by Collaboratve Fisheries Research West (CFR West) and involves collaborations among the recreational angler community and the San Diego Oceans Foundation. Since October, Lyall and local anglers have tagged over 3,493 fish and recaptured 125 tagged fish. In November, we deployed 40 acoustic receivers off the coast of La Jolla. In the near future, we anticipate implanting 70 fish with acoustic tags in order to track movement and behavior in relation to spatial marine management. Graduate student Lynn Waterhouse and I are currently developing a proposal to perform a stock assessment on white seabass (Atractoscion nobilis). The stock assessment will be under the auspices of CAPAM. Lynn and I have also begun working on a nested patch occupancy model applied to PIT tagged salmon in branching river networks in the Upper Columbia River Basin and the Snake River. I have hired programmer/analyst Brian Stock to develop MixSIAR, an open-source graphical user interface (GUI) software application written in R and JAGS. The MixSIAR GUI assists ecologists in the use of recent advances in Bayesian mixing models to better analyze their stable isotope data. The MixSIAR GUI will be freely available online. The tool is schedule for release at the 2013 ESA meeting. Brian will continue to work on the MixSIAR project as a PhD student starting Sept 2013, as well as studying data-poor fisheries stock assessment methods. I hired lab manager Devon O'Meara to develop the Catch Reporter™ program and assist with day to day lab operations. The goal of the Catch Reporter™ project is to freely distribute a smart phone application that will engage the fishing community in recreational catch reporting. A prototype of The Catch Reporter™ cell phone application allowing reporting of tagged fish is currently available for Android and IOS platforms; however the full version, allowing reporting of all catches, is under development.

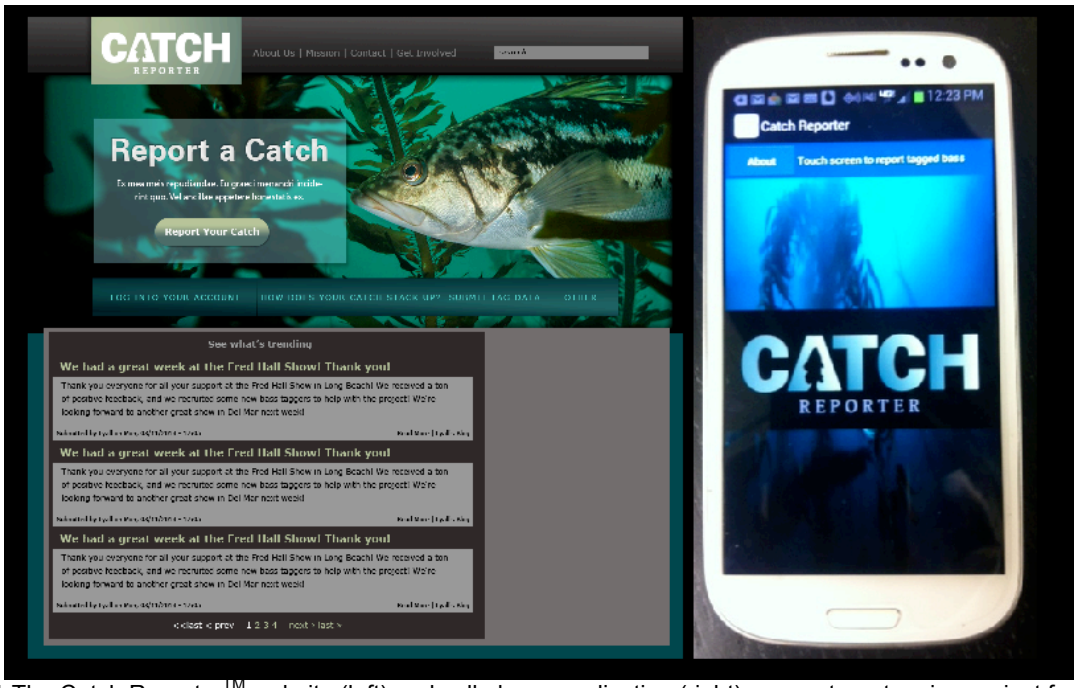


Fig. 1 The Catch Reporter™ website (left) and cell phone application (right), support our tagging project for *Paralabrax*. They allow recreational anglers to report tagged fish instantly from home or at sea. In the near future, the website and cell phone app will undergo updates to allow anglers to report all of their catches including fish of all species. This tool will increase the quality of catch statistics by efficiently leveraging a large body of interested and willing volunteer participants, and by automating the data collection and reporting. In addition to improving the quality of fisheries data available to managers, the program will actively engage recreational anglers who have historically felt left out of fisheries research initiatives and policy decisions

Fig. 2 To measure fine-scale movement patterns of calico and sand bass, we will surgically implant acoustic transmitters into 70 fish in the La Jolla kelp bed. These tagged fish will be detected by an array of 40 underwater acoustic receivers that are attached to subsurface moorings throughout the La Jolla area. The detection range of the receivers covers almost the entire kelp bed, so we will be able to monitor fish movements continuously for the 2-year battery lives of the transmitters

Workshop on Application of Non-Linear Time Series Analysis

George Sugihara (SIO)

NOAA Technical Contact: Roger Hewitt (NMFS/SWFSC)
Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
Amendment No.: 38

Research Objectives and Specific Plans to Achieve Them

A 3-day workshop was held at SIO for 30 NMFS stock assessment scientists in order to fast-track methods and concepts of nonlinear time series analysis (NLTS) and State Space Reconstruction (SSR) into NMFS the portfolio of quantitative methods used by stock assessment scientists. The methods provide a rigorous foundation for ecosystem-based management of fisheries (EBM) as well as a means for forecasting stock abundance.

The first of the 3 days involved lectures, dissemination and and open discussion of the new methods as they might meet challenges of EBM. The second and third days involved hands-on training with NLTS software tools developed by the Sugihara Lab. The third day involved applying these tools to two actual fishery time series brought in by the NMFS participants. These were selected to be challenging to the methods: stocks with apparently random recruitment (altantic menhaden and pacific hake).

Research Accomplishments

We held a workshop at Scripps Institution of Oceanography in April, attended by roughly thirty fisheries scientists from NOAA NMFS Fisheries Science Centers, along with members and collaborators of the Sugihara lab, and WHOI. The purpose of the workshop was to explain how state-space reconstruction methods could be used to study and predict fishery time series, and how the methods might be adapted for use by NMFS stock assessment scientists. Initial collaborations suggests that the methods might produce reasonable forecasts for Atlantic Menhaden and Pacific Hake recruitment, which have not been successfully predicted by other methods.

OUTREACH

Tagging Training for SEACAMP Students

B. Semmens taught 7th grade students about tagging research during a SEACAMP fieldtrip, so they could help participate in tagging effort during fishing trips.

K-12 Education - SIO

T. Koslow and CalCOFI personnel trained San Diego area high school students in the lab for science fair projects on the California current and CalCOFI's role in monitoring it.

Public outreach and education about biodiversity relating to Salmon

T. Levi of CSTAR, in cooperation with the Haines, AK community, gave a public talk on the importance of salmon to bears, eagles and other wildlife.

Integration of HF Radar data on Surface Currents into public exhibit

To educate and bring awareness of ocean energy to the general public, the "Boundless Energy Exhibit" at Scripps' Birch Aquarium was updated with integrated surface currents as collected by the HF radar network.

Voices in the Sea

Web site (www.voicesinthesea.org) with marine mammal vocalizations allows the public and students to hear how "voices" between species compare, providing a unique dimension to learning about marine mammals. Created in partnership with the Pacific Life Foundation and the Aquarium of the Pacific.

Programme "PEOPLE" (European Union)

Researcher mobility program between U.S. (SIO), Italy, Brazil, Bulgaria and Portugal, in collaboration with Dr. Diego Vicinanza.

Ocean Tracks

An outreach effort to bring tracking data into high school classrooms.

Shipboard Monitoring Data Tracking

Data collected as part of B. Marinovic's Shipboard Monitoring project was provided to 3 High School interns to study/analyze as part of hands on training, in collaboration with UC Santa Cruz and SIP Program.

Science and Math Investigative Learning Experience (SMILE)

Teacher workshop to support STEM subjects, hosted by Oregon State University.

Sequoia Park Zoo lecture

D. Ward delivered a public lecture on the salmon life history and conservation.

Teacher at Sea on R/V Melville

Ms. Susan Oltman from DeKalb, Georgia served as 'teacher at sea' during the Melville's Stratus Ocean Reference Station keeping.

Salmon Biology K-12 Outreach – Gary Griggs and Eric Palkovacs (UC Santa Cruz)

Classroom presentations, DeLaveaga Elementary School (Santa Cruz CA) and Santa Catalina High School (Monterey CA)

Workshop for K-12 teachers in salmon biology and conservation

Provided information to elementary and high school students on salmon biology and conservation and research at Santa Cruz laboratory.

Trained 20 K-12 teachers in a salmon biology and conservation curriculum for the classroom

Monterey Bay Salmon and Trout Project

COMMUNICATIONS, NETWORKING, ACADEMIC DEVELOPMENT and AWARDS

ACTIVITY TYPE	OBJECTIVE	PARTNERS
Communications		
CORDC Mapping Site http://cordc.ucsd.edu/projects/mapping/	Provide online access to surface current mapping sites, radial data, and diagnostics for participating sites	
CCHDO web site http://cchdo.ucsd.edu/	Disseminate all public CCHDO data, documentation, and data information via the CCHDO web site http://cchdo.ucsd.edu.	NOAA
CalCOFI communications	CalCOFI web site (www.calcofi.org) Provide information & data to public on field work, conference, publications, volunteer opportunities	
Communication with different NOAA Offices	To improve cross-communication between line offices on drought issues	NOAA, NCDC
Communications between NOAA and other federal agencies	To improve coordination with and communication between agencies	DOI Climate Science Centers, DOI LCCs, USGS, BOR, USDA, NRCS
Leading National Integration Drought Information System (NIDIS) CA Pilot and SoCal Pilot Activity	To develop drought early warning information and communication and coordination of drought planning and mitigation efforts	NIDIS Program Office, CA Department of Water Resources, San Diego County Water Authority, Metropolitan Water District, and more than 25 other water agencies and water users
Communication with the public	Improve public education and awareness of drought	Media outlets, internet
UCSC Seymour Marine Discovery Center Docent orientation tour, February 2013.	Inform volunteer docents about research conducted at the laboratory	UCSC Seymour Marine Discovery Center
California Department of Fish and Wildlife salmon fishery information meeting, February 2013.	Presentation to public regarding upcoming salmon fishing season	CA Department of Fish and Wildlife
Cetacean public information website www.cetus.ucsd.edu	Provide on-line information on marine mammal research activity	Pacific Life Foundation
Argo Science Team web site (http://www-argo.ucsd.edu)	Provide information on the Argo project, its objectives, status and data system, including how to access Argo data.	International Argo partnership
Argonautics Newsletter (http://www.argo.ucsd.edu/Frnewsletter.html)	Distribute information on Argo status, applications, and progress on key issues.	International Argo partnership

Public Presentations: 10 Sept 2012: Annual Charles D Keeling lecture at University of Illinois, Champagne-Urbana, "The Unfolding Story of Rising Atmospheric CO_2 and Life in the Greenhouse". 29 Sept 2012: San Diego TV appearance on NBC Channel 7. **Professional Presentations:** 3 Apr 2012, National Academy of Science Board on Atmospheric Science and Climate meeting at Scripps Oceanography, Presentation on Scripps O_2 and CO_2 programs and challenges for time series measurements. 23 Apr 2012, Department of Energy Terrestrial Carbon Program Investigators Meeting, Lecture on "Changing land metabolic activity as seen from atmospheric records" 9 May 2012, Megacities Carbon Project Workshop, Presentation on "Plans for Southern California surface network expansion" 14 May 2012, National Oceanic and Atmospheric Administration, Global Monitoring Division, 40th Global Monitoring Annual Conference, presentation on "Two decades of atmospheric O_2 measurements and their implications". 12 July 2012, Workshop on Joint Oceanic and Atmospheric Biogeochemical data Assimilation, Göttingen, presentation on "Atmospheric O_2 and CO_2 measurements as constraints on ocean biogeochemistry" 17 July 2012, Weekly seminar at Max Planck Institute for Biogeochemistry, Jena, "Atmospheric constraints on a changing carbon cycle" 3 Sept 2012, Bjerknes Centre's 10-years Anniversary Conference on Climate Change in High Latitudes", Invited presentation on: "Atmospheric signatures of changing land and ocean biogeochemistry"	Dissemination of Global Carbon monitoring data and the effects the resulting Climatic changes could have on Society.	Ralph Keeling, SIO

Outreach as part of tagging studies in southern California	Inform the recreational angler community of tagging work by presenting at fishing shows, community events, and radio shows. Outreach is intended to create awareness of the tagging program, increase reporting of tagged fish, and involve citizens in the scientific process.	San Diego Oceans Foundation
Argo Marine Atlas project ftp://kakapo.ucsd.edu/pub/argo/Pacific_Marine_Atlas	Develop a data display tool to allow students and educators view Argo and other ocean datasets as maps, vertical sections, time-series plots, and line drawings.	PI-GOOS, SEREAD
SOPAC website	Precise hourly orbits are published on the SOPAC Web Site (http://sopac.ucsd.edu) and freely available.	International GNSS Service (IGS)
CSTAR member public talks: -"Watching wildlife and tracking eagles: understanding the ecosystem that supports salmon fisheries." Klukwan, AK -"Watching wildlife and tracking eagles: understanding the ecosystem that supports salmon fisheries". Haines, AK -"Bears and the ecosystem based management of Pacific salmon," Alaska Bald Eagle Festival, Haines, AK -"Salmon wildlife interactions in the Chilkat river watershed," Takshanuk Watershed Council. Haines, AK -"The importance of salmon to bald eagles," Alaska Bald Eagle Foundation. Haines, AK	Public talks given on ecosystem-based fisheries management	Taal Levi, UCSC
Shipboard Monitoring academic development	One PhD student participated in Shipboard Monitoring project with B. Marinovic	Ocean Sciences, UCSC
High Resolution XBT Network web site: http://www-hrx.ucsd.edu	Describe scope and objectives of the Pacific/Indian HRX network; display data from all cruises; provide downloadable datasets on a cruise-by-cruise basis.	CSIRO Australia, NIWA New Zealand, Tohoku University Japan
Outreach as part of tagging studies in southern California	Inform the recreational angler community of our tagging work, involve citizens in project science.	San Diego Oceans Foundation
R/V Melville communications	Routine HiSeasNet communications from ship to shore	
R/V Roger Revelle communications	HiSeasNet real-time HD video transmission	

ACTIVITY TYPE	OBJECTIVE	PARTNERS
Networking		
CalCOFI networking activities	Continuing collaborative relationships with other ocean observation programs on the west coast	Partner to SCCOOS, collaboration with MBARI
	Provide CalCOFI input to end-to-end coupled biophysical California Current ecosystem model including pelagic fish and fisheries	Co-PIs in collaboration with CAMEO/proposed NSF project (Curchitser, Rose, et al)
	Provide CalCOFI data to global ocean time series data center	CalCOFI partnership with OceanSites
	Ongoing partnerships with 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
	Provide CalCOFI input to integrated ecosystem assessment and ecosystem-based management of the California Current	Pacific Fisheries Environment Lab/SWFSC/NOAA
	Establish ocean acidification monitoring	Network with PMEL/NOAA
	Foster CalCOFI partnerships with North Pacific rim marine research	Active member of PICES, member PICES Technical Committee on Data Exchange (TCODE)
	Foster collaboration with fisheries acoustics groups in ICES and globally	ICES Fisheries Acoustics Science and Technology Working Group (WGFAST)
	Attended workshops on ocean observations, marine mammal observations, and water quality in the California Current System	University of Southern California, Pacific Ocean Foundation. Southern California Coastal Water Research Project (SCCWRP)
Collaboration with California State Department of Water Resources	Provide awareness of within-state sources of climate and drought information	State of California
Convene semi-annual meetings of the Monterey Bay Marine GIS User Group	The Monterey Bay Marine GIS User Group supports GIS training, capacity building, collaboration, and increased awareness of marine spatial data sets among the broader science community in Monterey Bay.	NOAA, USGS
Provide outreach and leadership through National Integration Drought Information System CA Pilot and SoCal Pilot Activity	To develop drought early warning information and communication and coordination of drought planning and mitigation efforts	NIDIS Program Office, CA Department of Water Resources, San Diego County Water Authority, Metropolitan Water District, and others detailed in section 5

Generated collaborations and communications among water managers in the 19 Western states, the Western RISAs, Western Governors' Association, NIDIS	To understand the use and value of drought early warning information for reducing drought impacts, and to develop and provide more effective information	Western Governors' Association, 19 Western states, Western RISAs, NIDIS Program Office
Presented at Oil Spill Area Committee Meetings in San Diego	Provided updated information regarding HF 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
DBCP-WIO4	Recruit GDP partners in the Indian Ocean Regio	Kenya Fisheries Research Institute (KFRI), Mauritius Oceanograhic Institute (MOI), Mauritius Meteorological services (MMS), Tanzania Meteorological Agency (TMA)
Pacific Island Global Ocean Observing System (PI-GOOS) Advisory Committee (Roemmich)	Assist Pacific island nations in gaining benefit from global ocean observations and products.	South Pacific Applied Geosciences Commission (SOPAC), NOAA, BoM Australia, NIWA New Zealand, Intergovernmental Oceanographic Commission, South Pacific nations
ScrippsO2.ucsd.edu ScrippsCO2.ucsd.edu	Disemmination of global oxygen and carbon dioxide datasets to public and research community	Ralph Keeling, SIO
Correspondence with Jordan Stout and Judd Muskat, OSPR	Area Committee – Contingency Plans for Oil Spill Response	NOAA OR & R and Office of Spill Prevention and Response
UNOLS Networking	Continued developing working relationship between UNOLS ship operators, the WHOI mooring group, and NOAA's National Data Buoy Center.	
Contribution to National archives with data collected onboard supported Research Vessels	Data sharing with federal archives such as NGDC and NODC	
ACTIVITY TYPE	**OBJECTIVE**	**PARTNERS**
Academic Development		
CCHDO Training	Train undergraduate research assistants in under-the-hood operations of a data center and web site via real-world experience with ongoing CCHDO activities.	
Fisheries Biology training	Train undergraduate and graduate students in Fisheries Biology. Teach the following courses: Fish Conservation and Management, Advanced Fish Conservation and Management, Ecology of Freshwater Fishes, Biology of Pacific Salmon, Graduate Seminar. Primary research advisor for 4 graduate students and 2 undergraduate research interns. Serve on graduate committees for 7 graduate students.	D. Ward, Humboldt State University

Fellowships Programs / Internships	Ms. Natalia Ribero Santos received a CNPQ Brazilian Government Scholarship to visit SIO (April-September 2012) and analyze change in Southern Ocean sing AX22 data Ms. María Dolores Pérez Hernández was sponsored by Universidad de las Palmas de Gran Canaria (ULPGC) to visit SIO and analyze mass and heat budgets of the South Indian Ocean using XBT transects IX15/21.	Brazil
Teach Statistical Methods in Marine Biology course to undergraduate students at UCSD	UCSD	B. Semmens, UCSD
Underrepresented fellowship program between CSTAR and Stonybrook Univ.	Fellowship program for eligible underrepresented students whose immediate academic plans include entering the professoriate to encourage completion of thesis work	Santiago Salinas: W. Burghardt Turner Dissertation Fellowship, Stony Brook University
Undergraduate students: 2	Provide research experience in fisheries science through school-year and summer employment	UCSC, UC Davis
Graduate students: 2 PhD, 3 MS	Support graduate education and research	UCSC, UC Davis
Post-doctorate scholars: 5	Support professional development	UCSC
CalCOFI academic development	Guest lectures on aspects of CalCOFI, ocean observations and ocean climate	Center for Marine Biological Conservation, D Checkley, M Ohman, L Levin
Programme "PEOPLE" (European Union)	Reseracher mobility between US, Italy, Brazil, Bulgaria and Portugal	Dr. Diego Vicinanza,
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 island school systems. See http://www.argo.ucsd.edu/FrEducational_use.html	SOPAC, UNESCO, NOAA, NIWA/NZ, IOC, Education ministries in Cook Is, Samoa, and Tonga.
Nonlinear Time Series Workshop held at SIO (April 2012)	Explain and promote nonlinear state-space reconstruction techniques for time series forecasting by NMFS scientists.	NOAA NMFS (members from multiple fisheries science centers in attendance)
Participated in NOAA IOOS Data Management and Communications (DMAC) discussions	To provide guidance for HF radar real-time vector data formats and distribution	NOAA IOOS
CORC Student Development in Ocean Remote Sensing	Undergraduate student Samuel Wilsons joined CORC. In addition, 3 postdocs and 1 graduate student were partially supported by CORC	U. Send, SIO

Graduate student development in ocean observing	Graduate students Samuel Wilsons, Jesse Powell, and Xue Fan, and post-doctoral scholar SungHyun Nam are using the CCE mooring data for their research	U. Send
SOPAC international scientific consultation	Provide ongoing scientific and technical consultations to scientists and graduate students from USA, Germany, France, Italy, Finland, Sweden, Japan, China, Taiwan, Korea, India, Indonesia, New Zealand, Australia, Brazil, Argentina, South Africa	Yehuda Bock, SIO
XBT Transects data sets	Primary data set for PhD thesis of SIO graduate student, Gordon Stephenson HRX data also employed by SIO graduate student Yvonne Firing.	NSF
Students-at-sea training aboard R/V Melville	Student research training with students from University of Concepcion, Chile	

AWARD	RECIPIENT	YEAR
Awards and Honors		
Navy Superior Civil Service Award	Curtis Collins	2012
PICES Ocean Monitoring Service Award (POMA)	CalCOFI program (received by Tony Koslow (SIO) and Steve Bograd (NOAA) on behalf of CalCOFI	2012
NOAA Fisheries 'Nancy Foster Habitat Conservation' Award	Mary Yoklavich	2012
University of Hawaii H.J. Wiens Memorial Award	Lisa Wedding	2012
NOAA Fisheries Team Member of the Year for SWFSC	Kerrie Pipal, Arliss Winship	2012
USGS competition, "App-lifying USGS data, for the best overall application using USGS APIs for data access	Carl Boettiger, as part of OpenSci project team	2012
National Science Foundation Graduate Research Fellowship	Juan Lopez	2012
National Science Foundation Postdoctoral Fellowship in Biology and Mathematics	Carl Boettiger (to work with CSTAR Director Mangel and CSTAR NMFS colleague Stephan Munch)	2013
Fellow, American Geophysical Union	Dan Cayan	2012
Paper cited as "Editors Choice" by Science Magazine	Paper cited as "Editors Choice" by Science Magazine	2012
Paper cited by the Faculty of 1000	Sugihara et al.	2013
Paper cited by the Faculty of 1000	Perretti, Sugihara, Munch	2013
Keynote Lecture ASLO 2012 (Kyoto)	Sugihara	2012

REPRESENTING CIMEC

EVENT	DATE / LOCATION	REPRESENTATIVE
2013 Detection, Classification, Localization and Density Estimation Workshop	June 10-14, 2013, St. Andrews, Scotland, UK	Simone Baumann-Pickering
2013 Gulf of Mexico Oil Spill & Ecosystem Science Conference	January 21-23, 2013, New Orleans, LA	Kait Fraisier
2013 USNC-URSI National Radio Science Meeting	January 9-12, 2013 / Boulder, CO	Seth Gutman
2nd Annual Symposium of effects of Climate Change on the World's Oceans	May 16, 2012, Yeosu Korea	W. Sydeman, J. Koslow
3rd MERIS/(A)ATSR & OCLI-SLSTR (Sentinel-3) Preparatory Workshop, ESA-ESRIN	October 15-19, 2012, Frascati, Italy	M. Kahru
4th Argo Science Workshop	Venice Italy September 2012	Dean Roemmich, Donata Giglio, Nathalie Zilberman
5th International Symposium on Deepsea Corals	April 2012, Amsterdam, Netherlands	Mary Yoklavich
AGU 2013	3-7th December 2013, San Francisco	Rick Thomas
AGU Meeting	San Francisco California December 2012	Donata Giglio
American Fisheries Society Annual Meeting	August 2012, Minneapolis, MN	Mary Yoklavich, Arliss Winship, Sean Hayes
American Geophysical Union	December 3-7, 2012, San Francisco, CA	M. Jacox
American Geophysical Union (AGU)	December 3-7, 2012 / San Francisco, CA	Jianghui Geng
American Institute for Fisheries Research Biologist symposium	June 2012, New Bedford, MA	Brian Wells
American Society for Limnology & Oceanography (ASLO) conference	July 8-13, 2012, Shiga, Japan	E. Deyle, C. Perretti, G. Sugihara, H. Ye
American Society for Limnology & Oceanography (ASLO) conference	February, 2013, New Orleans, LA	M. Ohman, G. Sugihara
Annual Meeting of the Society for American Archaeology	April 2012/Memphis, TN	Christie Boone
Antarctic Marine Living Resources (AMLR) NOAA/SWFSC "Science Friday",	January 2013/La Jolla, CA	Jarrod Santora
Area Committee Meeting – Contingency Planning Oil Spill	March 7, 2013/ Carlsbad, CA	L. Hazard
Area Committee Meeting (U.S./Mexico) Oil Spill	August 22-23, 2012, San Diego, CA	L. Hazard
Bay-Delta Science Conference	October 2012, Sacramento, CA	Eric Danner, Tommy Williams, Lee Harrison, Sean Hayes, Jason Hassrick, Candan Soykan
Bay-Delta Science Conference	Oct. 16-18, 2012: Sacramento CA	Anthony Clemento, John C Garza
Biowaves Passive Acoustics Workshop	February 12-15, 2013	G. Campbell
Bjerknes Centre 10-year anniversary meeting on climate at high latitudes	3 Sept, 2012, Bergen, Norway	Keeling
Bren School (Lecture)	2013, UC Sana Barbara, CA.	G. Sugihara
CA State University Monterey Bay seminar	October 2012,Monterey, CA	Lisa Wedding
CA State Water Resources Control Board Review and Update of the Delta Plan: Workshop 2: Bay-Delta Fishery Resources	October 2012, Sacramento, CA	Eric Danner
CalCOFI Annual Conference	December 2012, Asilomar, CA	John Field, Rebecca Miller, Lyndsey Lefebvre
CalCOFI Annual Meeting		Eric Bjorkstedt
CalCOFI Conference/Symposium	December 3-5, 2012, Monterey, CA	G. Campbell, J. McGowan, J. Koslow, A. Thompson

CAPAM workshop on Selectivity: theory, estimation, and application in fishery stock assessment models	March 11-14, 2013, La Jolla, California	B.X. Semmens (lead organizer, presenter), Lynn Waterhouse (Organizer) Devon O'Meara (Organizer) Brian Stock (Attended) Darren Johnson (Attended) Lyall Bellquist (Attended)
CAPAM workshop on Selectivity: theory, estimation, and application in fishery stock assessment models	March 11-14, 2013, La Jolla, California	B.X. Semmens (lead organizer, presenter), Lynn Waterhouse (Organizer) Devon O'Meara (Organizer) Brian Stock (Attended) Darren Johnson (Attended) Lyall Bellquist (Attended) Eric Bjorkstedt
CCE LTER Workshop	May 7-8, 2012, Scripps, La Jolla, CA	G. Campbell
CLIOTOP – Climate Change and Top Predators, 2nd symposium	February 2013, Noumea, New Caledonia	Elliott Hazen, Dave Foley
Coastwide Salmonid Genetics Meeting	July 9-12, 2012: Davis CA	Alicia Abadia-Cardoso, Anthony Clemento, Eric Crandall, Hilary Starks, Eric Anderson, John C Garza
Comparative Human Ecodynamics on the Northern Ring of Fire: A GHEA Workshop on the Aleutians and Kuril Islands	november 2012/seattle, wa	Cristie Boone
Conservation & Ecology of Marine Forage Fishes Research Symposium	September 12-14, 2012, Friday Harbor, WA	J. Thayer
DBCP 28 Technical Workshop and Assembly	Fremantle, Australia, Oct 1-5	Centurioni
Diadromous Species Restoration and Recovery Network	Jan 2013, Orono, ME	Eric Palkovacs, Emily Argo, Dan Hasselman
Eastern Pacific Ocean Conference	September 2012, Mt Hood, OR	Brian Wells
Eco-evolutionary Dynamics Working Group	Sept 2012, Napa, CA	Eric Palkovacs, Dan Hasselman
Ecological Society of America Annual Meeting	August 2012/Portland, Oregon	Taal Levi, Justin Yeakel
Ecological Society of America Annual Meeting	August 2012, Portland, OR	Will Satterthwaite
Endangered Species Act Working Group	June 2012, Gloucester, MA	Eric Palkovacs
ENSO Diversity Workshop	February, 2013, NCAR, Boulder, CO	M. Ohman
ENVICOP workhop	Milan, July 27	Centurioni
ESRI Ocean Summit	November 2012, Redlands, CA	Lisa Wedding
Evolutionary potential in marine populations workshop	September 2012. List auf Sylt, Germany	Santiago Salinas
First International Conference on Oceanography in the Bay of Bengal	Colombo, Sri Lanka Nov- 28-29	Centurioni
Gordon Conference: Polar Marine Science	10-15 March 2013, Ventura, CA	Gordon Stephenson
Gulf and Caribbean Fisheries Istitute Annual Meeting	5 November 2012 - 9 November 2012	B.X. Semmens (Presenter)
Hatfield Marine Science Center (Lecture)	April 5, 2012, Oregon State University	R.M. Suryan
HF Radar Metric	July 25, 2012, San Diego, CA	L. Hazard, T. Cook,
HF Radar Metric Briefing	October 31, 2012 / Webinar	L. Hazard, T. Cook
IDEADOS Workshop	November, 2012, Palma de Mallorca, Spain	J. Koslow
In Honour of Dr. Colin Clark: Developments and Challenges in Fisheries Economics	May 2012/Vancouver, BC, Canada	Marc Mangel (Keynote Speaker)
International Argo Data Management Team Meeting	Hyderabad India, November 2012	John Gilson
International Argo Steering Team Meeting	Wellington New Zealand, March 2013	Dean Roemmich, John Gilson
International GeoHab Conference	May 2012, Orcas Island, WA	Mary Yoklavich, Lisa Krigsman
IOOS DMAC Meeting	–September 10-14, 2012 / Washington, DC	L. Hazard

IOOS Summit	November 13-16, 2012 / Herndon, VA	E. Terrill
King Abdullah University of Science & Technology (Lecture)	October, 2012, Thuwal, Saudi Arabia	M. Ohman
Led, presented, and participated in National Integrated Drought Information System (NIDIS) Pilot Activity meeting.	5/10/2012, San Diego, CA	Anne Steinemann
Led, presented, and participated in National Integrated Drought Information System (NIDIS) Southern California Pilot Activity, experimental drought monitor meeting.	September 4-5, 2012, San Diego, CA	Anne Steinemann
LTER All-Scientists Meeting	September 10-14, 2012, Estes Park, CO	M. Ohman
Marine Geospatial Ecology Tool workshop	July 2012, Monterey, CA	Lisa Wedding
Meeting of Western Society of Naturalists	November 7-10, 2012	Darren Johnson (Presenter)
Monterey Bay Marine GIS User Group meeting	July 2012, Santa Cruz, CA	Lisa Wedding
Moss Landing Marine Lab seminar	September, 2012, Moss Landing, CA	Will Satterthwaite
MPI Jena weekly meeting	17 July, 2012, Jena, Germany	Keeling
NAS Board on Atmospheric Science	3 April 2012, Scripps Inst. Oceanography	Keeling
NASA Applied Sciences Annual Meeting	April 2012, Seattle, WA	Eric Danner
NASA Ocean Color Research Team Workshop	April 23-25, 2012, Seattle, WA	M. Kahru
National Academies Committee to Evaluate US Fisheries Rebuilding	2012, New Orleans, LA	G. Sugihara
National Steering Team Meeting	July 16-18, 2012 / Boulder, CO	E.Terrill
NIDIS Reauthorization Workshop. Presentation: "California NIDIS Pilot."	9/25/2012, San Diego, CA	Anne Steinemann
NMFS Sacramento Office Seminar on Life History Models	February 2013, Sacramento, CA	Will Satterthwaite
NMFS Southwest Region Restoration Center workshop	May 2012, Santa Cruz, CA	Eric Danner
NOAA Climate Observations Division Annual Meeting	25-27 June, 2012, Silver Spring MD	Dean Roemmich, Nathalie Zilberman
NOAA GMD annual meeting	14 May 2012, Boulder, Colorado	Keeling
NOAA National Habitat Assessment workshop	September 2012, Seattle, WA	Mary Yoklavich
Nonlinear Time Series Workshop	2013, Scripps Inst. Oceanography, La Jolla, Ca	G. Sugihara
Nonlinear Time Series Workshop	April 17-19, 2012, La Jolla, CA	(PIs and all collaborators)
North Pacific Marine Science Organization (PICES) Annual Symposium	October 12-21, 2012, Hiroshima, Japan	J. Koslow, S. Bograd
North Pacific Marine Science Organization (PICES),	October 2012/Hiroshima, Japan	Jarrod Santora
NWPdrifter workshop (WMO-DBCP)	Sedona, Az, May 21	Centurioni
OCD review	Silver Spring, June 15-28	Centurioni
Ocean Optics XXI	October 8-12, 2012, Glasgow, Scotland	M. Kahru
OCSD Effluent Diversion	September 11-28, 2012, Orange County, CA	L. Hazard, J. Chen, T. Cook, E. Terrill, M. Otero
ONR workshop on Arabian Sea	Arlington, July 24	Centurioni
Pacific Seabird Group	February 2013/Portland Oregon	Jarrod Santora
Past, current and future research on kittiwakes in Kongsfjorden: The opportunity of an international integration	20-22 March 2013, Trondheim Norway	Simone Vincenzi
PICES Annual Meeting	October 2012, Hiroshima, Japan	Elliott Hazen, Dave Foley
Presented at and participated in National Integrated Drought Information System (NIDIS) Klamath Basin Pilot Activity,	6/5/2012, Sacramento, CA	Anne Steinemann

planning meeting.		
Radiowave Operators Working Group	November 13 - 16, 2012 / St. Petersburg, FL	L. Hazard, T. Cook
River Herring Working Group	Jan 2013, Orono, ME	Eric Palkovacs, Emily Argo, Dan Hasselman
Royal Amsterdam Academy (Lecture)	2012, Amsterdam, Netherlands	G. Sugihara
Salmonid Restoration Federation	16 March 2013, Fortuna, CA	Meiling Roddam/Darren Ward
Scientific and Statistical Committee Groundfish Subcommittee (Pacific Fishery Management Council)	March 2013/Tacoma, WA	Melissa Monk
Seminar to Center for Population Biology, UC Davis	November 2012/Davis, CA	Carl Boettiger
Shasta Science and Restoration meeting	22 March 2013, Mt Shasta, CA	Meiling Roddam/Darren Ward
Society for Conservation Biology	July 2012, Oakland, CA	Eric Palkovacs, Emily Argo
Society for Conservation Biology Annual Meeting	July 2012, Oakland, CA	Elliott Hazen, Lisa Wedding, Arliss Winship
Southern California Marine Mammal Workshop	February 1-2, 2013, Newport Beach, CA	C. Johnson
SPURS planning meeting	Miami, 15-21 January	Centurini
SUNY – Stonybrook Seminar Series	March 2013, Stonybrook, NY	Elliott Hazen
Third International Symposium on the Ocean in a high CO2 world	September 24, 2012, Monterey, CA	S. Nam, U. Send
U.S. Coast Guard Tour	October 12, 2012 / San Diego, CA	L. Hazard
UCSC-Stanford Species Interactions Workshop	Dec 2012, Santa Cruz, CA	Eric Palkovacs
University of California, Irvine; Environmental Engineering Seminar Series. Presentation: "Developing Indicators to Detect, Forecast, and Mitigate Drought."	6/1/2012, Irvine, CA	Anne Steinemann
WCRP CLIVAR Global synthesis and Observations Panel	Woods Hole Massachusetts, December 2012	Dean Roemmich
West Coast Genetic Stock Identification Meeting	October 2012, Olympia, WA	Mike O'Farrell, Will Satterthwaite, Shanae Allen
Workshop on joint ocean/atmosphere biogeochemical data assimilation	12-14 July, 2012 Göttingen,Germany	Keeling

CIMEC PARTNERS AND COLLABORATORS

INTERAGENCY

Antarctica Ecosystem Research Division, NMFS
Atlantic Oceanic and Meteorological Laboratory (AOML)
Fisheries Ecology Division, NMFS
Integrated Ocean Observing System (IOOS)
Monterey Bay National Marine Sanctuary
National Aeronautics and Space Agency (NASA)
- AMES Research Center
- Jet Propulsion Lab (JPL)

National Data Buoy Center (NDBC)
National Ocean Service (NOS)
National Parks Service (NPS)
National Science Foundation (NSF)
National Weather Service (NWS)
Northeast Fisheries Science Center (NEFSC), NMFS
Northwest Fisheries Science Center (NWFSC), NMFS
Office of Naval Research (ONR)
Pacific Fisheries Management Council
Pacific Islands Fisheries Science Center (PIFSC)
Pacific Marine Environment Lab (PMEL)
Pacific States Fisheries Commission
Redwood National Park
Southeast Fisheries Science Center (SEFSC)
Southwest Fisheries Science Center (SWFSC)
U.S. Army Corps of Engineers (USACE)
U.S. Bureau of Reclamation (USBR)
U.S. Department of Agriculture (USDA)
U.S. Fish and Wildlife Service (USFWS)
U.S. Geological Survey (USGS)

PARTNERSHIPS

Australian Antarctic Division (AAD)
Australian Bureau of Meteorology and CSIRO
British Antarctic Survey (BAS)
CalFed Science Program
California Coastal Conservancy
California Department of Fish and Game (CDFG)
California Department of Forestry and Fire Prevention
California Department of Parks and Recreation
California Department of Water Resources (CDWR)
California Ocean Protection Council
California Polytechnic State University San Luis Obispo
California Salmon Commission
California State University Monterey Bay (CSUMB)
California Wetfish Producers Association
Centro Investigacion Cientifica y de Educacio Superior de Ensenada (CICSE), Mexico
Centro Regional de Investigacion Pesquera (CRIP), Instituto Nacional de la Pesca, Mexico
Columbia River Intertribal Fisheries Commission.
Commission for the Conservation of Antarctic Marine Living Resources (AMLR)
Commonwealth Scientific and Industrial Research Organisation (CSIRO)—Australia
Cramer Fish Sciences
CSIRO
Dalhousie University

Duke University Marine Laboratory
East Bay Municipal District
Environment Canada
Farallon Institute
Fisheries Centre, University of British Columbia
Georgia Institute of Technology
Hoopa Valley Tribe
Humboldt State University, CA, USA
ifM-Geomar, Kiel, Germany
IFREMER, France
INCOIS, India
Investigaciones Mexicanas de la Corriente de California (IMECOCAL)
IOS, Canada
IRD, Noumea, New Caledonia
James Cook University
JAMSTEC, Japan
KORDI, South Korea
Lenfest Ocean Program
Lindquist Consulting Inc.
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Thompson, A.R., T. Auth, M.E. Hernandez-Rivas, N.M. Bowlin, R. Brodeur, S. McClatchie, S.P.A. Jimenez-Rosenberg, A.T. Hinojosa-Medina, W. Watson 2012 Ichthyoplankton dynamics throughout the California Current system: a comparative analysis of fish assemblages in Oregon, California, and Baja California CalCOFI Conference, Asilomar, CA
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Wells, B.K. 2012 Coastal turbulence, upwelling, and wind shear time series examined 1946-2012: Extending Schwing and Mendelssohn (1997) Eastern Pacific Ocean Conference, Mt. Hood OR

Wells, B.K. 2012 The role of the environment and harvest on stock status: contrasting California salmon and rockfish fisheries. American Institute for Fisheries Research Biologist Workshop, New Bedford MA

Wells, B.K., J.A. Santora, J.C. Field, R.B. MacFarlane, B.B. Marinovic, and W.J. Sydeman 2012 Population dynamics of Chinook salmon (Oncorhynchus tshawytscha) relative to prey availability in the central California coastal region Marine Ecology Progress Series. 457: 125-137

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Ye, H., E. Deyle, C.H. Hsieh, G. Sugihara 2012 Dynamic Connectivity In The California Current And Gulf Of Maine: Identifying Ecosystem Interactions Using Chaotic Time Series Analysis ASLO, Shiga, Japan

Young, L., R.M. Suryan, D. Duffy, W.J. Sydeman 2012 Climate change and seabirds of the California Current and Pacific Islands Ecosystems: Observed and potential impacts and management implications Final report to the U.S. Fish and Wildlife Service, Region 1

Zhang, X., B. Cornuelle, and D. Roemmich 2012 Sensitivity of western boundary transport at the mean North Equatorial Current bifurcation latitude to wind forcing Journal of Physical Oceanography

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PUBLICATION SUMMARY

	CIMEC Lead Author				NOAA Lead Author				Other Lead Author			
	2010-11	2011-12	2012-13	2013-14	2010-11	2011-12	2012-13	2013-14	2010-11	2011-12	2012-13	2013-14
Peer Reviewed	22	30	76		24	6	38		11	38	40	
Non Peer Reviewed	19	9	29		14	8	10		7	14	13	
	41	39	105		38	14	48		18	52	53	

Total Publications for this period: 206

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
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
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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