The Cooperative Institute for Oceanographic Satellite Studies (CIOSS) Year 9 Annual Progress Report (January 1, 2011 - December 31, 2011)
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Front Cover: Three-day average sea-surface temperature (SST) for the time period 23-25 June 2003 constructed from measurements by the Advanced Microwave Scanning Radiometer (AMSR) on the NASA Earth Observing System (EOS) Aqua satellite. The near all-weather measurement capability of the AMSR has been providing unprecedented temporal sampling of global SST with a spatial resolution of approximately 50 km since 1 June 2002. Numerous interesting features are evident in this figure, including cusp-like patterns associated with tropical instability waves in both the Pacific and the Atlantic, a meandering ribbon of warm water associated with the Gulf Stream, and large areas of cold water associated with the eastern boundary currents off North and South America and northwest Africa.
The Cooperative Institute for Oceanographic Satellite Studies (CIOSS)  
Year 9 Annual Progress Report  
Award #: NA08NES4400013  
(January 1, 2011 – December 31, 2011)

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EXECUTIVE SUMMARY

Background
CIOSS was established in 2003 by a memorandum of agreement between NOAA and Oregon State University (OSU). Housed within the College of Earth, Ocean and Atmospheric Sciences (CEOAS, formerly COAS, the College of Oceanic and Atmospheric Sciences), CIOSS is an Academic-Federal center of excellence for research and education, with a focus on satellite remote sensing of the ocean and its air-sea interface. For many applications, its research combines satellite data with models of the ocean, atmosphere and marine ecosystems. Support for CIOSS comes from a combination of core NESDIS/STAR/SOCD funded research and strategic partnerships with other funding agencies within NOAA.

CIOSS Research and Outreach activities are organized around five themes: (1) satellite sensors and techniques; (2) ocean-atmosphere fields and fluxes; (3) ocean-atmosphere models and data assimilation; (4) ocean-atmosphere analyses; and, (5) education and outreach related to ocean systems and remote sensing. Each of these themes is described more fully in Section I-D below. Although each CIOSS research project is characterized as falling into one of the above themes, CIOSS research can be viewed more holistically as basic research that improves our ability to integrate satellite data into models and analyses of the ocean and atmosphere, along with applied research that uses our understanding of oceanic and atmospheric processes to address problems of societal concern. This helps NOAA to accomplish its mission of applying science to meet the nation’s economic, social and environmental needs.

Brief Synopsis of Activities in ‘Year 9’ (Calendar Year 2011)

This Annual Report covers the calendar year of 2011. Since CIOSS’ anniversary date is April 1, this report covers parts of CIOSS Year 8 (4/1/2010 - 3/31/2011) and Year 9 (4/1/11-3/31/12), with the emphasis on Year 9. In the Executive Summary we present brief synopses of CIOSS administrative actions, research and outreach projects. Full project reports are available in Section II-B-2.

Task-I: Administrative Activities (Project 1)

Administrative activities support the operation of CIOSS. These include communications with NOAA/STAR program managers and research personnel; preparation of reports and proposals, including post-award actions; documentation of procedures used in managing CIOSS; monitoring and projections of the CIOSS budget; maintenance of the CIOSS web site; participation in national meetings of CI Directors and Administrators, as well as meetings to review specific NESDIS programs (e.g., Climate Data Records, GOES-R3, etc.); facilitating meetings of the CIOSS Council of Fellows and Executive Board; organizing and running workshops and short courses; and logistical support for visitors and scientific exchanges.
During 2011, CIOSS prepared and/or submitted the following proposals: (a) the Year 9 and Year 10 annual Omnibus Proposals; (b) several proposals to different NOAA offices (GIMPAP, GOES-R3) to improve the CIOSS coastal ocean forecasting system; (c) proposals to the IPO (Integrated Program Office) for work needed to prepare for color sensors on the Visible/Infrared Imager Radiometer Suite (VIIRS); and (d) a proposal for funds to support student and post-doc participation in the Fifth Coastal Altimetry Workshop. Reports include our annual report (this document) and summaries of workshops, short courses and outreach activities. An updated CIOSS brochure was also produced.

Tasks II: Research and Outreach Activities, Organized by CIOSS Theme

The summary of activities in Research Themes 1 and 2 are combined.
Research Theme 1 - Satellite Sensors and Techniques:
In this theme we concentrate on development of, and preparations for, future satellite sensors; evaluation and quality control for present satellite sensors; and retrospective Cal/Val activities that allow continuous climate-quality records to be constructed from data derived from multiple sensors.
Research Theme 2 – Satellite Fields and Fluxes:
Theme 2 research projects focus on the development, evaluation and distribution of improved fields of surface ocean parameters and air-sea fluxes that are derived using satellite data (alone or in combination with in situ data and models). The goal is often to develop fields with higher spatial resolution or accuracy than presently available, or fields that reduce gaps between the coast and the first retrievable data from the satellite sensor.

Ocean-Color Cal/Val:
Most of the CIOSS-supported efforts in satellite Cal/Val are focused on ocean color sensors. Looking from the perspective of the future, VIIRS and MERIS are the priority ocean color sensors, using MODIS and HICO while they exist to broaden the suite of coincident measurements for the priority sensors. In this context, Project 6 funding for Drs. Curtiss Davis and Ricardo Letelier as part of the VIIRS JPSS (formerly IPO) Cal/Val team provides the central glue for CIOSS ocean color Cal/Val, while other projects have provided important contributions of support for this central effort. In Project 3, we received one year of Ground Systems funds two years ago that allowed the Davis-Letelier team to add the computer processor and disk capacity that are being used for MERIS, MODIS and VIIRS processing. Although the original plan was to use three years of Ground Systems funds to build the necessary system, no funds have been available since the first year. The system that was set up in the first year is presently adequate, but will need augmentation in the future to meet the needs of the data that will be received with the new Direct Download receiving station (see Project 10 below).

Another IPO project (Project 4) supported the purchase and modification of a SeaPRISM above water radiometer system that is now installed on an oil platform (Eureka) 8 miles off of the LA harbor and providing in situ data for near-real time Cal/Val. Management of that system has been transitioned to Burt Jones (USC). In Project 10, STAR/SOCD
partially funded the acquisition of a third key element for ocean color Cal/Val on the U.S. West Coast – a new satellite receiving dish for the Direct Broadcast station at OSU. The station was installed in September 2011 and is receiving MODIS and VIIRS (engineering data at present), as well as several other satellites. OCM-2 is being tracked and will be down-loaded and processed when those responsible for its data in India allow it. A dedicated Cal/Val effort will be needed to merge data from OCM-2 with data from the other sensors. Omnibus Projects 5 and 11 over the past 2 years have supported the development of automatic co-location software for archived in situ data (HOT, MOBY, and U.S. West Coast data from cruises and moorings in 5 "golden regions," and satellite data from VIIRS, MERIS and MODIS. Separate funding from the Navy provides 90 m data from the hyperspectral HICO sensor at these locations too. All of this has been brought together in VIIRS preparations in Project 6. The VIIRS work includes successful dry runs conducted this past July and August, part of the JPSS funded activities. There are 9 "milestones" in the JPSS cal/val project and most have been met or are ongoing.

The new "OPSCON" for VIIRS have defined 3 Categories of activity:
Cat I: Near-real time monitoring of VIIRS stability (sensors and algorithms)
Cat II: Evaluation of proposed changes in the LUT (Look-up tables) for creating SDR’s out of RDR’s.
Cat III: Retrospective cal/val using QC’d data.

Present activities at OSU fall under these categories:
CAT I:  
- Ingest near-real time data from VIIRS and compare satellite instruments  
  - VIIRS from GRAVITE now; VIIRS from the OSU DB station when NOAA allows this. Local creation of SDR’s & Ocean EDR’s in APS  
  - MERIS from Canada  
  - MODIS from the OSU DB station  
- Receive and archive near-real time in situ data from the Eureka SeaPRISM system (LA Harbor) through AERONET  
- Receive HICO data (NRL project)  
- Receive processed VIIRS L3 data from NRL (APS processing) to compare to standard products from GRAVITE for five west coast “golden regions” (LA Harbor, Santa Barbara Channel, Monterey Bay, Newport Oregon and the Columbia River outfall).  
- Export data to NOAA (West Coast CoastWatch and HQ), NASA, NRL, CCNY  
- Place data on our local web page for display (password protected until VIIRS data are released)  
- Calculate automated statistics: means, standard deviations, correlations of in situ and satellite radiances, linear/non-linear regressions between VIIRS, MERIS, MODIS, HICO to assure multi-platform EDR continuity in time (under development).
CAT II: Test LUT changes for five west coast “golden regions”, using an archive of in situ and satellite RDR’s, co-located for those regions. First we will process the RDRs to SDRs using the U. Wisconsin ADL (RDR to SDR) software. Then we will use both APS and GRAVITE for processing to EDRs. Compare the SDR’s and EDRs using the old and new LUT’s.

CAT III: Longer-term (> 1 Year) cal/val: We will use MOBY, HyperPRO and other in situ data from HOT, the Oregon Coast, Santa Barbara, and additional cruises as funded. Evaluate remote sensing reflectances, and IOP’s with optical data and chlorophyll using HPLC chlorophyll-a. The primary goal is to evaluate the vicarious calibrations performed using MOBY data, and assess effects on the coastal and HOT data products.

Other Ocean Color Projects:
HABs: In Project 15, Dr. Angelique White is evaluating the “Bloom” product that is produced by David Foley at the West Coast node of the NESDIS CoastWatch program. This product provides maps (Research Theme 2) of estimated increases in surface chlorophyll-a pigment concentrations over the past 8 days to identify where phytoplankton blooms of any type are occurring. A graduate student (Morgaine McKibben) is working with Dr. White and assessing the appropriate de-correlation scales for these types of composites and temporal differences, communicating these results and other metrics back to David Foley. The present product uses MODIS data that is received at the OSU downlink station and forwarded to CoastWatch. Future work will evaluate the MCI index relative to available dinoflagellate bloom indices using MERIS 300 m data. When VIIRS data become available, a bloom deviation product will be computed using VIIRS data and it will be cross-correlated with MODIS- and MERIS-derived bloom indexes.

Other Sensors, Themes 1 and 2:
CIOSS provides partial funding for several projects involving other satellite sensors, with primary support coming from NASA

Altimetry:
NASA funding supports several altimeter projects at OSU, where CIOSS Fellows Dudley Chelton and Ted Strub have been on the altimeter Science Teams since their inception in 1987. Cal/Val is one of the activities engaged in by members of the Science Teams, with intensive efforts directed towards TOPEX, Jason-1 and Jason-2 after each of their launches. As part of Strub’s present grant, he is working to retrieve alongtrack data closer to the coast than in traditional altimeter data processing. In an initial effort, altimeter data have been combined with coastal tide gauge data to create a sea level anomaly product that has no gaps next to the coast. Omnibus funding from ORS has supported the transition of the modified altimeter data to JPL (Project 14). Project 13 is partially supporting a graduate student from India to work with altimeter data next to the coast of India as part of his thesis project. In Project 18, funding from the NOAA Laboratory for Satellite Altimetry (LSA, directed by Laury Miller) has also supported travel to the fourth and fifth Coastal Altimetry Workshops for students and early career scientists, in order to
increase the use of altimeter data in coastal studies. CIOSS Fellows Chelton and Strub are also supported by NASA to advise in the design of future altimeters (SWOT).

**Scatterometry:**
Similarly, NASA funding supports four separate grants to OSU PI’s to work with scatterometer wind data. One project led by Strub is specifically supporting refinements to the land mask that allow wind data to be retrieved from areas closer to the coast than possible with the standard land mask. The same omnibus funding (Project 14) from ORS that supports transition of altimeter products is supporting the transition of the modified wind fields to JPL and other interested parties. Present activities on winds involve the evaluation of a newly processed QuikSCAT data set. NASA funding has also allowed CIOSS Fellows Chelton and Strub to provide advice on the design of new scatterometers. The next planned U.S. scatterometer will be the dual frequency scatterometer. There may someday be a more innovative XOVWM (experimental ocean vector wind mission).

**SST:**
CIOSS Fellow Dudley Chelton is continuing to work with Dick Reynolds on improvements to, and evaluation of, SST fields that are processed and archived at two NESDIS labs (NCEP and NCDC). Reynolds has retired from NOAA but is employed as a Fellow of CICS-NC. Support for this work comes from both NASA and CICS-NC. Several projects at OSU have a focus of air-sea interactions (SST-winds). In the past, Chelton’s work on this topic has been funded by CIOSS Omnibus projects.

**Surface Velocity:**
The objective of Project 9a is to evaluate methods of using sequences of Geostationary SST images to estimate fields of surface velocities. These statistical and kinematic methods trace their heritage back to the estimates of winds from cloud motions in Geostationary satellite fields. In most oceanographic applications, SST fields from Polar Orbiting satellites have been use to estimate surface ocean currents. Improvements in the GOES SST fields since 1995 make it possible to use the GOES fields, which are (potentially) separated by much shorter time intervals (in the absence of clouds). GOES-R SST fields will be even more improved, although the interference due to clouds cannot be eliminated. We are evaluating these methods, in comparison to the assimilation of the SST fields (and other data) into ocean forecast models (Project 9b).

**Research Theme 3 - Models and Data Assimilation:**
This is an important research area for CIOSS, helping NOAA/NESDIS to prepare to play a stronger role in the IOOS system. Models that assimilate in situ and satellite-derived fields are expected to be central components of ocean observing systems. The models will increase the demand for satellite-based products for the ocean, similar to the demand for satellite-based atmospheric products created by weather forecast models. As is common in the atmospheric sciences, fields from these data-assimilating ocean models will increasingly be used for oceanographic analyses, using the models’ complete coverage without missing data due to clouds and land masks. The models also provide a link between deeper fields and the satellite observations of the ocean surface. Moving
beyond the purely physical fields of currents and water properties, marine ecosystem models have become an important component ocean models, as a result of NOAA’s interest in Ecosystem Approaches to Management and Integrated Ecosystem Assessments. Growing concerns about Ocean Acidification and Hypoxia also require that models have realistic representations of biochemical processes. In the past, ecosystem modeling projects at OSU have been funded through partnerships with NOS in the U.S. GLOBEC project, which has now ended.

CIOSS Omnibus funding supported the modeling and data assimilation efforts for physical variables during its first five-year period. During the past several years, funding to add and evaluation data assimilation of satellite physical variables into the basic circulation models has come from other STAR sources. Below we combine the annual reports for the physical modeling and data assimilation activities in **Project 7** (“End-of-Year” funding to evaluate the benefit of data assimilation), and **Projects 8 and 9b** (GIMPAP and GOES-R3 funding to improve estimates of surface temperature and surface current fields by assimilating GOES and GOES-R SST fields). The one effort that was funded through the Omnibus Proposal in Year 9 is **Project 12** (Spitz et al.), which is investigating the addition of ecosystem and biochemical components to the model, with the goal of providing predictions (or at least “nowcasts”) for phytoplankton blooms and for hypoxia. While progress has been made in developing ecosystem models that can be run for specific historical cases, the lack of real-time boundary conditions for biochemical variables is presently a problem that prevents the inclusion of realistic ecosystem model fields in the near-real time forecast fields.

One of the major success stories of the CIOSS partnership is the development of coastal circulation models with the ability to assimilate satellite (and other) data, especially physical variables (surface height, currents, temperature and salinity). The Oregon Coastal Pilot Prediction system now has the capability of assimilating GOES SST and altimeter alongtrack SSH data. It can also assimilate coastal radar fields of surface velocities. The output fields from the model include SST, surface velocities and salinity (present and two days into the future). The model SST and surface current fields are available from a local web site and also from the NANOOS Visualization System (NVS). NANOOS is the Pacific Northwest IOOS Regional Association. The SST fields have been used by recreational fishers and charter fishing companies to plan cruise tracks, with the goal to minimize the fuel used to get from the coast to the SST frontal regions for tuna fishing. We are presently increasing our interactions with the fishing community, in order to improve the products constructed with the model fields. For example, they have requested maps of surface current convergences, where floating material accumulates and attracts fish. Outreach to the fishing community and other users will be the focus of the “modeling” activity supported by the Omnibus projects during Year-10.

Some projects address multiple themes but are reported here in one theme for administrative purposes. **Project 2** consists of two efforts that are constructing climatologies of satellite- and model-derived fields, which are scientifically of interest in themselves but also useful for more applied purposes. Because of its strong modeling connection, this project is included in Theme 3, although it could have been placed under
Theme 4 (Data Analyses) or Theme 2 (Fields and Fluxes). The objective of Project 2a is to use the available time series of satellite data to provide maps of surface variables showing the monthly seasonal cycle of SST, SLA (sea level anomaly), wind and chlorophyll-a pigment concentrations in a 500-km wide band around the NE boundary of the Pacific Ocean, from Baja California to the Aleutian Islands. These seasonal cycles provide a base state against which to quantify “anomalies” of climate variability and future climate change. In Project 2b, the velocity fields of the modeling efforts (Projects 7, 8, 9b) are used to calculate trajectories of water parcels and plankton during different seasons. These can be used to quantify the retention characteristics for an area and connectivity between multiple areas. Applications for these fields include the location of Coastal Marine Reserves and other management issues concerning the transport of larvae of commercially important species, ultimately affecting the survival of a given year’s youngest stages. Other applications include planning for spills of oil and other toxic substances, salvage operations, etc.

**Research Theme 4 - Oceanic and Atmospheric Data Analysis:**
Projects in Theme 4 use satellite, *in situ* and model fields, singly or in combination, to attain better understanding of the oceans, atmosphere, and marine ecosystems. These are the more traditional types of “basic-research” topics that are supported by NSF and NASA. Although NOAA is a “mission-oriented” agency and supports more applied research grants, it also engages in basic research. During the first five years of CIOSS, its projects included more basic research topics in air-sea interaction and ocean circulation. During the second five years, the focus has been on helping NESDIS, STAR and SOCD to produce and QC the data (including model fields), rather than analyzing the data to answer basic science questions. As noted above, however, Project 2 could have been listed under this theme.

**Theme 5 - Education and Outreach:**
This theme considers formal and informal means of educating students, other scientists, resource managers, and the general public about ocean science and related aspects of meteorology and biological/ecological processes. This theme also includes activities that transfer technologies from research use to operational use.

**SMILE:**
In Project 16, Ryan Collay coordinates the Science & Math Investigative Learning Experiences (SMILE) program, an after school “club” activity designed to motivate students to graduate from high school and attend college in a field of science, math or education. It targets districts with large populations of student that are under-represented in higher education attendance, especially in fields of science and math. CIOSS works with the SMILE high school program to develop topics that stress remote sensing and oceanography, within the context of climate variability and change.

On a broader scale, SMILE personnel are working with educators in the Suitland (MD) school district to implement a SMILE-like program in their district. This follows visits to
OSU by S. Quinton, one of the Suitland educators, in August 2010 and a visit by A. Christensen (SMILE) to Suitland in October 2010. A successful proposal by the Suitland educators is providing a funded mechanism for ongoing dissemination of the SMILE approach.

**CoRP Symposium and Student Exchanges:**
Five CIOSS members attended the annual CoRP Symposium in Asheville, North Carolina, during August 17-18, 2011. CIOSS Fellows Dudley Chelton and Alexander Kurapov gave presentations, as did graduate student Meredith Payne. Meredith Payne received the award for Best Oral Presentation. The other two attendees were Roberto Venegas and Peng Yu, Faculty Research Assistants who presented posters. Funding for these visits comes from the CoRP program, detailed in **Project 17**.

**Coastal Altimetry Meetings Travel Funds:**
As mentioned above, in **Project 18** CIOSS used funding provided by L. Miller in the LSA (NESDIS/SOCD) to support travel to the Fifth Coastal Altimetry Workshop ([http://www.coastalaltimetry.org](http://www.coastalaltimetry.org)), which was held in San Diego, California in October. The time and location were chosen to overlap the meetings of the international Ocean Surface Topography Science Team and the ARGO float science review. CIOSS sponsored travel costs for ten scientists (graduate students and two of their professors).
I. INTRODUCTION

A. The Establishment of CIOSS
The Cooperative Institute for Oceanographic Satellite Studies (CIOSS) was established in 2003 between the National Oceanic and Atmospheric Administration (NOAA) and Oregon State University (OSU) by a Memorandum of Agreement (MOA). CIOSS was selected competitively from proposals submitted in response to a Request for Proposals posted in the Federal Register Notice. Initial research collaborations are between OSU’s College of Earth, Ocean and Atmospheric Sciences (CEOAS, formerly COAS, the College of Oceanic and Atmospheric Sciences, http://coas.oregonstate.edu/) and the Center for Satellite Applications and Research (STAR, formerly the Office of Research and Applications, http://www.orbit.nesdis.noaa.gov/star/), within NOAA’s National Environmental Satellite, Data, and Information Service (NESDIS, http://www.nesdis.noaa.gov/). As stated in the MOA, the creation of CIOSS recognizes the “mutual, evolving and long-term interest in cooperative research projects and operational programs” involving oceanographic issues, shared by OSU/CEOAS and NOAA. Further information about CIOSS, including the text of the MOA, the Five-Year Plans, annual and other reports (from workshops, etc.) can be found on its web site at http://cioss.coas.oregonstate.edu/. Information about OSU can be found at http://oregonstate.edu.

B. CIOSS Vision and Mission Statements
Vision Statement: CIOSS is a cooperative (Academic-Federal) center of excellence for research and education, which involves satellite remote sensing of the ocean and its air-sea interface, along with models of the ocean and overlying atmosphere. CIOSS provides a mechanism to bring together the resources of a research-oriented university (OSU), NESDIS and other NOAA line offices, with additional partners at other universities, government and private agencies. With these partners, CIOSS conducts research of mutual interest to CIOSS/CEOAS and NOAA. This research helps NOAA to accomplish its Mission Goals and helps NESDIS to fulfill its role in providing the remote sensing component of the Integrated Ocean Observing System (IOOS), which includes operational and research components within NOAA, ONR, NSF and NASA. CIOSS contributes to the development of ocean observing and modeling systems, along with public understanding of those systems, through:

- Research that helps to develop and improve our understanding of, and operational products related to, the upper ocean and air-sea interface. It does this by using data from present and past satellites and by helping to plan future satellite sensors;
- Research that helps to incorporate and assimilate those products and understanding into ocean and atmosphere circulation models; and
- Education and training in the same topics, reaching a wide range of “audiences” in formal education (K-16 education, graduate school, ongoing professional training) and informal education (public outreach).
CIOSS Mission, Goals and Objectives: The CIOSS mission is to enhance and improve the use of satellite remote sensing for oceanographic research, operational applications and education/outreach. To do this, CIOSS has the following broad goals and objectives:

- Foster and provide a focus for research related to NOAA’s mission responsibilities and strategic objectives in the coastal and open ocean, emphasizing those aspects of oceanography and air-sea interaction that utilize satellite data, along with models of oceanic and atmospheric circulation;
- Collaborate with NOAA research scientists in using satellite ocean remote sensing through: evaluation, validation, and improvement of data products from existing and planned instruments; development of new multi-sensor products, models, and assimilation techniques; and investigation and creation of new approaches for satellite data production, distribution, and management;
- Improve the effectiveness of graduate-level education and expand the scientific training and research experiences available to graduate students, postdoctoral fellows and scientists from NOAA and other governmental laboratories and facilities; and
- Educate and train research scientists, students, policy makers and the public to use, and appreciate the use of, satellite data in research that improves our understanding of the ocean and overlying atmosphere.

C. CIOSS Strengths and Focus on Ocean Margins
CIOSS has been established within CEOAS at OSU to make use of the extensive and broad-ranging expertise of CEOAS faculty in satellite remote sensing, in situ data collection, data analysis, modeling and data assimilation. CIOSS supports research that enhances the ability of NOAA/NESDIS to accomplish its mission, while also training scientists in the use of remotely sensed data. Leveraging specific CEOAS strengths, a major focus is on the large-scale continental margins of the U.S., with applications to other ocean margins of the world. Within that focus, a “test bed” for satellite technique development, modeling and data analysis is the California Current, along the U.S. west coast. The focus on continental margins is aligned with the present national priority to create an integrated observing system for the “coastal” ocean, interpreting the word “coastal” in a broad sense. This is also a region where many CIOSS Fellows are collaborating in multi-institutional field programs, providing a wealth of field data with which to test remote sensing and modeling methods. This focus on ocean margins does not preclude research on regional to basin scales, which are also important topics within the broad range of CIOSS research.

D. CIOSS Research and Outreach Themes
The following five themes of mutual interest to NOAA and OSU are stated in the Five-Year Plan.

Theme 1: Satellite Sensors and Techniques: Evaluation of existing and proposed satellite sensors, algorithms, and measurement techniques.
**Theme 2: Ocean-Atmosphere Fields and Fluxes:** Development, evaluation and analysis of improved fields of physical and biological parameters in the upper ocean, and of surface parameters and fluxes at the air-sea interface, using combinations of remote sensing, in situ data and modeling.

**Theme 3: Ocean-Atmosphere Models and Data Assimilation:** Use of satellite-derived fields to force and evaluate numerical models of the oceanic and atmospheric circulation, including the assimilation of those fields using methods of inverse modeling. For some applications, the ocean models will include components of marine ecosystems.

**Theme 4: Ocean-Atmosphere Analyses:** Dynamical and statistical analyses of data sets derived from satellites, models and in situ instruments, in order to increase our understanding of the physical, chemical, biological, geological and societal processes that affect, and are affected by, the ocean-atmosphere system.

**Theme 5: Outreach:** We include three broad Outreach areas, each to be related to CIOSS research and its results.

**Formal Education** of students (K-12, undergraduate and graduate students), other scientists, resource managers and the general public in aspects of oceanography, surface meteorology and the use of remotely sensed data sets and numerical models. Short courses and training workshops are included in this category, as are workshops designed to develop or evaluate present and planned sensors and techniques.

**Informal Education** of the same groups in the same subjects, but in contexts outside of the formal educational system, short courses and workshops. This may take the form of web-based material, presentations, forums, and exhibits at public science museums.

**Data Access** includes activities that enhance the use of data sets derived from satellites and models by research scientists, students, educators, resource managers and the general public.

**E. CIOSS Task Structure**
For budgetary and administrative purposes, CIOSS uses a simple structure to partition activities into three “tasks,” as do most of the NOAA CIs. Task I involves NOAA/NESDIS’s basic support for the administration and general operations of CIOSS, including some education and outreach, using core funding. Tasks II and III consist of research and additional outreach projects, differentiated by the degree of collaboration with NOAA personnel.

**Task I: CIOSS Core Office Administration and Outreach**
Provides general administrative support for CIOSS research and core outreach activities (all Themes). Task I includes but is not limited to the following activities:
General operation of CIOSS, including providing salaries for the Administrative Program Specialist, Director, Deputy Director and other administrative staff members;
Necessary funding for domestic and international travel for the Director and other CIOSS staff, Fellows and participants in CIOSS workshops;
Publication of the annual and other reports, newsletters, articles, brochures, etc.;
Outreach activities supported by the annual core funding from STAR/SOCD, primarily the organization of workshops and short courses, sponsored or hosted by CIOSS. CIOSS may also help to organize workshops sponsored by other agencies, on topics included in the CIOSS Research Themes.

Task II: CIOSS Research and Outreach, in Close Collaboration with NOAA Personnel
Provides support for research projects consistent with CIOSS’ Research and Outreach Themes, if the projects involve substantial collaborations with NOAA colleagues; these include support for outreach beyond that covered in Task I, when NOAA personnel are involved. Details of these projects are developed in each proposal, as specific opportunities are identified.

Task III: CIOSS Research and Outreach, with Limited Collaboration with NOAA Personnel
Provides support for research projects in CIOSS’ Research and Outreach Themes, similar to those in Task II, in which collaboration with and participation by NOAA personnel are not substantial. Details of these projects are also developed in each proposal, as specific opportunities are identified.

F. CIOSS Management
Organizational Structure
A simplified picture of the CIOSS organizational structure (as it existed in 2011) is presented in Figure 1, in which the blue-shaded boxes represent elements of CIOSS and the white boxes represent the organizations and people with whom CIOSS interacts most closely. Not shown are the extended organizational structures for NOAA and its components, only those that interact with CIOSS: Paul DiGiacomo, Ingrid Guch and Ericka Rosier are located in STAR, which is directed by Al Powell (http://www.orbit.nesdis.noaa.gov/star/star_orgchart.php): STAR is part of NESDIS (http://www.nesdis.noaa.gov/About/nesdis_org.html), a NOAA line office led by Mary Kicza; Jane Lubchenco is the Administrator of NOAA (the Department of Commerce Undersecretary for Oceans and Atmosphere, http://www.pco.noaa.gov/org/NOAA_Organization.htm). The figure also does not show the larger structure within OSU, only those associated with CIOSS: the Director of CIOSS is appointed by the Dean of CEOAS (Mark Abbott, http://coas.oregonstate.edu/), who is appointed by the President of OSU (Edward Ray, http://oregonstate.edu). The CIOSS MoA is signed by the NOAA Administrator and the OSU President, demonstrating that it encompasses collaborations between personnel within NOAA and OSU at all levels.
Within CIOSS, most administrative tasks are carried out by the Administrative Specialist (Amy Vandehey), Director (Ted Strub) and Deputy Director (Hal Batchelder) (Figure 1). All three interact with the managers within NESDIS/STAR, primarily the Director of STAR (Al Powell), the Cooperative Research Program (CoRP) Chief (Ingrid Guch) and the Satellite Oceanography and Climate Division (SOCD) Chief (Paul DiGiacomo). The Deputy Director primarily assists in developing the annual Omnibus Proposal and Annual Report, also attending Council and NOAA Directors’ Meetings and filling in for the Director when needed. The Administrative Specialist interacts with the CoRP Chief and the STAR Program Support Specialist for grants. The CIOSS Director and Administrative Specialist interact with a CEOAS Grants Accountant, who has been assigned to CIOSS by CEOAS. The CEOAS Grants Accountant is the primary contact with the OSU Administrative Accountants.
There are presently 30 CIOSS Fellows (listed on the inside of the front cover of this report): nineteen at OSU, two at NOAA Fisheries in Pacific Grove, CA, and nine at NOAA/STAR/SOCD. A Council of Fellows (with CEOAS and SOCD members, see below) advises the Director when issues arise. Most of the interactions between the Director and Council members are carried out through individual discussions (in person, over the telephone) and emails, with periodic in-person and teleconference meetings. Council members participate in the process of evaluating proposals for the annual Omnibus Proposal. An external Executive Board also advises both NOAA and CIOSS administrators. The Board consists of 7 members, two of them non-voting ex-officio members. During 2011, the members were:

- Mark Abbott (Chair): OSU, Dean of CEOAS
- Mary Kicza: NOAA, Assistant Administrator for NESDIS
- Al Powell: NOAA, Director of STAR
- Chris Sabine: NOAA, Director of PMEL
- Stephen Brandt: OSU, Director of Oregon Sea Grant
- Ted Strub (Ex-Officio): OSU/CEOAS, Director of CIOSS
- Curt Davis (Ex-Officio): OSU/CEOAS, Chair of CIOSS Council of Fellows

The CIOSS Council of Fellows consists of 13 Fellows (asterisks on the inside of the front cover), two of them non-voting ex-officio members. During 2011, the members were:

- Curt Davis (Chair, Ecosystems), OSU/CEOAS
- Mark Abbott (Executive Board Chair, Ecosystems), OSU/CEOAS
- Jack Barth (Ecosystems), OSU/CEOAS
- Hal Batchelder (Ecosystems and Modeling), OSU/CEOAS
- Paul Chang (Winds), NOAA/NESDIS/STAR/SOCD
- Dudley Chelton (Altimetry, Winds, SST), OSU/CEOAS
- Paul DiGiacomo (SOCD Chief, Ex-Officio, Satellite Products), NOAA/NESDIS/STAR/SOCD
- Alexander Ignatov (Chief of the Satellite Ocean Sensors Branch), NOAA/NESDIS/STAR/SOCD
- Ricardo Letelier (Ecosystems), OSU/CEOAS
- Laury Miller (Chief of the Laboratory for Satellite Altimetry), NOAA/NESDIS/STAR/SOCD
- Roger Samelson (Modeling), OSU/CEOAS
- Ted Strub (Director, Ex-officio, Altimetry, Satellite Products), OSU/CEOAS
- Menghua Wang (Chief of the Marine Ecosystems & Climate Branch), NOAA/NESDIS/STAR/SOCD

**Communications**

During 2011, most communications between OSU and NOAA Council members occurred through emails and conference calls related to specific projects and proposals that were submitted to NOAA. The CIOSS Director (Strub) also takes part in weekly teleconferences between I. Guch and the NOAA Branch Chiefs at each of the NESDIS CI’s, providing frequent contact between CIOSS and the CoRP office. Communications with P. DiGiacomo more often occur as telephone calls between the two, with conference calls used when needed.
Proposal and Reporting Procedures

Beginning in Year-6, the Administrative and Research parts of the Omnibus have been submitted separately. The Administrative portions of the budgets for all five years (Years 6-10) were included in the CIOSS Five-Year Plan for 2008-2013 and approved with that plan as a multi-year proposal. The procedure is for NOAA to award the Administrative funds for each year after the Annual Progress Report is submitted, which is now due at the end of January of each year and should cover the previous calendar year. The research projects for each year are proposed separately in the annual Omnibus Research proposal.

As described above, the projects to be included in the Annual Omnibus Research Proposal are developed through interactions of the CIOSS Fellows and STAR Program Managers prior to submission. As opportunities arise, other proposals are prepared for submission, usually as a result of external or internal NOAA announcements of opportunities and after discussions between CIOSS personnel and NOAA partners and program managers.

During the year, the PI’s for the funded projects receive quarterly (or monthly, if requested) budget summaries from the CEOAS Grants Accountant. OSU’s Office of Post-Award Administration personnel assure compliance with all regulations and submit semi-annual financial reports to NOAA for all NOAA grants at OSU, including CIOSS. The PI’s submit annual technical Progress Reports to CIOSS for each project, which become part of the CIOSS Annual Technical Progress Report (this document, see the detailed individual reports below).
II. YEAR 9 FUNDING SUMMARY AND PROJECT REPORTS

A. Distribution of Year 9 Funding by Theme, Task and Mission Goal

In Section II-B we list all projects active during Year 9, along with their funding, CIOSS Research Theme, CIOSS Task number and NOAA Mission Goal. Using those numbers, here we present the percent of funds used for each Theme, Task and Mission Goal. The total funding listed for Administration and the 17 individual research and outreach projects is $1,067,500 (rounded to the nearest $100). In grouping projects by Research Theme, we exclude Administrative costs, resulting in a total of $831,000.

Note: Funds in addition to the core SOCD support are included here. If only core funding were included, the total for Research and Outreach (Tasks II and III) would be only $263,547 and the percentages for Themes 1-5 would be 38%, 23%, 23%, 0% and 16%, respectively.

The distributions are:

CIOSS Research Theme: $831,000 (excluding Administration)
- Sensors and Techniques: $332,500; 40%
- Fields and Fluxes: $60,900; 7%
- Modeling: $358,600; 43%
- Satellite Data Analyses: $0; 0%
- Education and Outreach: $79,000; 10%
CIOSS Task Number $1,067,500

I. Administration and Core Outreach: $236,500; 22%
II. Research & Outreach with NOAA Collaborations: $831,000; 78%
III. Research & Outreach without NOAA Collaborations: $0; 0%

CIOSS Funding by Task
NOAA Mission Goal: $1,067,500
1. Ecosystem Management: $712,400; 67%
2. Climate Variability: $0; 0%
3. Weather and Water: $82,600; 8%
4. Transportation: $0; 0%
5. Mission Support: $272,500; 26%

CIOSS Funding by NOAA Goals with Mission Support
B. Reports of Year 9 Administration, Research & Outreach Projects

1. Listing of All Projects by Task

The projects active in Year 9 are grouped by task and listed alphabetically. To facilitate finding the projects throughout the rest of the report, the projects are then listed in a table, which gives the corresponding page number for the beginning of each report. For each project, we give the CIOSS Task number, CIOSS Research Theme, NOAA Mission Goal, and the funding amount. The amounts for Year 9 only are used to develop the summaries of funding distributions presented above in the Introduction. More detailed progress reports are then presented in Section II-B-2.

For reference, the NOAA Mission Goals are provided below (from the existing NOAA Strategic Plan rather than the Next Generation Strategic Plan). We also list Mission Support as a 5th NOAA Goal, under which the CIOSS Administration funds fall. Although we do not identify any projects with a primary focus on Goal 4 (Transportation), projects that increase our ability to observe and model the coastal ocean circulation and improve forecasts of weather and ocean conditions have obvious applications to marine transportation in helping vessels to avoid hazardous conditions, aid in search and rescue, and set courses that use knowledge of the SST fields and currents to reduce fuel consumption.

The five NOAA Mission Goals are:

1) Protect, Restore, and Manage the Use of Coastal and Ocean Resources (Ecosystems);
2) Understand Climate Variability and Change;
3) Serve Society’s Needs for Weather and Water Information;
4) Support the Nation’s Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation.
5) Provide Critical Support for NOAA’s Mission

The active Year-9 Projects, grouped by Task Number, are:

CIOSS Task number, Lead PI: Project Title, [CIOSS Research Theme], (NOAA Mission Goal), funding amount for 2011-2012, and primary NOAA contact person. Other NOAA Collaborators are listed in the individual project headers.

Task I:
Strub, Batchelder, Vandehey: Administration, [No Theme], (Mission Support), $236,454, Ingrid Guch

Task II Research:
Batchelder, Strub: EOY Satellite-Derived Climatology: The California Current System Large Marine Ecosystem [Theme 3], (Ecosystems), $77,009, Paul DiGiacomo
Davis: CIOSS Ground Systems Proposal: Development of a CIOSS Satellite Processing System for Merged Ocean Color Products, [Theme 1], (Ecosystems), no new funds for Year 9, Ingrid Guch
Davis: VIIRS Calibration and Validation Activities – Establishing a SeaPRISM site on the West Coast of the United States, [Theme 1], (Ecosystems), no new funds for Year 9, Karen St. Germain

Davis, Letelier: Use and Validation of MERIS Coastal Products for US West Coast Waters, [Theme 1], (Ecosystems), $60,034, Paul DiGiacomo

Davis, Letelier: VIIRS Calibration and Validation Activities – Time series cal/val for Open Ocean and Coastal Ocean Color EDRs, [Theme 1], (Ecosystems), $142,860, Heather Kilcoyne

Kurapov: EOY Performance Analysis of a Coastal Ocean Data Assimilation System, [Theme 3], (Weather and Water), no new funds for Year 9, Laury Miller

Kurapov: GOES SST Assimilation for Nowcasts and Forecasts of Coastal Ocean Conditions, [Theme 3], (Ecosystems), $85,704, Paul DiGiacomo

Kurapov, Strub: CIOSS Support to the GOES-R Risk Reduction Program, [Theme 3], (Ecosystems), $135,823, Paul DiGiacomo

Letelier: Support for the Installation of a Direct Broadcast Satellite Dish, [Theme 1], (Ecosystems), $90,000, Paul DiGiacomo

Letelier: Use of Long-Term Open Ocean Time-Series Bio-Optical Data in the Validation and Refinement of Ocean-Color Algorithms, [Theme 1], (Climate Variability), no new funds for Year 9, Paul DiGiacomo

Spitz, Batchelder, Kurapov: Coupled Real-Time Oregon Coastal Ocean Biophysical Simulations for Forecasting Production Processes, Oxygen Dynamics and Potential Hypoxia on the Oregon Shelf, [Theme 3], (Ecosystems), $60,085, Paul DiGiacomo

Strub: CIOSS Graduate Student Fellowship in Ocean Remote Sensing, [Theme 1], (Weather and Water), $39,575, Paul DiGiacomo

Strub, Risien: Transition of CIOSS Results to the Web, [Theme 2], (Weather and Water), no new funds for Year 9, Paul DiGiacomo

White: Benchmark Characterization of Bloom Characteristics for Coastal Oregon, [Theme 2], (Ecosystems), $60,852, Paul DiGiacomo

Task II Outreach:

Collay: CIOSS Outreach: Development of Oceanographic Remote Sensing Curriculum for the SMILE High School Program, [Theme 5], (Weather and Water), $43,000, Paul DiGiacomo

Strub: CIOSS Support to the NESDIS Cooperative Research Exchange Program, [Theme 5], (Mission Support), $11,000, Ingrid Guch

Strub: Coastal Altimetry Meetings Travel Funds, [Theme 5], (Mission Support), $25,000, Laury Miller
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<th>Project #</th>
<th>Task</th>
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2. Detailed Progress Reports for Each Project

Progress reports are presented below for all projects active during 2011. These are organized by CIOSS Task number, starting with Task I (Administration and Core Outreach), followed by the individual research and outreach projects included in Task II. None of the funded projects in 2011 fell under Task III.

**Task I: Administration & Core Outreach**

**PROJECT 1**

**Title:** Administration

**Principal Investigators:** P. Ted Strub, Hal Batchelder, Amy Vandehey

**Name and NOAA Office of the Primary Technical Contact:** Ingrid Guch, NESDIS/STAR/CoRP

**CIOSS Research Theme:**
None

**Related NOAA Goal from the NOAA Strategic Plan:**
Goal 5 – Supporting NOAA’s mission

Task I activities include administrative support for CIOSS operations, research and core outreach activities (all Themes). These include, but are not limited to: (1) General operation of CIOSS; (2) Preparation of proposals; (3) Logistical support for CIOSS workshops and meetings, as well as domestic and international travel for CIOSS personnel and participants in CIOSS workshops; (4) Publication of the annual and other reports, newsletters, articles, brochures, etc.; and (5) Outreach activities supported by the annual core funding from STAR/SCOD.

**CIOSS Office Activities:**
The CIOSS Administrative Specialist, Director and Deputy Director engage in the following activities:
- Compiled reports, publications, and statistics for the CIOSS Annual Technical Report. A new CIOSS brochure was published in March.
- Discussed projects to be included in the annual Omnibus proposal to NOAA-NESDIS with the Council of Fellows and potential collaborators.
- Continued developing the CIOSS website, including information for workshops, updating of the “News and Notes” section, meeting summaries, etc.
- Continued developing the CIOSS Handbook and Proposal Manual to document procedures (as they change) and provide future guidance on the details of each of the activities needed to administer the program.
- Monitored CIOSS budgets and periodic projections of budget balances. Efforts to train a new CIOSS/CEOAS accountant in the details of the NOAA CI program.
Prepared, submitted and tracked CIOSS proposals and post-award action requests through NOAA Grants.gov, Grants Online, GMD, and the OSU Sponsored Research Office.

Submitted CIOSS “Hot Items” for the NOAA CI website, in addition to monitoring and submitting items to the CoRP Blog.

Coordinated logistics for a NOAA Satellite Data course held at OSU in March, taught by Cara Wilson and Dave Foley (NOAA CoastWatch).

Regularly participated in SMILE planning meetings to develop the overall yearly theme, as well as more specific curriculum and activities for after-school clubs and the annual challenge event.

Coordinated with the SMILE program as a presenter at the Winter teacher workshop (January) and participated in the April High School Challenge event on the OSU campus.

Coordinated logistics and funding for Oscar Pizarro and Catalina Aguirre’s visit to Ted Strub and Jack Barth to work on a collaborative project on seasonal variability in May.

Planned and prepared for various Council of Fellows meetings to discuss a CIOSS follow-on.

Planned and participated in strategic planning and interactions with NOAA Program Managers, CIOSS and other NOAA personnel in order to develop and nourish partnerships.

Compiled information for the CoRP Summer Exchange Program.

Arranged housing for Dick Reynolds’ visit to collaborate with Dudley Chelton in July-August.

Director and administrative specialist attended the annual NOAA CI Meeting in March. The director and administrative specialist attended the NESDIS CI meeting hosted by CICS-NC in June and August, respectively.

Handled logistics for travel to the CoRP Science Symposium at CICS-NC in Asheville, NC in August, and for the 5th Coastal Altimetry Workshop held in San Diego, CA in October.

Director attended various NOAA meetings to present CIOSS projects and seek additional funding, including a Climate Data Records meeting in Asheville, NC (August), and a GOES-R meeting in Huntsville, AL (September).

Provided logistical assistance and funding for Clive Dorman (Scripps – San Diego, CA) and Amy MacFadyen (NOAA-Seattle, WA) to visit CIOSS Fellows and others in the Oceanography department (November).

Participated in multiple teleconferences and e-mails, including compiling statistics, to address Task I funding issues with NOAA administration.

Compiled list of Milestones from CIOSS Fellows’ projects and coordinate submission of monthly Power Point mini-reports.

Proposals Prepared and/or Submitted during 2011:

CIOSS Research and Outreach Omnibus – Year-9 (4/1/11-3/31/12), P. T. Strub, $263.5K. Projects 5, 12, 13, 15 and 16.

CIOSS Research and Outreach Omnibus – Year-10 (4/1/12-3/31/13), P. T. Strub, in preparation for a February 2012 submission.
CIOSS Task I – Year-9 (4/1/11-3/31/12), P. T. Strub, $236.5 K. Project 1. In fact, a formal proposal is not needed for Task I, since it was included in the 2008-2013 Five-Year Plan. The year’s work plan still needs to be prepared, reviewing and projecting budgets for the year.

Satellite-Derived Climatology: The California Current System Large Marine Ecosystem, H. Batchelder, P.T. Strub, $77.0 K. End-of-Year Funding. Project 2a, 2b.

VIIRS Calibration and Validation Activities: Time Series Cal/Val for Open Ocean and Coastal Ocean Color EDRs, C. Davis, R. Letelier, $142.9 K. IPO funding. Project 6.

GOES SST Assimilation for Nowcasts and Forecasts of Coastal Ocean Conditions, A. Kurapov, $85.7 K. GIMPAP. Project 8.

CIOSS Support to the GOES-R Risk Reduction Program #25, A. Kurapov, P.T. Strub, $135.8 K. GOES-R3 funding. Project 9a, 9b.

Support for the Installation of a Direct Broadcast Satellite Dish, R. Letelier, $90.0 K. Project 10.


Coastal Altimetry Meetings Travel Funds, P.T. Strub, $25.0 K, Jason Altimeter Program funding. Project 18.


Reports Prepared during 2011:

Annual Report – Year 8: Starting in Year-6, NOAA reporting requirements changed and NOAA asked that the Annual Progress Report be submitted 60 days before the anniversary date (January 30). NOAA determined that the period to be covered is the calendar year prior to the report’s due date (spanning two CIOSS performance years). The report for Year 8 covered activities in calendar year 2010 and was submitted by OSU through Grants Online on February 1, 2011.

Development of the Omnibus Proposal:

For the Year 9 Omnibus, discussions between Director Strub and Paul DiGiacomo (NOAA) began in October 2010. After a series of emails, phone conversations, and a meeting of the CIOSS Council of Fellows, an initial set of projects was selected and proposals for those were received in early December. A synopsis of these was sent to DiGiacomo, who requested a set of conference calls to fine-tune the proposals further. During January 2011, CIOSS fellows and NOAA scientists took part in conference calls to work out differences in the details of the proposals, which were submitted in the Year 9 Omnibus Proposal in February 2011.

Toward the end of 2011, the process was started again, somewhat later than in 2010. Those in NESDIS were preoccupied with the launch of NPP and the actions needed to evaluate sensor performance as quickly as possible. Those in CIOSS at OSU concentrated on the Annual Progress Report. Discussions of possible projects began internally within CIOSS in late December, with discussions between Strub and DiGiacomo scheduled for January 2012.
Council of Fellows and Other Meetings:

April 7 – NOAA Regional Team Visit: CIOSS was encouraged by John Cortinas (NOAA) to contact our local NOAA Regional Initiative Team to introduce them to the scope of our NESDIS Cooperative Institute, and discuss possible collaborations. This resulted in a visit in April from Timi Vann (NWS, Seattle - Office of ASST, Regional Coordinator) and John Stein (NOAA NMFS/Acting Science Director, Northwest Fisheries Science Center). Michelle Schmidt (NWS-Western Region - Salt Lake) was unable to attend at the last minute. Timi and John were interested in talking with CIOSS about some of NOAA’s collaborative activities in the region and to give an update on agency priorities, and how those priorities are being executed regionally. They also wanted to take the opportunity to meet with other groups on the OSU campus, such as Oregon Sea Grant and the regional integrated sciences and assessments (RISA) program, funded by NOAA.

AGENDA

9:00 AM - Welcome by COAS Dean Mark Abbott; Initial discussion of the visit objectives. NOAA team, CIOSS Director Ted Strub and CIOSS Admin Specialist Amy Vandehey

9:40 AM - Meet with Phil Mote and Josh Foster, Director and Program Manager of RISA and the CSC

10:40 AM - Meet with Stephen Brandt, Director of OSU Sea Grant

1:30-3:00 PM - 15-Minute Presentations to the Regional Team

1:30 PM - CIOSS Intro, Ted Strub

1:40 PM - Curt Davis: CIOSS Theme 1, Satellite Sensors and Techniques: Ocean Color (Bio-Optics) Sensor Development

1:55 PM - Angelicque White: CIOSS Theme 2, Ocean-Atmosphere Fields and Fluxes: Harmful Algal Blooms in the Pacific Northwest

2:10 PM - Hal Batchelder: CIOSS Theme 3, Models and Data Assimilation: Ecosystem Models off Oregon and Washington


2:40 PM - Ryan Collay: CIOSS Theme 5, Outreach and Education: The OSU SMILE Program

3:30 PM - Timi Van, John Stein: NOAA's Western Regional Collaboration: Regionally-Tailored Implementation of NOAA-Wide Programmatic Priorities
November 1 – Local Council of Fellows Meeting: A meeting was held with the local CIOSS Council of Fellows and OSU’s Vice President for Research, Rick Spinrad. The meeting was primarily to discuss CIOSS’ future and the present timeline for NOAA to decide if they want to fund an Ocean Remote Sensing CI. One outcome of this meeting was the preparation of a written statement from CIOSS Director Ted Strub (with Rick Spinrad’s support) summarizing the benefits to NOAA of continued support for a CI with this type of research focus.

Participation in NOAA CI Meetings during 2011:

March 22-24 – All-NOAA CI Directors and Administrators Meeting: Ted Strub and Amy Vandehey attended the all NOAA CI Director and Administrator’s Meeting that was held in Silver Spring, MD. Presentations and notes from the meeting can be found on the CIOSS website: http://ciooss.coas.oregonstate.edu/CIOSS/meetings.html.

June 7-8 – NESDIS CI Directors Meeting, August 17-18 – NESDIS Administrators Meeting: CICS-NC hosted this year’s NESDIS CI Directors and separate Administrators meetings in Asheville, NC. Ted Strub and Amy Vandehey attended their respective meetings. Notes from the Admin meeting can be found here.

Meetings and Workshops sponsored by CIOSS:

March 23-25 - NOAA Ocean Satellite Data Course: This annual 3 day course, organized by Cara Wilson and Dave Foley, (NOAA/NMFS/SWFSC - Environmental Research Division) provides an overview of the types of environmental satellite data available, where and how to access the data, and methods of working with the data, including importing into GIS applications and the use of OPeNDAP. CIOSS associate Nick Tufillaro presented a lecture on “MERIS data and products.”

August 16-17 - Annual NESDIS CoRP Science Symposium: CIOSS sponsored the travel costs for five students and staff to attend the annual STAR Science Symposium at NCDC in Asheville, NC: Dudley Chelton (Professor), Alex Kurapov (Professor), Peng Yu (post-doc), Roberto Venegas (faculty research assistant), and Meredith Payne (graduate student). This year's theme was, “Using satellite observations and models to understand and communicate information on climate variability and change.”

Presentation and poster titles for those given by CIOSS researchers are given below.

- Dudley Chelton – Satellite Observations and Numerical Model Simulations of the Influence of Sea-Surface Temperature on Surface Winds (presentation)
- Alexander Kurapov – Coastal-Interior Ocean Flux Estimates From a High-Resolution Data Assimilative Model (presentation)
- Meredith Payne – Ecoregional analysis of nearshore sea-surface temperature in the North Pacific (presentation – won best oral presentation award)

October 16-21 - Coastal Altimetry Workshop – 5: Support was provided for workshop costs and travel to allow graduate students and other early career scientists to attend the Fifth Coastal Altimetry Workshop and Ocean Surface Topography Science Team Meeting in San Diego, CA (October). Supporting the workshop and participation by graduate students increases the future use (and number of users) of altimeter data in coastal regions, addressing a wider range of applications with societal benefits.

The following people were supported to attend this meeting, along with their presentation titles:
M. Le Henaff, I. Androulidakis and Prof. V. Kourafalou, RSMAS, Miami: “Modeling and in Situ Observations around the Florida Keys Coral Reefs: Potential Applications of Coastal Altimetry”
M. Nienhaus and Prof. S. Bulusu, U. N. Carolina: “Altimetry Observations of Coastal Kelvin Waves in the Bay of Bengal”
K. Tseng, Ohio State U: “Radar Altimetry Waveform Retracking Applied to Coastal Ocean and Narrow Inland-Water Bodies”

Outreach - SMILE:
January 28 – Winter High School Teachers Workshop: Teachers were given the club activities to present to their afterschool SMILE clubs in preparation for the High School Challenge. Amy Vandehey presented an activity on locating fish depending on environmental conditions with Jay Peterson and Bill Peterson (NOAA-Newport).

April 14-15 – The SMILE High School Challenge: The event took place at Western Oregon University and Oregon State University. In this year's challenge, students used remote sensing data (satellite, rover, buoy, array) to determine the location and habitat characteristics that support various fisheries (including Salmon), in order to make informed decisions that helped their community catch and market healthy, sustainable, and economically viable seafood. Based on ocean conditions and habitat, students located possible fisheries and decided if they are sustainable, economically viable, and healthy for human consumption.

May 12-13 – Spring High School Teachers Workshop: Workshops provide professional development learning opportunities for high school teachers serving as SMILE Club advisors and help teachers gain ocean science content knowledge, as well as enhance pedagogical skills that foster engagement. Teachers have a chance to evaluate the programs presented during the year for future curriculum development.

August 9-11 – Summer High School Teachers Workshop: SMILE held their Summer Teacher Workshop at La Sells Stewart Center in Corvallis. The theme for the 2011-12
SMILE High school after school activities and Challenge Event is climate change, microbes and oceans and human health.

*Post-doc with CIOSS Funding:*
*Peng Yu* worked with Alexander Kurapov adding data assimilation to the real-time coastal forecast system. (Project #8 and #9b)

*Graduate students with CIOSS Funding:*
*Laxmikant Dhage*, a Master’s student in Physical Oceanography, worked with Ted Strub on alongtrack satellite altimetry data in the Indian Ocean (Project #13).

*Morgaine McKibben*, a PhD student in Biological Oceanography, worked with Angel White on detection of Harmful Algal Blooms. (Project #15).
Task II: Research with NOAA Collaboration

PROJECT 2a

Title: EOY Satellite-Derived Climatologies: The California Current Large Marine Ecosystem—Surface Forcing and Response Along Western North America

Principal Investigator: Ted Strub

Name and NOAA Office of the Primary Technical Contact: Paul DiGiacomo, NESDIS/STAR/SOCD

NOAA Collaborator on the Project: Doug Pirhalla, NOAA/NOS/NCCOS/CCMA

CIOSS Research Theme:
Theme 3 – Ocean-Atmosphere Models and Data-Assimilation

Related NOAA Goal from the NOAA Strategic Plan:
Goal 1 – Ecosystems

Project Description

This project has two areas of focus: Project 2a presents Large-Scale climatological fields of surface forcing (wind stress) and surface ocean response (sea surface temperature [SST], sea surface height [SSH] and surface chlorophyll-a pigment concentrations [CHL]) in the 500 km next to the coast in the area stretching from Baja California (~23°N) to the Gulf of Alaska (~62°N), derived from satellite sensors; and Project 2b presents Regional-Scale fields describing the Lagrangian connections between different areas and retention within an area, derived from ocean circulation models that assimilate satellite fields. Project 2b is restricted to the region along the coasts of Northern California to Washington, since that is the domain of the circulation model used in these analyses (the same model described in Projects 7, 8 and 9). The areas chosen for Lagrangian analysis are also regions of existing or proposed Marine Protected Areas. Project 2a is described herein; Project 2b is described in the next section.

Satellite Climatology: The California Current System (CCS) displays strong variability in physical and biological properties on timescales ranging from subseasonal (Strub et al., 1991; Legaard and Thomas, 2008) and seasonal (Huyer et al., 1975, 1979; Strub et al., 1987a, 1987b; Lynn and Simpson, 1987; Hickey, 1989; Strub and James, 2000; Venegas et al., 2008), to interannual (e.g., Chelton, 1982; Huyer and Smith, 1985; Strub and James, 2002; Huyer, 2003), and decadal (McGowan et al., 1996, 1998; Mantua et al., 1997; Chavez et al., 2002). In addition, temporal variability in distant forcing, such as El Niño and La Niña conditions, often produce strong anomalies within the CCS domain (Chavez et al., 2002; Thomas et al., 2003).
This project expands on past work at both CIOSS and NOAA (Pirhalla et al., 2010) to construct climatologies that quantify seasonal changes in surface physical and biological conditions in the CCS Large Marine Ecosystem (LME), using satellite data from the past several decades. There are numerous uses for these climatological fields, which characterize important components of habitat in the CCS LME, along the U.S. West Coast. Satellite sensors estimate sea surface temperature (SST), surface concentrations of Chlorophyll-a (CHL), surface wind stress (TAU) that drives nutrient enrichment, and sea surface heights (SSH) used to estimate surface currents and monitor regional sea level rise. Climatologies are required to assess the magnitude of anomalous conditions in the CCS LME (during an El Niño, for example). They also form the basis for ecological characterizations of marine natural resources, which is the first step to ecosystem-based management of biological and physical marine resources. The statistical measures of variability in the CCS are also used to validate computer models of the coastal ocean. The models then provide more reliable estimates of surface currents and the degree of “retention” and “connectivity” of sub-regions within the CCS. The models also provide estimates of subsurface currents and conditions. We focus our analyses on the region from Alaska to the southern tip of Baja California in Mexico, using high-resolution satellite-derived fields.

Specific goals are to:

1. Identify the regional variability along the Pacific West coast of United States using synoptic and repetitive coverage afforded by multi satellite-derived parameters (CHL, SST, SSH and TAU),

2. Describe and quantify variability across local to regional spatial scales of variability on CHL, SST, SSH and TAU.

Climatology products:

- Seasonal, annual and interannual patterns of CHL, SST, SSH and TAU from retrospective satellite-derived data

- Relationship between satellite-derived sea surface parameters (CHL, SST, SSH and TAU)

The study region goes from the Aleutian Islands to the tip of Baja California where we will evaluate twenty-five years (1985-2010) of satellite-derived SST, thirteen years (1997-2010) of CHL, nineteen years (1992-2010) of SSH, and eleven years (1999-2010) of TAU data, along the first ~500km offshore. We will examine their temporal means and seasonal cycles, as well as their seasonally removed variability. Chlorophyll concentrations come from the Sea Viewing Wide Field of View Sensor (SeaWiFS), using the OC4 version 3 algorithm with standard NASA global coefficients at 1.2 km resolution. SST data comes from the Advanced Very High-Resolution Radiometer (AVHRR). Sea surface wind data comes from daily QuikSCAT data in the Jet Propulsion Laboratory (JPL) archive. The gridded altimeter SSH data comes from AVISO – SSALTO/DUACS including data from the TOPEX, Jason-1 and Jason-2 (all with a 10-
day exact repeat period), Geosat Follow On (GFO) (with a 17.5-day exact repeat period), and ERS and ENVISAT (with a 35-day exact repeat period) altimeters. A similar approach was developed by Venegas et al., (2008) along the Washington-Oregon coast (Figure 1).

Figure 1. Eight-year mean of (a) chlorophyll pigment concentration in mg m\(^{-3}\), (b) sea surface temperature in °C, (c) sea surface dynamic height derived as a long-term mean dynamic topography in cm, with reference to 500 m and derived from Levitus et al. (1998) climatology, and (d) six-year mean of QuikSCAT wind stress (TAU) in N m\(^{-2}\). From Venegas et al. (2008).

Since NOAA funding for this “End-of-Year” project did not arrive until September 2011, our efforts up to the present have been concentrated on a related analysis of satellite data from the sources as used here over the entire Pacific Ocean Basin. Although funded by a separate source (the U.S. GLOBEC Pan-Regional Synthesis Project), the results of this larger-scale study (now finished and submitted as Thomas et al., 2012) provide the basin-scale context for our CIOSS Climatology Project.

Figure 2. Thirteen-year mean Chlorophyll-a concentration from the complete SeaWiFS time series.
The primary variable of interest in the GLOBEC project is surface chlorophyll. Figure 2 presents the mean surface chlorophyll-a concentration field from the entire 13+ year SeaWiFS time series. The 500km wide regions that will be the focus of our CIOSS climatology project are similar to the areas outlined for the CCS and the Humboldt Current System (HCS) in this Figure, with the difference that the CIOSS climatology will extend around the Gulf of Alaska (GoA) to the tip of the Aleutian Islands. The temporal mean CHL pattern presents a simple picture of high phytoplankton concentrations next to the coast along the eastern boundaries in both hemispheres. There is a region of lower CHL next to the coast in the Southern California Bight and along the much larger “bight” between southern Peru and central Chile. An important difference between the eastern boundary currents (EBCs) in the two hemispheres is the much greater distance and more convoluted path between the Equator and the CCS, compared to the HCS. Thus we expect variability in the HCS to be much more closely linked to variability along the equator (the ENSO cycle, Madden-Julian oscillations, seasonal activity in the equatorial currents, etc.) than the CCS.

Figure 3. First two modes of log CHL over the entire Pacific basin (left) and over the two Pacific EBCs (right). At the bottom are shown the time series averaged over calendar months for the first (solid) and second (dotted) modes, black for the CCS and red for the HCS.
To look at the dominant seasonal patterns of variability in CHL (after subtracting the mean shown by Figure 2), we present the first two EOFs (Empirical Orthogonal Functions) of CHL over the entire basin and over the two EBCs (separately calculated) in Figure 3. The first basin-scale spatial pattern shows the alternation in sign between the hemispheres and between the high- and mid-latitude regions, representing winter high-latitude minima and mid-latitude maxima, delineating the contrast between light-limited and nutrient limited regions (opposite patterns occur in summer). At low latitudes (10-20°), the second mode represents off-equator maxima in hemispheric spring, possibly associated with tropical instability waves. In the CCS (our primary interest), the first mode describes the winter minimum next to the coast, inshore of the basin-scale winter maximum at mid-latitudes. The second mode is associated with the earlier seasonal bloom in spring due to coastal upwelling at lower latitudes (off Baja California), which moves to mid-latitudes by summer.

Thomas et al. (2012) describe in much more detail the interannual variability of the four variables of interest, using monthly anomalies (after removing the long-term monthly seasonal cycle). For our region of interest (the CCS), they show that anomalies in CHL are more closely correlated to anomalous SSH and SST than alongshore wind stress, with a stronger relationship at lower latitudes. Forcing by wind stress becomes more important in the northern half of the CCS and we expect that trend to continue into the GoA. The SSH and SST anomalies are, in turn, connected to SSH and SST anomalies at the equator, with a characteristic ENSO time series. Although ENSO has the strongest influence on CHL in the CCS, the Pacific Decadal Oscillation (PDO) is also significantly correlated with both, also correlated to the ENSO over this time period, during which the 1997-1998 El Niño was the dominant event.

The work by Thomas et al. (2012) will serve as the immediate context for our closer examination of the climatology along the larger “coastal” domain along western North America, from Baja California to the Aleutian Islands. Our climatology will serve, in turn, as the context for studies of the Lagrangian connections between specific points along the Pacific Northwest, the subject of Project 2b (described next).

References


PROJECT 2b

Title: EOY Satellite-Derived Climatologies: The California Current Large Marine Ecosystem—Lagrangian Analysis of Retention and Connectivity Along the Pacific Northwest

Principal Investigator: Harold Batchelder

Name and NOAA Office of the Primary Technical Contact: Paul DiGiacomo, NESDIS/STAR/SOCD

NOAA Collaborator on the Project: Doug Pirhalla, NOAA/NOS/NCCOS/CCMA

CIOSS Research Theme:
Theme 3 – Ocean-Atmosphere Models and Data-Assimilation

Related NOAA Goal from the NOAA Strategic Plan:
Goal 1 – Ecosystems

Project Description

Lagrangian Statistical Analysis of Retention and Connectivity: Many benthic and demersal marine species produce pelagic larvae that develop for weeks to months in the open ocean. Distant populations of relatively sessile adult organisms (like crabs and barnacles) are connected to each other only through this pelagic dispersal phase. The resulting connectivity of populations provided by larval dispersal has important consequences for the management of commercial species, the design of marine reserve networks, the spread of invasive species and the adaptation or extinction of species in the face of environmental change. The large numbers of weak swimming larvae and episodic settlement events have led to the widespread belief that advection by currents and other sources of mortality often overwhelm larvae by carrying them far from natal populations (both alongshore and across-shore), which results in unpredictable recruitment in time and space. However, characterizing the entire larval dispersal phase through in situ observations remains a major challenge for marine ecologists and fisheries scientists (Kinlan and Gaines 2003, Cowan and Sponaugle 2009). Therefore, modeling approaches are increasingly relied on to assess larval connectivity between populations (reviewed in Cowan and Sponaugle 2009).

A network of five marine reserves (MR) has been established in Oregon’s territorial sea (Figure 1), e.g., the region that extends from the shoreline to 3 nautical miles offshore. Two sites, Otter Rock and Redfish Rocks, were designated as marine reserves in 2009, and following extensive stakeholder input, three other sites at Cape Falcon, Cascade Head and Otter Rock are being implemented (ODFW 2011). Each site has a recommended MR with adjacent marine protected areas (MPA) that have less complete harvest restrictions.
Marine reserves provide protection for adult populations within the reserve and increase both fish and invertebrate abundance in adjacently fished areas by a direct spillover of adults and recruits. The lack of field studies that directly measure the “recruitment effect” of MR/MPAs can partially be attributed to the difficulty in quantifying the numbers of larvae leaving a MR/MPA, a limited understanding of larval dispersal distances, and a poor knowledge of connectivity between populations (Botsford et al. 2001, Gaines et al. 2003, Largier 2003, Palumbi 2003, Shanks et al. 2003). Based on population models and studies conducted on advection, cross-shelf transport, and hydrographic influences on larval dispersal and recruitment (Quinn et al. 1993, Wing et al. 1995, Alexander & Roughgarden 1996, Bjorkstedt et al. 1997, Botsford et al. 1998) arguments have been made to site MR/MPAs in areas of major eddies or countercurrents that would have a positive effect on the dispersal and subsequent recruitment of target species (Murray et al. 1999). However, if reserves are placed in regions characterized solely by larval retention, then the reserve might be ineffective in repopulating nearby areas beyond the reserve (Roberts et al. 2003). Alternatively, MR/MPAs sited in areas characterized by high offshore transport may have few larvae return to repopulate the reserve, leading to a recruitment-limited, unsustainable and ineffective reserve source population (Roberts et al. 2003). Therefore, knowledge of connectivity along large geographic areas is pivotal in creating successful networks of MR/MPAs.

Specific goals of this project are to:
1. Determine potential larval connectivity patterns using Lagrangian particle tracking for the five newly established or proposed marine reserves and protected areas, and for a possible future reserve site at Cape Arago.
2. Delineate potential larval source and destination strengths along the entire Oregon coast.

Progress

We previously examined connectivity among the Oregon territorial sea marine reserves using a 1 km resolution Regional Ocean Model System model for the full 2002 calendar year. In the past year, we focused on particle tracking analysis for the first half of 2011. Many benthic invertebrates, like barnacles and crabs, reproduce and have their pelagic larvae in the water column during late-winter to mid-summer. The best available physical fields for 2011 are the output of Alexander Kurapov’s 3 km horizontal resolution real-time Oregon forecast model. Since August 2010, this model has included assimilation of GOES SST and HF radar surface currents, which enable more accurate ocean state estimation than models without assimilation (Alexander Kurapov, pers. comm.) This model is run daily using observed wind fields and best estimate initial conditions to provide a nowcast, and using winds from a mesoscale atmospheric model to produce 24 hr- and 48 hr-forecasts (ocean states are saved at 4 hr intervals). There is no data assimilation in the forecasts. We assembled a time-series of ocean states at 4 hr intervals for the period Jan-July 2011 using the individual daily nowcasts. An offline particle tracking model (POROS, Batchelder 2006 and unpubl.) is used to conduct all simulations. This model has greater flexibility for including detailed, sometimes species specific behaviors and physiology, than can be accomplished with on-line “float” codes.
Particle tracking model investigations are being implemented in a step-wise fashion. To date, we have focused on connectivity and transport of a couple of benthic groups that have relatively short pelagic larval durations (PLD), and from sampling done off Northern California, different cross-shelf and depth distributions of their larvae. Specifically, barnacles have PLD ~ 11-21 days; larvae are most often found nearshore, and near the surface (5-15 m depths). Conversely, pagurid crabs, have longer PLDs (49-90 days), with larvae whose depth distribution and distance offshore are life-stage dependent. Younger life stages are more inner-shelf and shallow (<20 m depth), while middle aged larvae are deeper (20-45 m) over the mid-shelf (Morgan et al., 2009).

A series of simulations were done to mimic the transport of both barnacles in the nearshore (bottom depths < 25 m) and pagurid crabs at midshelf release locations (bottom depths of 30-80 m) on the central Oregon shelf. The results of pagurid crab simulations are shown in Figures 1 and 2 to compare alongshore transport distance as a function of organism depth (10 m vs. 30 m), week of first half of 2011, and pelagic larval duration (10, 14 or 20 days). During the winter downwelling period (weeks 1-11), most individuals were advected northward (Fig 1. left panel). Advection to the north was more rapid for individuals at 10 m than at 30 m. The upper-left inset histogram (Fig. 2) of the transport distance difference after 10 days shows that few of the individual members of the ensemble had values near the mean (red vertical line) of the ensemble, but rather were bimodally distributed. During the spring transition (weeks 12-15) the mean difference between shallow and deep particles was small (slightly to the south; Fig. 1, center panel), and the distribution was nearly normal, with shallow particles travelling up to 80 km further north or south than deeper particles. During the upwelling period (weeks 16-26; Fig. 1, right panel; illustrated by week 23; Fig 2, bottom inset), the difference in alongshore transport distance between shallow and deep individuals was very variable, with peaks at ca. 50 km and 90 km further south, and a broad peak between 20 km south and 20 km north. The distribution was clearly not normal. The results indicate that transport distances (1) are controlled by the depth of the individual, with shallower individuals experiencing greater alongshore advection, (2) are seasonally controlled by the strong wind-forcing, and (3) are very variable within a simulation depending on specific release location (within the green initial locations, Fig. 1).

Additional simulations are needed to examine the second half of 2011, as are simulations that consider additional factors, such as the influence of ambient temperature on development rate (stage duration), and ontogenetic and diel shifts in depth distribution. All three factors should have a significant influence on the transport distance and potential connectivity among Oregon territorial sea marine reserves. All are likely also to impact retention times within local regions, which will also be examined in the coming year.
Figure 1. Positions of organisms after 10 days of advection initialized at the locations marked in green on week 10 (left panel), week 14 (center panel) and week 23 (right panel) using real-time Oregon forecast model nowcasts for 2011. Red (blue) dots are the locations of organisms that maintain themselves at 10 m (30 m) depth.
Figure 2. Plotted is the difference in alongshore (N-S) transport distance of virtual pagurid crab larvae at two behaviorally-maintained depths (10m and 30m) from a source region on the central Oregon coast (off Newport). The first four pagurid crab larval stages have a stage duration at 10C of ca. 10 days each. The first two stages are predominantly found at 5-15m (mean 10m), while the 3rd and 4th larval stages are more often found at 20-45m (mean 30m). Blue (green) [red] line is the mean alongshore difference (km; positive to the North) after 10 (14) [20] days of transport, based on release of ca. 1000 particles near Newport. The three inset figures show the frequency distribution of the difference for all of the particles for the 10 d PLD (blue line) from three specific release times.

**Lagrangian Modeling Products:**

- Climatology of Lagrangian statistics (retention times and connectivity between regions) using five years of simulation results from the real-time Oregon forecast system
- Identification of source and sink regions, and characterization of their temporal variability.
- Characterization of the influence of organism behavior (depth keeping; ontogenetic depth shifts) and temperature controlled larval development to connectivity and local retention.
References
PROJECT 3

Title: CIOSS Ground Systems Proposal: Development of a CIOSS Satellite Processing System for Merged Ocean Color Products

Principal Investigator: Curtiss O. Davis

Name and NOAA Office of the Primary Technical Contact: Ingrid Guch, NESDIS/STAR/CoRP

NOAA Collaborators on the Project: Paul DiGiacomo, STAR, Dave Foley, NESDIS/CoastWatch

CIOSS Research Theme:
Theme 1 – Satellite Sensors and Techniques

Related NOAA Goal from the NOAA Strategic Plan:
Goal 1 – Ecosystems

Background and Objectives
Following the leadership of the International Ocean Color Coordinating Group (IOCCG) the international community is establishing the Ocean Color Radiometry Virtual Constellation. The fundamental idea is to use data from all of the ocean color sensors to achieve one much more complete ocean color radiometry data set that will extend over decades. This will take considerable work and the space agencies with ocean color sensors were fully supportive of this effort. One immediate task is to compare and merge the data from existing high quality sensors. Then as new sensors are launched and on orbit calibration is completed they are added to the Virtual Constellation. The goal is to produce a continuing climate quality data set for ocean color. The work proposed here is to develop a computing environment including hardware and software for the comparison and merging of ocean color data for the west coast of the United States and Hawaii. The system will be used to address data merging for these selected waters and act as a prototype system that can be expanded by NOAA for other regions of interest.

This work relates directly to the NOAA Strategic Goal for Weather, Water and Ecosystems. More specifically in this project we support the CoastWatch mission to provide and ensure timely access to near real-time satellite data to protect, restore, and manage U.S. coastal ocean resources, and understand climate variability and change to further enhance society's quality of life. Through CoastWatch the primary users will include Federal, State, and local marine scientists, coastal resource managers, and the general public.

With funding from NESDIS, CIOSS Fellows Curt Davis and Ricardo Letelier have organized and led a series of workshops related to merging data and products from different ocean sensors, and the creation of Climate Data Records (http://cioss.coas.oregonstate.edu/CIOSS/workshops/CDR_meeting_05/Final_Agenda1.h
At these workshops plans and procedures were developed to merge data from U.S. ocean color sensors (MODIS, SeaWiFS, HICO and in the future VIIRS) and the European Space Agency’s MERIS. HICO is a U.S. Navy hyperspectral sensor with 90 m spatial resolution that was launched September 10, 2009 and is currently operating on the International Space Station. VIIRS, the operational follow-on to MODIS, was launched on the NPP satellite on October 28, 2011.

We have direct access to and experience with all of the ocean color data sets that we plan to use in this project. We have worked extensively with SeaWiFS and MODIS data and OSU has operated a ground station to receive MODIS data for over a decade. With NOAA support we are receiving the daily MERIS Full Resolution data that is collected and processed by the Canadian Space Agency. Curt Davis is the HICO project scientist and he has access to all the HICO data and is routinely requesting that HICO data be collected for west coast sites including the Columbia River, Newport Oregon, Monterey Bay, Los Angeles Harbor, Santa Barbara Channel and the HOT and MOBY sites near Hawaii. Curt is also on the Integrated Program Office funded VIIRS cal/val team and we are receiving VIIRS processing software and VIIRS proxy data made from MODIS data. We are now receiving some VIIRS data for the west coast of the U.S. for test and validation.

**Approach**

This project builds on our experience with ocean color data and the recommendations of the workshops, namely to implement a system to merge data from the available color sensors for the West Coast of the United States and Hawaii. Ricardo Letelier and Curt Davis are currently receiving all available full resolution satellite ocean color data from operating U.S. sensors (MODIS and HICO) as well as from the European sensor MERIS for the U.S. West Coast and Hawaii. Relevant data from SeaWiFS (no longer operational) have been archived. VIIRS data will similarly be received as soon as available.

The PIs and their teams have ample experience with the latest satellite operational processing systems in both the US (e.g. SeaDAS and APS) and Europe (e.g. BEAM), and currently provide operational processing and data serving for MODIS. To meet the demanding storage and processing needs for this project, servers were purchased and set up with processing software to process, analyze, merge and host data from these ocean color sensors.

The resulting data will have the highest spatial resolution possible, and will be made available to the CoastWatch program and the IOOS Regional Associations along the U.S West Coast. The system will serve as a prototype for similar systems at CoastWatch HQ. All system designs, software, data and products will be available to NOAA for use and distribution through Coast Watch.

**Progress and Results**

This project was initiated in May 2010. The focus of the initial effort was on designing and procuring the optimal system for our data system needs. A system was procured and
installed in June 2010. The new system is a Dell PowerEdge C2100, a customized system developed by Dell for Google. It runs on dual Intel 6-core Xeons (Intel Xeon X5660, 2.8Ghz, 12M Cache, Turbo, HT) and provides 24 Gigabytes of memory (1333MHz Dual Ranked RDIMMS). The system is built around a RAID array that supports 12 disks (2TB 7.2K RPM 3.5inch hot plug SATA drives).

This Dell PowerEdge C2100 has been up and running since June of 2010, and has rapidly become the workhorse of our operation storing all the satellite data we have obtained from MERIS, HICO and MODIS. The system is currently storing 3 terabytes of processed satellite data. We have installed Matlab, SEADAS, IDL and ENVI on this system which we use to create data products from the processed data, such as 8 day composites.

We began receiving and processing proxy VIIRS data in spring 2010 in preparation for the real VIIRS data in early 2012. Therefore, we moved forward quickly to procure a server for the VIIRS data and configured a Dell server for the VIIRS data similar to the servers we currently operate for the MERIS and HICO data sets. This system was procured and installed in October 2010. Here we purchased a new system from Dell, a Dell PowerEdge R510. This is the product that grew out of the Dell PowerEdge C2100 that Dell developed for Google, and that we purchased above. Since we already had the bulk of the disk space purchased above, we opted for a configuration that used 12 500GB 7.2K RPM 3.5inch hot plug SATA disk drives, dual 4 - core Intel Xeons (Intel Xeon E5620 2.4GHz, 12M Cache, Turbo, HT) and 24 Gigabytes of memory (1333MHz Dual Ranked RDIMMS).

This Dell PowerEdge R510 has taken on the role of a development platform as we await routine delivery of VIIRS data which is expected in early 2012. It also has Matlab, SEADAS, IDL and ENVI installed which are used to develop new products and algorithms and will be used to work with VIIRS products.

Additionally, a system dedicated to the analysis and display of the data, and for sharing results with NOAA was required. In November 2010 we purchased an Apple Mac Pro with two 2.66Ghz 6-core Intel Xeon “Westmere” processors, 6GB of memory, an Apple RAID card, two 2TB 7.2K RPM 3.5 inch SATA drives, ATI Radeon HD 5770 1GB graphics card (which can support up to 3 monitors), and one 27 inch Apple LED Cinema Display. We also purchased a copy of Final Cut Express software from Apple. Subsequently the system was expanded by adding 8 GB additional memory and two additional 2TB disks.

To support teleconferencing with NOAA and others we purchased a 60 inch plasma LG high definition TV/Monitor for our video conferencing display and a Logitech C510 HD USB web camera with built-in microphone. Several conferences have been successfully held with this new system. The MERIS full resolution data and the VIIRS proxy data are now processed, managed and stored on these machines in a fully automated manner. We have created a highly efficient and fully integrated system.
PROJECT 4

Title: VIIRS Calibration and Validation Activities: Establishing a SeaPRISM site on the West Coast of the United States

Principal Investigator: Curtiss O. Davis

Name and NOAA Office of the Primary Technical Contact:
Dr. Karen St Germain, NPOESS Integrated Program Office (IPO) (301-713-4739, karen.stgermain@noaa.gov)

NOAA Collaborators on the Project: Mike Ondrusek, NESDIS/STAR and Menghua Wang, NESDIS/STAR

CIOSS Research Theme:
Theme 1 – Satellite Sensors and Techniques

Related NOAA Goal from the NOAA strategic plan:
Goal 1 – Ecosystems

Background
Of the various applications envisioned for the VIIRS solar reflective bands, those associated with ocean color are the most stringent in terms of sensor calibration, characterization, and stability. The ocean color requirements for radiometric accuracy and precision have been established through various modeling studies and years of data analysis using the CZCS, SeaWiFS, MODIS, and other satellite ocean color data sets. The derived products such as remote sensing reflectance, chlorophyll-a, and primary productivity are sensitive to calibration uncertainties at the 0.1% level. This sensitivity is due to the relatively small ocean reflectances compared to those of the atmosphere, i.e., the combined Rayleigh and aerosol reflectances (~ 90% of the total radiance over the open ocean is due to atmospheric scattering). Thus, small erroneous trends in sensor calibrations can be easily misinterpreted as real geophysical signals resulting from inter-annual oscillations or climate trends. Because of this, highly accurate on-orbit calibration is essential for producing ocean products, and those products must be validated for a wide range of coastal and open ocean environments.

This activity is a part of the Integrated Program Office (IPO) ocean Environmental Data Record (EDR) calibration and product validation team effort lead by Bob Arnone (Naval Research Laboratory at Stennis Space Center; NRLSSC). As part of that team we will work with Bob Arnone and others to establish a plan for maintaining the on-orbit calibration of the VIIRS Visible and Near IR (VNIR) channels and for validation of ocean products. More specifically our work will focus on the validation of ocean color products (water-leaving radiance and chlorophyll) for the coastal and open ocean.

Experience with SeaWiFS, MODIS and MERIS makes it clear that ocean products must be validated in the open ocean and in coastal regions. Here we have procured a
SeaPRISM system and are deploying it for routine validation of proxy and after launch VIIRS data for the ocean off Southern California. We are coordinating and sharing methods and results with others operating SeaPRISM systems for product validation for representative sites on the US East and Gulf Coasts. We will support the development of the procedures for using the SeaPRISM data for routine, automated VIIRS product validation.

This effort was coordinated with the other VIIRS Ocean Color Subject Matter Experts (SMEs) and agencies to provide a coherent cal/val activity for Oceans. An evolving cal/val plan has been developed which includes 28 blocks of investment to ensure an “end to end” cal/val approach (Table 1). This project addressed investment blocks 7 and 21 in coordination with other SME’s efforts.

This project addressed components of the cal/val plan for Ocean EDRs for the VIIRS sensors on NPP and NPOESS. The project contributed to two components of the cal/val plan (Table 1 below) specifically focused on the validation of coastal ocean color products from VIIRS. Our approach included 3 specific activities: a) Procure, modify, calibrate and test a SeaPRISM system for deployment on a tower or platform off the west coast of the United States (7); b) Work with colleagues on the West Coast of the US to identify and establish an agreement for deploying the SeaPRISM system on an oil platform or other tower or platform of the West Coast of the U.S. (7); c) Initiate a plan to use the SeaPRISM data for the automated match up of the SeaPRISM data with ocean color imagery products to validate those products (21).

These components of the plan were coordinated with the interagency team (NASA, NOAA, NAVY and IPO) and are coupled with ongoing activities in operations. The efforts will provide an automated cal/val capability and risk reduction to the VIIRS sensor capability to produce ocean EDR products.

**Approach and Progress**
This project was initiated in July 2009 and closed out in May 2010.

Activity a)
SeaPRISM radiometers are now used worldwide for the validation of coastal ocean products from satellite ocean color sensors. In late 2009, we procured a SeaPRISM system like the ones used on the U.S. East Coast and other locations for this purpose. After an initial system test at OSU, the system was sent to NASA Goddard Space Flight Center to be modified and calibrated by the AERONET program according to the established protocols to make it identical to the others deployed on the AERONET Ocean Color (AERONET-OC) network (http://aeronet.gsfc.nasa.gov/new_web/ocean_levels_versions.html). The modification included installing custom filters purchased by GSFC for this purpose and designed specifically for this instrument. The VIIRS calibration plan calls for using all of the AERONET-OC sensors around the world for coastal product validation. After another intensive testing period at OSU, the SeaPRISM was shipped to the University of Southern California for deployment.
TABLE 1. VIIRS Ocean EDR CAL - Val Plan component overview. An X below a topic indicates that it was addressed in this effort.

<table>
<thead>
<tr>
<th>Science and Operational Investments.</th>
<th>Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proxy VIIRS Data Stream</td>
<td>&quot;Insitu&quot; data collection</td>
</tr>
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</table>
Activity b)
The SeaPRISM site needs to be at least 2 miles offshore on a stable platform. With the aid of Burt Jones at the University of Southern California, a suitable location was identified on an oil platform off the coast of Southern California (Platform Eureka). The SeaPRISM was deployed on the platform in spring 2010. The SeaPRISM data are being used to validate VIIRS proxy data. The continued operations and maintenance of the SeaPRISM has been transitioned to Burt Jones.

Activity c)
We will work with NRLSSC and others to establish protocols and automated procedures for using the SeaPRISM data to validate proxy and after launch VIIRS data. At the VIIRS Ocean EDR Team meeting July 23-24, 2009 in Silver Spring, MD we established working groups for many of the component areas of the program. I was initially the team leader for the SeaPRISM group, but have since passed that to Giulietta Fargion.

Milestone 1. Procure SeaPRISM system.
We initiated procurement of the SeaPRISM in July 2009 as soon as funding was available. The SeaPRISM was delivered to OSU December 1, 2009. The SeaPRISM was set up and we completed acceptance testing of the SeaPRISM in early December 2009. Milestone Completed.

Milestone 2. Send the SeaPRISM system to the AERONET project at GSFC for filters and calibration.
After receiving the SeaPRISM we contacted Alex Tran and Brent Holben at the AERONET project at GSFC and they agreed to add the SeaPRISM to the AERONET program. We delivered the SeaPRISM to Alex Tran at AERONET and the correct filters have been installed and it was calibrated by GSFC. We received the Calibrated SeaPRISM at OSU on March 3, 2010. Milestone Completed.

Milestone 3. Receive the GSFC calibrated SeaPRISM back at OSU, set it up and test operations and data stream.
After receiving the SeaPRISM back from GSFC we tested it and then added a PC Netbook to collect and store the data and modified the setup to allow us to send the data over the internet. Curt Vandetta sent test data to Alex Tran at GSFC and Alex confirmed that we have it setup correctly and he received good data. The SeaPRISM was shipped to Burt Jones at USC. Milestone Completed.

Milestone 4. Work with colleagues in Southern California to identify and gain permissions to use a suitable site for the SeaPRISM.
We have worked with Burt Jones at USC to identify a suitable site for the SeaPRISM on an oil platform off the coast of Southern California. Burt contacted several platform operators. In January 2010 Burt and colleagues visited Platform Eureka off of LA Harbor were we have been offered an excellent site. The Platform is 8 miles offshore and the location is on the top level on the south west corner of the platform with no obstructions to the view of the sky or ocean. The Platform operator is also providing 110 V power and a high speed internet connection for transmitting the data. The SeaPRISM
was shipped to Burt Jones in April 2010. Burt Jones established an agreement with the operators of Platform Eureka to mount the SeaPRISM on the platform. He developed appropriate attachment hardware. The SeaPRISM was installed in May 2011. We have completed our part of the project.

**Milestone 5.** Set up the SeaPRISM on Platform Eureka and initiate data collection.
Burt Jones has installed the SeaPRISM and it has been operating since May 2011. We have completed our part of this project.

**Milestone 6.** Develop methods for validation of VIIRS data with SeaPRISM data.
Initiated work on validation of coastal products for the west coast of the US using in situ data collected at OSU and MERIS full resolution data as a proxy for VIIRS data. Efforts focused on geolocation of data sets and matching up in situ and satellite data. Since April 2010 we are also developing a database of VIIRS proxy data that we are getting from NRL SSC.

OSU has completed their part of this project and handed the SeaPRISM and its operation over to Burt Jones at USC. The only task we will continue working on with Burt, Bob Arnone and others is Milestone 6 (To develop methods for validation of VIIRS data with SeaPRISM data). Per direction from the IPO (now JPSS) this work is to be continued in by Curt Davis under his task “VIIRS Calibration and Validation Activities: Time series cal/val for Open Ocean and Coastal Ocean Color EDRs”. All other OSU tasks are completed. This Project is closed out.
PROJECT 5

Title: Use and Validation of MERIS Coastal Products for US West Coast and Hawaiian Waters

Principal Investigators: Curtiss O. Davis and Ricardo Letelier

Name and NOAA Office of the Primary Technical Contact: Paul DiGiacomo, NESDIS/STAR/SOCD, paul.digiacomo@noaa.gov

NOAA Collaborators on the Project: Paul DiGiacomo, NESDIS/STAR, Mike Ondrusek, NESDIS/STAR and Dave Foley, NESDIS/Coast Watch

CIOSS Research Theme:
Theme 1 – Satellite Sensors and Techniques

Related NOAA Goal from the NOAA Strategic Plan:
Goal 1 – Ecosystems

Project description

Background and Objectives
U.S. ocean color sensors SeaWiFS and MODIS are beyond the end of their planned lifetimes and SeaWiFS ceased operating in December 2010. NOAA and other U.S. ocean color users have turned to the European Space Agency's (ESA) MERIS as a possible data source to fill the gap until a new US ocean color sensor is operational. MERIS is scheduled to operate until 2014 and a follow-on sensor on Sentinel 3 is expected to be launched in 2012 and provide high quality data for the foreseeable future. Compared to MODIS, MERIS has additional spectral channels at 620 nm for suspended sediments and 709 nm for extreme plankton blooms that have proven particularly effective for coastal and Great Lakes waters. In a direct comparison Lee and Carder (2002) found that the MERIS channel set was superior to the MODIS channel set for coastal waters. MERIS can also collect 300 m ground sample distance data for selected coastal regions, and this is particularly useful for imaging bays and estuaries. ESA has begun direct broadcast to Canada of 300 m MERIS data for North American coastal waters.

The goal of this research is to obtain MERIS 300 m data for the U.S. west coast and Hawaii and evaluate their products compared to MODIS products and in situ validation data. This will include analysis of MERIS standard products and coastal products. In particular, MERIS coastal products are processed using a Neural Network approach that is “trained” using data from European coastal waters (Doerffer and Schiller, 2007). The coastal algorithms outperform the standard processing algorithms used for the open ocean which fail in waters with high suspended sediments, very high phytoplankton or high Colored Dissolved Organic Matter (CDOM). For this project we will acquire full 300 m
resolution MERIS data (MERIS-FR) for the West Coast and Hawaii and evaluate the MERIS products against MODIS products and against measured remote sensing reflectance and in-water optical properties, pigments, suspended sediments and CDOM. Additionally, when the collection of \textit{in situ} data is sufficient we will add it to the European data set and update the neural network training set to include U.S. coastal waters. These retrained neural network algorithms should provide the best solution for U.S. coastal waters.

\textbf{Approach}

On related projects we have purchased two HyperPRO IIs (Satlantic Inc., Canada) to collect bio-optical data off the Oregon Coast and at Station ALOHA off Hawaii as part of the Hawaii Ocean Timeseries (HOT: http://hahana.soest.hawaii.edu/hot). Since May 2009 The HyperPRO IIs have been deployed in a series of HOT cruises and cruises off the Oregon Coast. The HyperPRO II data include spectral downwelling irradiance and upwelling radiance, temperature, salinity, chlorophyll fluorescence and backscattering. The system is calibrated by Satlantic and we use the Satlantic software for processing including all of the latest corrections based on NIST calibrations. HyperPRO II and other data collected on each station including HPLC pigments, productivity, CDOM and sediment particle load will be placed in a data base with web access. Using automated procedures developed at OSU the data will be matched with MERIS and MODIS data collected at the same time. This matched data base serves as the basis for our analysis. We have evaluated the approaches currently in use for validation of coastal products (e.g. Antoine, et al., 2008; GLOBColour; Maritorena and Siegel, 2005) and selected an approach developed jointly with Bob Arnone (NRLSSC) and others for the VIIRS validation work (see Section 7 VIIRS EDR validation) for this effort.

For coastal waters the present MERIS case-II neural network algorithms are ‘trained’ based on data collected in European coastal waters and there is a need to develop databases along the US continental margins to validate and train the algorithms in our waters. When the collection of \textit{in situ} data is sufficient we will add it to the European data set and update the neural network training set to include U.S. coastal waters. We will then evaluate the retrained neural network algorithms to see if they provide the best solution for U.S. coastal waters.

In this effort we are collaborating with Dr. Michael Ondrusek (NOAA STAR) who is generating a bio-optics database for case-II waters off the East Coast of the United States and Paul DiGiacomo (NOAA STAR) who is leading the NOAA effort to acquire and use MERIS data. We will also work directly with Dave Foley (NOAA CoastWatch) who is distributing products derived from the MERIS data for the U.S. West Coast.

Looking ahead we are working to develop standardized procedures for automated validation of open ocean and coastal ocean color products. In the long term, we envision a transition path to continue this effort to support the next generation of ocean color sensors including those recently launched by NOAA and NASA (VIIRS in 2011), the
Navy (HICO on the ISS in September 2009), as well as foreign sensors such as GOCI, from Korea, onboard COMS-1 (launched in June 2010).

**Progress and Results**

**2009 Results**

In June 2009 we initiated collecting HyperPRO II data on the Oregon Coast (Figure 1). Data collection is facilitated by cruises supported by several programs. Weekly sampling was initiated as part of the MILOCO program (Microbial Initiative in Low Oxygen areas off Concepción (Chile) and Oregon, [http://mi-loco.coas.oregonstate.edu](http://mi-loco.coas.oregonstate.edu)) to provide in situ and model data for the testing and validation of our remote sensing products for this region.

![Collecting HyperPRO data and an example data set from the MILOCO cruise off the Oregon coast taken June 4, 2009.](image)

**Fig 1.** Collecting HyperPRO data and an example data set from the MILOCO cruise off the Oregon coast taken June 4, 2009.

The second field program is the Center for Coastal Margin Observation and Prediction (CMOP, [www.stccmop.org](http://www.stccmop.org)) a focused study of the Columbia River System including characterization of the River water properties with sampling extending through the estuary and as much as 100 km up river. The third field program is Monitoring Oregon Coastal Harmful Algae (MOCHA): [http://bioweb.coas.oregonstate.edu/~struttonlab/hab_intro.html](http://bioweb.coas.oregonstate.edu/~struttonlab/hab_intro.html).

In August 2009 we initiated our efforts to collect, and process, MERIS-FR data for West Coast, US waters. OSU is currently receiving, processing, and supplying ESA CAT-1 MERIS users with MERIS data of the US West Coast. The initial gateway to the data is on OSU hosted servers at [http://meris.coas.oregonstate.edu](http://meris.coas.oregonstate.edu). This server acts as a ‘back-up’ for NOAA efforts lead by Dave Foley to supply his Coast Watch customers with data products. OSU receives its data directly from the Canadian Space Agency (CSA) and OSU is routinely supplying NOAA with MERIS 300 m L1 and L2 data, to fill gaps in NOAA’s MERIS database.

In addition, OSU is collaborating with leading researchers in Harmful Algal Bloom (HAB) detection (Jim Gower IOS Canada, Rick Stumpf, NOS/NOAA, and Stewart...
Bernard, South Africa) in developing state-of-the-art algorithms and codes for the operational detection of HAB’s in the Northwest (Figure 2). Also, with the improved ground sampling distance (GSD) of MERIS (300 m) and the Naval Research Lab’s HICO (100 m) instrument, we are also looking at the use of remote sensing for assessing the quality of fresh water sources in the Northwest (http://www.oregon.gov/DHS/ph/hab/).

Fig 2. MERIS 300 m data for 24 October 2009 indicating regions of bloom activity (green [low], red [high]) off of the Northwest Coast of the US. This is used by NOAA to aid in monitoring and tracking HAB activity on US west coast waters.

A primary goal of the work at OSU is to improve the accuracy of MERIS products for the US west coast waters. To that end we are: 1) setting up a uniform data processing chain for all satellite data including MERIS, MODIS, and NRL’s HICO, and 2) continuing to collect in-situ data to calibrate ESA’s neural net models for complex waters.

For goal 1), in addition to ESA’s ‘BEAM’ software, OSU is using both NASA’s SeaDAS and NRL’s Automated Processing System (APS) to uniformly and consistently process MERIS L1B data to L2, L3 products. The algorithm consistency helps ensure a consistency of the final product comparison and cross-sensor calibration. OSU uses two recently purchased dedicated servers devoted to the operational processing of MERIS/MODIS/HICO data and OSU is involved with improving its web portal to these data sets which is found at:

http://omel_test.coas.oregonstate.edu/home/datasets/realtime.shtml

This site provides a direct link to the MODIS data and links to the HICO website http://hico.coas.oregonstate.edu and the MERIS website listed above.
For goal 2), OSU researcher Nick Tufillaro was certified in Inversion Procedures in Ocean Color Remote Sensing during an advanced training course/workshop held in Lauenberg, Germany 10-14 August, 2009. The course, led by Roland Doerffer, focused on ESA’s neural net procedures to calibrate sensor data (ESA’s algal 2), and Nick is also working on additional neural net methods to cross-validate data between MODIS, MERIS and HICO. Initial results were reported at the February 2010 Ocean Sciences meeting.

**2010 Results**

We continue to receive the MERIS 300m west coast data from Canada including making adjustments for the MERIS orbit change at the end of October 2010. We now have almost two years of data. The data is archived and we are pulling out selected scenes for Monterey Bay, LA Harbor, Santa Barbara Channel, Lake Tahoe and the Oregon and Washington coasts for use in the product comparisons and analysis.

In 2009 we adapted the MCI (Gower et al., 2005) and FLH (Gower and Borstad, 2004) methods for 300 m west coast MERIS data, and presented our findings for the detection of west coast HAB’s at the 2010 Ocean Sciences meeting. Figure 3 shows MCI and FLH indicators for a high concentration of *Akashiwo sanguinea* during October 2009 causing the death of thousands of seabirds.

![Figure 3](image)

Fig 3. Example of MERIS indicators for HAB’s off the Northwest coast (Presentation at Ocean Sciences Meeting 2010).

During 2010 we continued collecting in-situ verification data with the HyperPRO sensor as part of routines cruises for the MILOCO and MOCHA projects.

Following a request from Paul DiGiacomo we agreed to support him as a Champion User in the CoastColour project. Our part is to continue our work with MERIS 300 m data for the West Coast including using and evaluating the MERIS coastal products for our study area. In addition we will supply the in situ optical data, chlorophyll and other products.
for the CoastColour project’s use in evaluating the MERIS coastal products on a global basis.

We have also initiated work to correlate the in situ data and remote sensing measurements from MERIS, MODIS, VIIRS Proxy, and HICO; examples of those comparisons are shown in Figure 4.

![Fig 4. Inter-comparisons between MERIS, VIIRS Proxy, and HICO data off the Northwest Coast (30 September 2010).](image)

Code for automated match up and comparisons is being developed in Matlab at OSU. In addition we are collaborating with NRL, who are also developing an SQL database for the alignment of in-situ and remote sensing data. To support comprehensive cross-sensor comparison between satellite data and in-situ match-ups we greatly expanded our archival and computation resources including greater than 30 TB of on-line disk storage, which allows us complete real-time access to the 300 m L1 and L2 MERIS west-coast data and the comparison data sets including MODIS, HICO, VIIRS Proxy and in situ data from 2008 onward.
2011 Results

In 2011 the remote sensing work using the Hawaiian Ocean Timeseries (HOT; prior section 4) led by Ricardo Letelier was merged into this project and refocused on analyzing the long MODIS time series and validating MERIS open ocean data products using MODIS and the HOT in situ data. We continue to routinely collect and archive all of the MERIS data for the West Coast of the US (from the Canadian Space Agency) and now Hawaiian waters (from ESA) including the MOBY and HOT stations. We now have three years of routine data covering the entire west coast. In addition we have gone to the ESA archive and obtained all of the historic Hawaii and West Coast data going back to 2004. While this data does not include complete coverage it does provide a much longer time series for selected sites (e.g. Monterey Bay and the Columbia River). These data are all available to MERIS Cat 1 users and to NOAA Coast Watch (Dave Foley) for additional processing. We curate and provide additional products for selected sites of

Fig 5. Series of MERIS MCI images showing the development of a phytoplankton bloom (red) off of Vancouver Island 3 September 2011 and the transport of the bloom to the Washington Coast by September 11th.
interest to our research and NOAA. For example, (Figure 5) we documented the development of a large algal bloom off Vancouver Island in September 2011 that subsequently extended along the Washington Coast. We routinely produce the MCI product that uses the 709 nm peak to identify strong algal blooms. This information is passed to NOAA and Washington state managers for their further assessment of the bloom risk.

We also correlate the MERIS imagery with HICO data when available (Figure 6) which provides full spectral data for better analysis and matching spectral signatures to the dominate bloom species.

![Fig 6. HICO image of the Algal bloom off of the Washington Coast collected on September 9, 2011. HICO image lower left is rotated 90 degrees clockwise; Vancouver Island (north) is to the right of the image. Smaller images show the bloom structure in more detail. The HICO at sensor spectra (right) shows the strong peak at 709 nm (red line) indicating a major phytoplankton bloom.](image)

For the waters around Hawaii, work by Graduate Student Maria Kavanaugh has shown that Station ALOHA is near the boundary of two oceanic provinces (or Seascapes); in the summer it is in the Oligotrophic Boundary (OB) Seascape and in the winter in the Subtropical Seascape (ST). Because of this our time series analysis of satellite data using in situ data from Station ALOHA has broad application to these two major Seascapes representing most of the tropical North Pacific gyre.
In preparation for detailed chlorophyll matchups between in situ measurements at Station ALOHA (Hawaii) and satellite data, an archive of in situ and matched satellite data has been created. All available satellite data have been ordered from the Ocean Biology Processing Group (NASA) for MODIS (Level 2) and SeaWiFS (LAC) over the Hawaii region (18 to 25° N, 161 to 154°W). These data are all from the most recent reprocessing at NASA (version R2010). All available MERIS-FR satellite data (Fig. 8) from the same region have similarly been archived. One challenge with the MERIS data is that sunglint is common in these images. SeaWiFS pointing (+/- 20° fore and aft) and the time of day for MODIS (1330) are designed to lessen this issue, and there is far more glint-free data for those sensors. Consequently our focus for time series analysis at HOT is with MODIS and SeaWiFS data. The available good MERIS data will be used to assess the advantages of the 300 m spatial sampling and the additional spectral channels available with MERIS.
Fig 8. Example MERIS data from the OSU MERIS Hawaii website. Note the strong glint feature in the RGB image (bottom center). This is a major problem with MERIS data for the Hawaiian Islands.
Presentations


C. O. Davis and N. B. Tufillaro, Sensing of Coastal Waters from the International Space Station and Satellites, OSU College of Engineering Invited lecture, March 2, 2011.

References


GlobColour web site: http://www.globcolour.info/data_access.html


PROJECT 6

Title: VIIRS Calibration and Validation Activities – On-Orbit Calibration of VIIRS

Principal Investigators: Curtiss O. Davis and Ricardo Letelier

Name and NOAA Office of the Primary Technical Contact: Heather Kilcoyne (JPSS)

NOAA Collaborators on the Project: Mike Ondrusek, NESDIS/STAR and Menghua Wang, NESDIS/STAR, Paul DiGiacomo, NESDIS/STAR

CIOSS Research Theme:
Theme 1 – Satellite Sensors and Techniques

Related NOAA Goal from the NOAA Strategic Plan:
Goal 1 – Ecosystems

Project description

Background
The Visible/Infrared Imager Radiometer Suite (VIIRS) will be the operational sensor for ocean color, Sea Surface Temperature (SST), land and some atmospheric products on the NPOESS spacecraft. The first VIIRS was launched on the NPOESS Preparatory Program (NPP) October 28, 2011 and this project is focused on the calibration and validation (cal/val) of the VIIRS ocean color products. Of the various applications envisioned for the VIIRS solar reflective bands, those associated with ocean color are the most stringent in terms of sensor calibration, characterization, and stability. The ocean color requirements for radiometric accuracy and precision have been established through various modeling studies and years of data analysis using SeaWiFS, MODIS, MERIS and other satellite ocean color data sets. The derived products such as water-leaving radiance, chlorophyll-a, and primary productivity are sensitive to calibration uncertainties at the 0.1% level. This sensitivity is due to the relatively small ocean reflectances compared to those of the atmosphere, i.e., the combined Rayleigh and aerosol reflectances (~90% of the total radiance over the open ocean is due to atmospheric scattering). Small erroneous trends in sensor calibrations can be easily misinterpreted as real geophysical signals resulting from inter-annual oscillations or climate trends. Thus highly accurate on-orbit calibration is essential for producing ocean products, and it must be maintained for the duration of the mission.

This project is a part of the Joint Polar Satellite System (JPSS) Project Office ocean Environmental Data Record (EDR) cal/val team to establish a plan for maintaining the on-orbit calibration of the VIIRS Visible and Near IR (VNIR) channels used for ocean and land applications and the accuracy of ocean EDRs. Unlike MODIS which has unique ocean channels, VIIRS uses the same detectors for both ocean and land sensing. Data is collected at high gain (ocean setting) until it saturates and then it automatically switches to low gain (land and clouds setting) and continues collecting radiance for that pixel. In
laboratory tests the detectors have been shown to be highly linear over the high and low gain ranges. It is proposed to establish and maintain the on-orbit calibration for the VIIRS VNIR channels using a wide range of calibration targets from bright land targets to dark ocean targets. Given the demonstrated linearity of the VIIRS detectors this approach should provide the most reliable calibration for VIIRS.

Specifically Curt Davis will work as part of the JPSS ocean EDR calibration and product validation (cal/val) team lead by Bob ArNONE (NRLSSC) and will coordinate the ocean calibration plan with the land calibration effort by Kurt Thome (College of Optical Sciences, U. Arizona) and others as directed by JPSS. The Ocean EDR plan will explicitly include calibration activities by NASA and the goal is to coordinate those efforts into a cost effective plan that meets the requirements of the VIIRS program and their customers (NASA, Navy, NOAA and others). NASA is primarily focused on producing global products that can be used as Climate Data Records (CDRs) building on the climatology from SeaWiFS and MODIS. Navy and NOAA have requirements for near-real time products for a diversity of environments, particularly coastal environments which have different calibration requirements compared to the open ocean. In particular, coastal environments with high levels of phytoplankton or Colored Dissolved Organic Matter (CDOM) can have very low signals in the blue, often less than 10% of the open ocean signal. To correctly calibrate the sensor for these low signals requires coastal (or high CDOM lake) calibration sites. The goal is to develop a plan that encompasses these dark sites, the open ocean sites and the brightest land sites to properly calibrate the full range of VIIRS ocean and land data without needing to extrapolate outside the calibration range.

**Approach and Progress**

This project was initiated in June 2008. Initial activities focused on working with Bob ArnONE to establish a draft Ocean EDR Calibration and Validation Plan. Curt Davis prepared the first draft of the plan building on an earlier plan from 2001 and on the current activities for calibration and validation of MODIS products. Bob ArnONE and others did extensive editing and updating of this early draft. A meeting was held in Silver Spring MD July 15-16, 2008 to engage NOAA, NASA and IPO participants in the effort to lay out a plan for VIIRS ocean product calibration and validation. Taking inputs from that meeting and after further iterations the draft plan was circulated widely on September 11, 2008. We received extensive comments from the NASA ocean color team. Their concerns were mostly focused on the need for proper sensor characterization and calibration. We agree with those concerns and they will be working with the IPO Sensor Data Record (SDR) team on these issues. The product of this effort was an initial VIIRS Ocean EDR calibration and validation plan which provided a basis for planning pre-launch and after launch calibration activities. Table 1 outlines the planned effort.
TABLE 1. VIIRS Ocean EDR CAL - Val Plan activities. An X below a topic indicates that it is to be addressed by the OSU team.

<table>
<thead>
<tr>
<th>Science and Operational Investments.</th>
<th>Components</th>
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</thead>
<tbody>
<tr>
<td>Proxy VIIRS Data Stream</td>
<td>&quot;Insitu&quot; data collection</td>
</tr>
<tr>
<td>1. Software versions - MODIS to VIIRS</td>
<td>Moby or AHAB calibration insitu data</td>
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<tr>
<td>2. Integrate sensor characteristics into software versions (Crosstalk, Polarization, etc)</td>
<td>Aeronet - SeaPrism data stream</td>
</tr>
<tr>
<td>3. Integrate Proxy software into NRTPE</td>
<td>Ship Cruise Data - field data stream, bio-optical and MERI-buoy measurements</td>
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<tr>
<td>4. Demonstrate VIIRS data stream to users.</td>
<td>Insitu data management tools</td>
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<tr>
<td>5. Model VIIRS proxy data using MODIS Lw to TOA</td>
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<tr>
<td>6. Instrument upgrades and NIST traceability</td>
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</table>
This cal/val plan being created by Subject Matter Experts (SME) calls for the development and execution of automated procedures for the calibration and validation of the Ocean EDRs from the NPOESS VIIRS sensor; specifically the SST and the ocean color products (water-leaving radiances and Chl). Current operational products of these EDRs are available from NOAA, NASA and NAVY using MODIS and AVHRR data. Limited cal/val efforts for MODIS and AVHRR are in place and operational in the Navy, NOAA and NASA. The Navy uses the Automated Processing System (APS) software for SST and ocean color processing using advanced algorithms specific to their operations. A similar software system exists at NOAA and NASA. APS uses the SDRs (Level 1b) from a variety of sensors and produces the EDR products such as water-leaving radiance Chlorophyll and Inherent Optical properties in addition to SST. The method which cal/val is performed on these data is based on matchups between satellite and in situ data sets in coastal areas.

To coordinate with the land calibration effort Curt Davis contacted Kurt Thome and discussed collaboration on the ocean and land calibration efforts. It became clear that the ocean EDR cal/val plan is far ahead of the land EDR cal/val plan and Kurt and I agreed to keep each other posted on progress for now and to develop more specific joint plans in the future after the discipline plans have solidified. Curt Davis attended a review of the overall SDR and EDR calibration and validation plans for VIIRS on November 18-19, 2009 which included an overview of the VIIRS SDR calibration plans and the VIIRS land EDR validation plans. This was a great opportunity to interact with those groups and advance our collaborations.

Experience with SeaWiFS, MODIS and MERIS makes it clear that ocean products must be validated for both open ocean and coastal regions. This is integrated into the plan and we are preparing to use the Hawaii Ocean Time Series (HOT) data set in the North Pacific Gyre, MOBY data and a long time series of mooring and ship data off the Oregon coast to validate VIIRS ocean color products for the open ocean and for an upwelling coast. These time series will be continued to overlap with VIIRS data collection. We anticipate that others will conduct product validation for representative sites on the US East (Mike Ondrusek, NOAA/STAR) and Gulf Coasts (Bob Arnone, NRLSSC) and we will coordinate our efforts with those SMEs. We will support the development of the procedures for archiving, and using the data for matchups based on the experience with SeaBASS. We will also support the establishment of protocols for ocean color product continuity and demonstrate real time continuity of ocean color data products based on the experience of GlobColour in merging ocean color data sets. All of these are ongoing efforts. The procedures for data match up and product validation were implemented in 2011 using VIIRS Proxy data that has been available since May 2010. These procedures have since been applied to data from the first VIIRS on NPP launched in October 2011.

**Milestone 1.** Support NRLSSC to continue to develop and coordinate the VIIRS Ocean EDR cal/val plan.

This is an ongoing activity by Curt Davis. Activity included co-organizing and supporting Bob Arnone to host the first VIIRS Ocean EDR Cal/Val team meeting in
August 2009 in Silver Spring, MD. A key outcome of that meeting was the establishment of teams for each of the subprograms (VIIRS, Proxy data, SST, etc.). Working with Bob Arnone, Bob May and Giulietta Fargion we have initiated the team activities. Curt helped Bob Arnone with the preparation of the Ocean EDR presentation at the NDPD program review 18-19 November, 2009, and attended the review supporting the ocean EDR program.

Curt supported Bob Arnone in hosting the first VIIRS Ocean EDR Annual Program Review. The review was held March 23-25, 2010 at the Integrated Program Office, Silver Spring, MD. As this was the first review several of the presenters were not familiar with the format and there was a significant learning process. Overall the review was very successful with most of the team members showing good progress in their work. The first annual review meeting notes and presentations are posted on the CIOSS website at http://cioss.coas.oregonstate.edu/CIOSS/VIIRS.html. When it is requested we are prepared to post additional information for the team at this site. Ongoing work includes numerous phone calls and telecons and reviewing documents from the VIIRS program such as the VIIRS Performance Verification Report and the VIIRS SDR Performance Report. June 28-29, 2010 Curt attended the Ocean Studies Board meeting on Assessing Requirements for Sustained Ocean Color Research and Operations. He presented an overview of the VIIRS ocean color cal/val plan and participated in extensive discussions on the role of VIIRS in meeting future ocean color requirements. This is an underway and ongoing activity.

**Milestone 2.** Establish data protocols for Oregon and HOT data and bring archive up to date, (protocols).

At the Ocean EDR team meeting in August 2009 it was recognized that several people were addressing protocols for various data sets and we established an in situ data management team lead by Giulietta Fargion to address this issue. We participated in the first team meeting teleconference on November 11, 2009. It was decided to follow the SeaWiFS SeaBASS data protocols and Giulietta has arranged with NASA to have the data sets included in SeaBASS.

Following up on discussions at the VIIRS Ocean EDR Annual Program Review we are reviewing the procedures for the collection and processing of the HyperPRO data. First we are reviewing the Satlantic processing as the first choice since it is available to everyone. We are reviewing how Satlantic smooths the near surface data to calculate $K_d$ and return near surface values of $E_d$. We are using the results of the SeaWiFS Data analysis Round Robin (July 1994, NASA Tech Memo. 104566, V. 26) as the reference for smoothing techniques. Also considering modifying sampling protocols for turbid coastal waters where multiple casts may be required to adequately sample the surface waters. We are working in collaboration with Chuck Trees, Mike Ondrusek and Giulietta Fargion on this issue.
Recent in situ data collected off the Oregon Coast and in Hawaiian waters continue to be processed and provided online as soon as possible. Data are available from our website (http://omel_test.coas.oregonstate.edu). HOT data collected by OSU are also submitted to HOT-DOGS (an online database maintained by the University of Hawaii). Oregon data collected as part of the MI-LOCO project have been submitted to the MI-LOCO database and a MI-LOCO data search webpage has been created. Processing of HyperPRO data from both Oregon and Hawaii is in progress.

Review of the Satlantic software showed that it did not include a module to produce smoothed profiles from the HyperPRO data. MATLAB procedures to do that routinely at OSU were developed by Amanda Whitmire and we are currently reviewing those procedures with Amanda and comparing them to the procedures from the 1994 SeaWiFS data Round Robin and will recommend an approach to the team in the near future. We also discussed including software for processing the multicast data in the HyperPRO software with Chuck Trees and Marlon Lewis (President of Satlantic). After a telecon with OSU, NRL, Chuck Trees, Giulietta Fargion, and Mike Ondrusek Satlantic agreed to provide Beta-multicast software for testing. We are currently testing and evaluating that software. This is an ongoing activity.

**Milestone 3.** Establish routine processing of co-located scenes (MODIS, MERIS, Proxy VIIRS and when launched VIIRS) and inclusion of new data into Oregon and HOT data bases (data).

Curt Davis and Nick Tufillaro have arranged for routine collection of the MERIS full resolution data for the west coast of the US and the routine archiving of that data at OSU. We have initiated procedures for matching up the MERIS data with the in situ data for the Oregon coast. Demonstration products were presented at the Ocean Sciences meeting in February, 2010. Ricardo Letelier is leading the effort to co-register and analyze the MERIS and MODIS data matched up with the HOT time series data. This activity is ongoing.

**Milestone 4.** Set up APS with VIIRS proxy data to evaluate color products from different satellites for Oregon and HOT (report).

We are currently running the latest VIIRS proxy data version of APS at OSU. Nick Tufillaro is a GRAVITE GTP user and since April 2010 he has participated in the regular VIIRS Proxy data telecons initiated by Mike Denning (NPOESS Integrated Program Office), where Nick provides regular feedback on Proxy data quality. We are currently downloading VIIRS Proxy data of West Coast sites and we are getting regular updates to APS from NRL (currently v4.0.9) that includes beta routines for VIIRS processing. Our first work focused on a subset of West Coast Regions of Interest (ROI’s) (e.g. Columbia River Mouth, Santa Barbara). Now we are extending the download to more regions of interest with GTP’s ROI new query method. Following some NRL procedures, we are evaluating statistical differences between sensors with a code base built mainly in Matlab at OSU. This activity is underway and continuing.
**Milestone 5.** Plan for ocean color product continuity and real-time continuity of ocean color data products (report).

A limited amount of work has been initiated on this Milestone. We are reviewing the current approaches such as used by GLOBColour for merging ocean color data sets. A team was established for this task lead by Rick Stumpf. The first team meeting teleconference was held in October 2010. Our focus is on merging VIIRS Proxy, HICO and MERIS data for the HOT and west coast ROIs.

We are collecting the merged data sets and in situ data but have not initiated the detailed analysis. We have created initial functional fits to the radiance data with an iterative optimization algorithm using ‘radial basis functions.’ Once the radiance fields are converted to a functional form we then compare or merge data products across sensors by a linear weighting of basis functions.

**Milestone 6.** Real-time continuity of ocean color data products using MODIS and MERIS data (demo).

As part of VIIRS prelaunch activities, two demos (19 July 2011 and 23 August 2011) were staged using VIIRS proxy data from GRAVITE, and MODIS, MERIS, and APS processed data of west coast ROI’s from NRL. Working in collaboration with NRL and CCNY, a web configurable reporting system was demonstrated showing statistical matchups on individual sensor bands for user-selected time periods. OSU developed the data base schema, CCNY focused on the presentation layer, and NRL demonstrated complete system integration and statistical match ups that were operational pre-launch. Currently OSU, CCNY, and NRL are optimizing their web tools for their customer needs. OSU’s reports summarizing the demo results are at:


OSU’s prototype for a local web interface is at:


and is shown below.
However, open access to data and reports are not being provided at present until the initial 2012 activities of VIIRS orbit calibration are complete. Some data and statistical match ups are being served from both the NRL and CCNY web sites which are accessible by links from the OSU web site. All three sites make use of an SQL database. The OSU and CCNY are building their presentation and analysis layer with shared code using Python and jQuery, with some of OSU’s analysis also being done in Matlab.

Further details are provided in the JPSS OPCON section below.

**Milestone 7.** Automate the matchup of in situ and VIIRS proxy data sets and demo web based tools.

Bob Arnone’s group at NRL is coordinating the match up sites for VIIRS. The ROI’s are called ‘golden regions,’ and consist of calibrated above water measurements provided by SeaPRISM’s, HyperSAS instruments, and other portable above water sensors.

OSU is currently responsible for providing automated match-ups for the following sites: Columbia River Mouth (COL), Newport, OR (NEW), Monterey, CA (MON), Santa Barbara Channel (SBC), Los Angeles Harbor (LOH), Moby, HW (MOB), and the Hawaii Ocean Time-Series (HOT). Match-ups consist of radiance values and associated statistics.
for predefined pixel squares (3x3, ..., 25x25) at the designated sites. All data is processed using APS to provide consistent algorithms across sensors. In addition, OSU is preparing to provide data and statistics over the entire swaths along the US west coast and Hawaii. The Los Angeles Harbor SeaPRISM (Platform Eureka) became operational in 2011 as described in Milestone 9. The initial web tools for OSU’s ROI’s were demo’ed as described in Milestone 6. First ‘peek’ ocean color views along the west coast processed at OSU are shown below.

![Figure 2. First ‘peek’ view of west coast ocean color from VIIRS: 8 December 2011, 21:10 GMT. (a) Northern Oregon Coast, (b) Southern Oregon Coast, (c) Northern California, (d) Expanded view of Bay Area, CA, (e) Southern CA, Los Angeles Harbor.](image)

Work is also planned to add glider data (OSU and USC) to the mix. The software for the glider component has not been started yet.

**Milestone 8.** Prepare for the Direct Broadcast of VIIRS on NPP.

This work is underway led by Ricardo Letelier. OSU has operated a MODIS direct broadcast station for NASA for over a decade. In 2008 the antenna failed. In 2010 a proposal to replace the dish was approved for funding and the new dish was installed in fall 2011. The antenna is now up and operating.

We have had the VIIRS software (called IPOPP – the International Polar Orbiter Processing Package) up and running for two years now. We are part of the IPOPP Alpha Test Program. The software is running in real-time, processing MODIS data without any
problems. We have the latest version (1.7b). The current version of IPOPP doesn’t use HDF-5; however, we are gaining experience using HDF-5 with HICO data.

**Milestone 9.** Develop methods for validation of VIIRS data with SeaPRISM data. (report).

In collaboration with Burt Jones at USC, the SeaPRISM site at ‘Platform Eureka’ was installed in the Los Angeles Harbor and became operational April 2011. Data is currently flowing to NASA Aeronet as well as NRL and OSU for matchups. Some power and communications issues are still hampering the full time operational capacity of the Eureka platform SeaPRISM, and it looks like (as of December 2011) curated above water data is only being provided about 1/3 of the time. Platform Eureka data is available at:

http://aeronet.gsfc.nasa.gov/cgi-bin/type_one_station_seaprism_new?site=USC_SEAPRISM&nachal=2&level=2&place_code=10

NRL showed some initial match ups from Platform Eureka with the first (peek) VIIRS west coast images. Images of the installation are shown below.

![Platform 'Eureka' SeaPRISM installation in Los Angeles Harbor. (a) Location, (b) Photo of SeaPRISM, (c) Data display from NASA Aeronet site for May 2011.](image)

**Figure 3.** Platform ’Eureka’ SeaPRISM installation in Los Angeles Harbor. (a) Location, (b) Photo of SeaPRISM, (c) Data display from NASA Aeronet site for May 2011.

**Redirected FY 11 activities following the JPSS OPSCON**

In early 2011, the reorganization of the program office from the IPO to the JPSS (Joint Polar Satellite Systems) office and the impending launch of VIIRS on NPP required a refocusing of the cal/val program towards directly supporting validation of VIIRS products immediately after launch and for the coming years of operation. The Operations concept (OPSCON, April 5, 2011) has three categories of activities. Cat. I - Near-real Time Monitoring: Monitoring VIIRS stability and algorithm stability using near real-time in situ data and inter-satellite comparisons. Cat. II - LUT Testing: Evaluate proposed changes to the Look Up Table (LUT) used to convert the Raw Data Records (RDR) to Sensor Data Records (SDRs). And Cat. III - Longer Term validation and calibration (>1 year): Vicarious calibration using MOBY and post-launch cruise data matchups for product validation.

In 2011 we were funded for 9 months to execute our portion of the OPSCON. This included further refining the OPSCON and participating in dry runs of the cal/val...
activities in July and August 2011 to demonstrate the software and procedures using VIIRS proxy data, including pulling VIIRS Proxy data from GRAVITE and testing validation software. Nick Tufillaro conducted extensive tests and provided feedback to Bob Arnone and the GRAVITE team to assure proper operations. Nick participated fully in the two GRAVITE demos, providing quantitative feedback on GRAVITE download statistics and errors. The relevant OSU web sites are provided in Milestone 6.

The goal is to be able to begin cal/val activities as soon as VIIRS NPP data are available. Following the OPSCON our work is primarily focused around the three Categories of Cal/Val activities described in Section 4.4 of this OPSCON.

Cat. I - Near-real Time Monitoring: Monitoring VIIRS stability and algorithm stability using near real-time in situ data and inter-satellite comparisons. Provide near-real time match up of data from the Platform Eureka SeaPRISM with MODIS, MERIS and VIIRS data. This includes the automated selection of the satellite data for that site, production of products to match the AERONET data, and statistical analysis of the in situ and satellite data.

At the current time OSU is receiving near real-time data from:

- MODIS data from NASA OCBP archived at OSU,
- MERIS FR data from ESA down linked by CSA archived at OSU,
- VIIRS SDRs and Ocean EDRs from GRAVITE (Ocean Channels SVM 01-07).

Additionally, we are currently receiving and archiving VIIRS L3 APS processed data for West Coast Golden Regions from Bob Arnone’s group at NRL, and SeaPRISM data from Platform Eureka in the Los Angeles Harbor.

The full orbit SDR for ocean color is about 8 GB. However by using the time stamps on the VIIRS granules we are only downloading and archiving the swaths surrounding our regions of interest (which encompasses all the US west coast and Hawaii) which reduces our GRAVITE draw to 0.5 GB per pass.
Data Output:

The MODIS, MERIS and VIIRS image data subsets for the West Coast (Oregon, Platform Eureka, Santa Barbara channel PNB, and Monterey Bay) and Hawaii (HOT plus MOBY) Golden Regions archived at OSU with co-located in situ data and results of automated statistical analysis of the matched up will be available on line at OSU (Figures 3 & 5). Statistical analysis includes those produced using the NRLSSC and LISCO validator tools, namely means and standard deviations. In addition to daily, weekly, and seasonal statistics and correlations between in-situ and remote sensing radiances, we will also produce (linear and nonlinear) regressions for calibration between remote sensing platforms (MERIS, VIIRS, MODIS, and HICO). These latter regressions will aid in multi-platform EDR continuity over time, as well as providing an additional check on sensor calibration. We are still working on codes for automating the match-ups, including the plotting and statistics. Right now we are generating these one at a time using Matlab routines. We are working on translating this to python to automate it and make it more compatible with CCNY’s routines.

We are also continually updating our NPP VIIRS cal/val web page to have the same look and feel as the CCNY web page.

Data on the websites are access controlled; we are not 'broadcasting' live VIIRS data to the general public at present until the initial VIIRS cal/val activities are completed.

Cat. II - LUT Testing: Evaluate proposed changes to the Look Up Table (LUT) used to convert the Raw Data Records (RDR) to Sensor Data Records (SDRs). The effects of a proposed new LUT are evaluated through trials for golden regions and performance assessment. We are maintaining archives of satellite data and co-located in situ data for 5
Golden Regions: Platform Eureka including the SeaPRISM data and any additional in situ data available from ship and glider measurements, the Oregon Coast, Santa Barbara channel PNB (Plumes and Blooms), Monterey Bay and HOT sites using validated in situ data from SeaBASS. As described above, the archived data will include statistical analysis of VIIRS data products based on the prior LUT.

We will also maintain an archive of the RDRs for the 5 West Coast Golden Regions and when a new LUT is received we will use the U. Wisconsin ADL (RDR to SDR) software to apply the new LUT and generate the new SDRs for these regions. The new SDRs are then processed to EDR\(_{\text{gov}}\) (processed with APS) and EDR\(_{\text{IDPS}}\) (processed by GRAVITE) for the 5 West Coast Golden regions and the extracted data sent to the SQL data base. The comparison of the EDR\(_{\text{gov}}\) and EDR\(_{\text{IDPS}}\) matchup will be generated from the SQL database for the 5 West Coast Golden Regions. The comparisons of the SDRs generated with the new and old LUTs and with in situ and MODIS and MERIS data will be performed and statistics determined. We will evaluate the effects of the new LUT particularly evaluating changes relative to the products from other satellites and the in situ data.

Cat. III - Longer Term validation and calibration (>1 year): Vicarious calibration using MOBY and post-launch cruise data matchups for product validation. 3a. continue to collect HyperPRO data and associated in situ data from HOT and the Oregon Coast Golden Areas during regular funded programs. This data will be quality controlled and sent to SeaBASS. Santa Barbara Plumes and Blooms (PNB, collected by Dave Siegel, UCSB) data will be acquired from SeaBASS. 3b. as funding permits schedule specific VIIRS validation cruises for the Oregon Coast or the Platform Eureka Golden Regions. Measurements will include the HyperPRO, IOPs, and HPLC pigments. 3c. evaluate the effects of a proposed MOBY based vicarious calibration on the data for the HOT, the Oregon Coast, Santa Barbara and Platform Eureka Golden Regions. Provide statistical results and input as to the benefits or problems with applying the vicarious calibration for these waters.

As an example, consider the daily operations at Oregon State. Oregon State ingests near real time data from remote sensing platforms (VIIRS (from GRAVITE), MODIS (from CSA), MODIS (from NASA), and in-situ data (Platform Eureka from AERONET) and stores that data in a local SQL database. Local processing in NRL’s APS and curating produces curated products for either display through an OSU hosted web site, or export to external databases at NRL, NOAA, NASA, or research partners such as CCNY. The processing flow at OSU is illustrated in figure 4.

For local display both product images and summary statistics are produced like that shown in Figure 5. From the curated data, match ups are made through a local web based query form, and the data is also exported to other web tools and databases at NRL, NASA, and other academic partners such as CCNY. Figure 6 shows the processing flow at OSU for matchups:
Figure 5. (a-b) automated sub setting of LA region (Platform Eureka) for VIIRS (Proxy) and MERIS for 12-13 April 2011; (c) mean values (3x3) of TOA radiances for VIIRS.

Queries to the OSU web form will result in match up information like that shown in Figure 7. An example of VIIRS data from the central coast of California including the Monterey Bay golden area is shown in Figure 8.
Figure 7. Platform Eureka SeaPRISM data matched up to VIIRS (proxy) data for 12 April 2011.

Figure 8. RGB image of three VIIRS ocean channels (667, 547, 443 nm) of the central California Coast showing Monterey Bay (bottom) and San Francisco Bay (top) filled with sediments from the Sacramento River taken on 8 December 2011.

The data base is built in SQL (see the schema in Fig. 9). We passed on our data base design to both NRL and CCNY and they both adopted/implemented it with some local changes.
Figure 9. OSU Validator schema built in SQL for managing data in relational database management systems for the in situ and satellite data.

Also OSU is funded separately to establish and operate a Satellite Receiving Station that will receive VIIRS real-time broadcast data for the West Coast of North America. The Receiving Station is up and operating and the antenna locks onto the NPP satellite and receives engineering data. The IPOPP software to capture and process the data is up and running. When VIIRS direct broadcast data become available the OSU team will capture and process the data and validate VIIRS direct broadcast products to assure that they are compatible with the standard VIIRS products.

Curt Davis continues to provide support to Bob Arnone for the planning and execution of the overall Ocean Color Cal Val program. These cal/val components are required for development of the operational data stream. The efforts are aimed at providing the JPSS and operational users (Navy, NOAA) a method to evaluate the ocean products from VIIRS and determine if they can be used operationally. Our activities are part of the Ocean EDR team OPSCON and will be coordinated with the interagency team (NASA, NOAA, NAVY and JPSS) and are coupled with ongoing activities in operations. The efforts will provide an automated cal/val capability and risk reduction to the VIIRS sensor capability to produce ocean EDR products.
PROJECT 7, 8, 9b

Title: 7- EOY Performance Analysis of a Coastal Ocean Data Assimilation System
8 - GOES SST Assimilation for Nowcasts and Forecasts of Coastal Ocean Conditions
9b - CIOSS Support to the GOES-R Risk Reduction Program
Principal Investigator: Alexander Kurapov

Name and NOAA Office of the Primary Technical Contact:
7 - Laury Miller, NESDIS/STAR
8, 9b - Paul DiGiacomo, NESDIS/STAR

NOAA Collaborator on the Project:
7 - Dave Foley, NESDIS/Coast Watch
8 - Laury Miller, NESDIS/STAR, Eileen Maturi, NESDIS/STAR, Dave Foley, NESDIS/Coast Watch
9b - Eileen Maturi, NESDIS/STAR

CIOSS Research Theme:
7, 8, 9b - Theme 3 – Ocean-Atmosphere Models and Data-Assimilation

Related NOAA Goal:
7 - Goal 3 – Weather and Water
8, 9b - Goal 1 – Ecosystems

Project description
Projects 7, 8, and 9b have involved tests of the data assimilation component of the real-time coastal ocean forecast system, set up off Oregon. The ocean model providing daily updates of 3-day forecasts of ocean conditions (in particular, surface currents and SST) has been in operation since 2005. Since then, it has obtained a number of modifications, including improved atmospheric forcing from the 12-km resolution NOAA-NAM, an extended domain (400x800 km, Figure 1), climatological boundary conditions, and most importantly assimilation of satellite and in-situ observations in near-real time (since August 2010). In particular, we have assimilated RADS along-track altimetry from Jason 1, Jason 2, and Envisat, hourly GOES SST, and daily maps of surface currents from a set of 7 high-frequency (HF) radars installed along the shore (data provided by P. M. Kosro, OSU). Mooring velocity data and hydrographic section data from gliders, not assimilated, have been used for the forecast system skill verification.

Project 7 entitled “Performance Analysis of a Coastal Ocean Data Assimilation System”, completed in March 2011, focused on the initial evaluation of the real-time product, in particular the relative impact of along-track SSH, analysis of the data assimilation correction on the ocean heat content (Kurapov et al., 2011), and changes to near-surface and subsurface transports associated with assimilation (see Kurapov et al., 2011, Yu et al., 2012).
Project 8 on “GOES SST Assimilation for Nowcasts and Forecasts of Coastal Ocean Conditions” and Project 9 on “CIOSS Support to the GOES-R Risk Reduction Program,” both started in 2011, focused on the methodology of assimilation of hourly GOES SST data in the coastal area and on the effect of assimilation of these data, to improve forecasts of not only SST, but also near-surface currents. Forecasts of SST, in particular frontal areas, help local fishermen planning trips between the coast and the offshore fronts. Knowledge of the near-coast currents can be important for navigation, search and rescue, and hazardous material spill response missions. One of the objectives of Project 9 was to provide model SST and velocity fields for testing statistical methods for obtaining surface velocities from SST imagery, using feature tracking algorithms (Project 9a).

**Technical Approach**

The forecast model is based on the Regional Ocean Modeling System (ROMS, [www.myroms.org](http://www.myroms.org)), a comprehensive, three-dimensional, nonlinear free-surface, terrain-following coordinate model featuring advanced numerics. The forecast model is run at the 3-km horizontal resolution. Assimilation is done at the 6-km resolution and the initial condition correction is then interpolated to the 3-km grid of the forecast model.

Data assimilation utilizes the representer-based variational approach (Bennett, 2002) in a series of short (3-7 day) time windows (Figure 2). In each window, the tangent linear and adjoint models are run iteratively to find a set of improved initial conditions (at the beginning of the window) such that the resulting nonlinear solution, started from those conditions, fits the data better than the prior model. The nonlinear run is continued into the next window, facilitating the forecast (which serves as the prior model in the next window). Due to the adjoint model dynamics and implied multivariate initial condition error covariance (Weaver et al., 2005), the correction is multivariate and three-dimensional. In particular, the SST data assimilation will contribute to the correction in the velocity field (Figure 3). To facilitate assimilation in the most effective way, we have developed and utilized our own tangent linear and adjoint codes AVRORA (Kurapov et al., 2009, 2011, Yu et al. 2012), which are algorithmically and dynamically consistent with ROMS.

Variational assimilation in a specified final length interval provides not only space interpolation, but also time interpolation of irregular, sparse, and noisy observations from different platforms. In particular, 72 original maps of hourly GOES SST are assimilated in each 3-day window. As the result of running the tangent linear model (forward in time) and adjoint model (backward in time), using the initial condition covariance applied to the result of the adjoint model, a set of smooth initial conditions is obtained. We verify routinely that the smooth model solution obtained using these initial conditions fits the original set of noisy data better than the prior model, in a least squares sense.

Also, as the effect of the linearized dynamics and model error covariance, the correction is multivariate. For instance, alongtrack altimetry measurements yield change not only in the model SSH, but also in velocities, temperature, and salinity, consistent with the ocean dynamics. Similarly, assimilation of SST affects all the fields (including model velocities and SSH). A series of experiments have been run, in which some of the data were
withheld from assimilation, to assess the impact of different data types on the forecast
and skill.

**Progress**

Since August 2010, fields of GOES SST and HF radar surface currents have been
assimilated routinely in the real-time model. At that time we started to receive a stream of
real-time RADS along-track altimetry data and we initially used those data for
verification of the data assimilation results. Quite surprisingly, we found that assimilation
of SST and surface velocities together yields improvement in the slope of SSH (by
comparison with the altimetry data) (Figure 4). This improvement is associated with the
corrected eddy structure and connectivity between the interior ocean and shelf waters,
particularly in fall and winter. By running additional, hindcast tests in which SST was
assimilated alone, we found that the SST observations contribute to approximately 50%
of this effect (in terms of the area-average RMSE). At the same time, assimilation of the
surface currents alone does not improve SSH during winter. As a result of these studies
we conclude that SST and HF radar observations complement each other, to provide
improved estimated of the SSH slope after assimilation (and hence, by geostrophy,
surface ocean currents). Assimilation of SSH in addition to SST and surface velocities in
fact does not improve SSH RMSE significantly, compared to the SST-HF radar velocity
assimilation result. However, we can see the important impact of SSH assimilation
locally, in the areas of large (30-100 km) eddies. This result suggests that availability of
SSH from a larger number of tracks (or wide swath altimetry) may provide a better
impact, better constraining nonlinear eddy variability.

One of the challenging aspects of coastal data assimilation, revealed in real-time
experiments, is assimilation in presence of river plumes (such as the Columbia River
(46N) plume in early summer). The river plume apparently modifies not only SSS, but
also SST, introducing a warm bias compared to our forecast model, which does not yet
include the river flow (Figure 5). This bias may be associated with details of surface heat
transport in the anomalously strongly stratified layer, introduced by the river. An
additional study has been run, using a 1-km resolution model that included the Columbia
River flow, to hopefully reproduce the warming effects in the model and study their
mechanics.

**Impacts**

As a result of this research, we have developed a real-time ocean forecast model that
provides daily updates of 3-day forecasts, in particular SST and surface currents. These
fields have been provided to the NOAA ORR (Office of Response and Restoration) lab in
Seattle via an opendap server. Dr. A. MacFadyen (NOAA ORR) has set up a version of
their GNOME (General NOAA Operational Modeling Environment) system that uses the
velocity fields from our model to predict the fate of oil spills and the trajectories of other
substances or objects. In the case of a spill or other emergency in the coastal ocean off
Oregon, our fields will be immediately accessible to ORR and other NOAA offices. As
we expand the region of coverage for our model to include the entire U.S. West Coast,
the region in which ORR can predict trajectories using this model will also be enlarged.
In addition, the forecasts fields are presently distributed to all interested parties via the NANOOS Visualization System (NVS, www.nanoos.org). NANOOS, the Northwest Association of Networked Ocean Observing System, is one of the 11 coastal ocean Regional Associations of integrated observing systems, focused on the Oregon and Washington coastal waters. These forecasts have become popular among fishermen who use them to plan their daily trips, as reflected in their online discussion boards (e.g., http://www.ifish.net/board/showthread.php?t=369346). The owner of one of the charter boat companies found these forecasts so useful that he has made a video tutorial (with narrative) explaining how to use the NANOOS forecast product (see his company’s web site at http://amigocharters.com/?page_id=58). This incident is motivating us to initiate a closer dialog with the fishing community, in order to improve our product and make it even more useful to the US public.

**Figure 1.** The area of the Oregon coastal ocean forecast model, showing bathymetric contours (200 and 2000 m) and some of the available data: (dots) Jason 2 and Envisat tracks, (gray) HF radar surface currents, (blue) glider tracks (used for verification), (star) the NH10 mooring equipped with an acoustic current profiler.

**Figure 2.** The scheme showing repeated implementation of the data assimilation component of forecast system in a series of 3-day time windows. The nonlinear (NL) forecast model provides a prior solution in a given window (e.g., 5/31-6/02). The correction to the initial conditions is obtained by fitting the data in this interval, which requires repeated implementation of the tangent linear (TL) and adjoint (ADJ) models. Then the nonlinear model is run, starting from the improved initial conditions, providing the analysis solution (in this window) plus the 3-day forecast, which becomes the prior solution for the next window.
**Figure 3.** Assimilation of GOES SST affects not only the model SST (color), but also SSH (contours), i.e., the surface geostrophic current component (in the direction of the contours). (Left) model before SST assimilation, (middle) model after SST assimilation, in closer agreement with the verification multi-satellite blended SST product shown on the right.

**Figure 4.** As the effect of combined GOES SST and HF radar surface current assimilation, the slope of SSH was improved in winter, as compared to the RADS along-track data (not assimilated in this case): (left) Jason-2 tracks 171 and 206; (middle) demeaned SSH plots along track 206, Jan 28, 2011 (black: altimetry, red: model without assimilation, green: analysis, blue: forecast); (right) track 171 SSH RMS model-data difference for the model using assimilation (green) vs. no assimilation (red).
Figure 5. As seen in these monthly GOES SST images, the coastal area off the Oregon is warm in May-June, potentially associated of the effect of the Columbia River plume on the near-surface heat balance and transport. This effect is less pronounced in 2001 (left panel), when the river discharge was minimal based on 11 year statistics and most pronounced in 2011 (right panel), when the river discharge was anomalously large. In 2009 (middle) the river discharge was close to average. Graphics courtesy of E. Simmons III, an NSF-REU summer undergrad intern.

Presentations acknowledging NOAA support:

- COAS Physical Oceanography Seminar, February 2011
- ROMS Users’ workshop, Hawaii, April 2011
- 2011 Assembly of the European Geophysical Ocean, Vienna, Austria, April 2011
- GODAE-OceanView GSOP-CLIVAR Workshop, Santa Cruz, June 2011
- Gordon Research Conference on Coastal Ocean Modeling, MA, June 2011
- Presentation at the Satellite Operational Facility (SOF), MeteoFrance, Lannion, Brittany, France, July 2011
- Presentation at NOAA-STAR, Camp Springs, MD, August 2011
- NOAA/NESDIS Cooperative Research Program (CoRP) 8th Annual Science Symposium, August, 2011
- (Invited speaker) PICES 2011 Annual Meeting “Mechanisms of Marine Ecosystem Reorganization in the North Pacific Ocean”, October 2011
- ONR conference, Denver, November 2011

References


PROJECT 9a

Title: CIOSS Support to the GOES-R Risk Reduction Program

Principal Investigators: P. Ted Strub and Alexander Kurapov

Name and NOAA Office of the Primary Technical Contact: Paul DiGiacomo, NESDIS/STAR

NOAA Collaborator on the Project: Eileen Maturi, NESDIS/STAR

CIOSS Research Theme:
Theme 3 – Ocean-Atmosphere Models and Data-Assimilation

Related NOAA Goal from the NOAA Strategic Plan:
Goal 1 – Ecosystems
Goal 3 – Weather and Water

Project Description

Background: In this project, we are implementing and evaluating two approaches to estimate ocean surface currents, using SST fields from geostationary satellites, in preparation for the use of improved sea surface temperature (SST) fields from GOES-R. The first approach is “Feature Tracking,” in which the displacement of small regions of pixels is estimated using sequential images from the same region. The second approach is “Data Assimilation” (DA), in which the SST fields are assimilated into a dynamical coastal ocean circulation model. We originally proposed to develop and evaluate both methods during the first two years of a three-year project, working with our NOAA colleagues to transition the methods to NOAA in the second and third years. Because of budget cuts to the GOES-R program, the proposed funding during Year-Two was cut and redistributed over Years Two and Three, while the fate of funding proposed for Year Three is not known at present.

During the first year of funding, we have begun the implementation and evaluation of both approaches at CIOSS. This report (9a) presents results from the Feature Tracking method. Results from the Data Assimilation approach are presented in a separate report (9b). The strength of the Feature Tracking methodology is that it uses satellite data alone and can be applied quickly to any region of the ocean where sequences of SST fields are available from satellites. The derived surface velocities are similar to the derived cloud motion velocities in the atmosphere, with uncertainties due to a number of factors (Emery et al., 1986; Tokmakian et al., 1990). The Data Assimilation methodology requires a 3-D numerical ocean circulation model with the capability to assimilate data from multiple times and variable locations (due to changing cloud cover). Although such models take time and resources to implement for a given region, their basis in ocean dynamics reduces their uncertainties.
A key assumption of the Feature Tracking approach is that the smaller features are passive tracers that move with the larger-scale ocean currents. However, oceanographic processes other than simple advection complicate the process of feature identification and tracking. These processes include upwelling and downwelling, diurnal warming, other air/sea interactions, convergences, rotation and other forms of distortion. Because of these processes, the ability to track small-scale features degrades as the temporal separation between images becomes longer than some decorrelation time scale, which changes in space and time. We note, however, that previous studies have been successful in finding realistic velocities in some regions using separation times of up to 24 hours for ocean color fields from CZCS (Tokmakian et al., 1990).

Most efforts to determine ocean surface currents from sequences of satellite images have used SST fields from polar-orbiting AVHRR or MODIS sensors. Similar methods have also been applied to ocean-color images from polar-orbiting sensors (CZCS, SeaWiFS or MODIS). Use of single polar orbiting satellites provides only two images of SST and one image of ocean color per day for most locations (at higher latitudes there may be more). Combined with frequent cloud cover, this causes temporal gaps in sampling of 3-8 days at mid-latitudes, making routine feature tracking difficult or impossible. This is especially true for the highly variable flows in coastal areas (temporal and spatial decorrelation time-scales decrease as you move closer to the coast). If tidal motions are important, the 12-hour difference between samples of SST from polar-orbiting satellites has the additional problem of aliasing the tides.

These problems with temporal sampling can be reduced by using SST data from geostationary satellites. During clear periods, separation times of 1 hour are available. When there are scattered clouds, composites of images from several of the hourly fields may include data from more areas due to the fact that clouds and the clear regions between clouds move during the continuous sampling by geostationary sensors. Off the U.S. West Coast, statistics show that the typical duration of gaps between clear instances of a given pixel decreases from several days to less than a day when geostationary fields are composited. There is still a question, however, as to whether such composite images can be used to estimate displacements and velocities.

**Technical Approach “Surface Velocities From Feature Tracking”:**
Initially, we are evaluating the feature-tracking algorithm known as the “maximum cross-correlation (MCC)” technique (Emery et al., 1986; Schmetz and Nuret, 1987; Kelly and Strub, 1992; Bowen et al., 2002), which estimates sea surface velocity (SSV) from sequential SST images. Originally, the MCC method was developed to track clouds from geosynchronous satellite data (Leese et al., 1971) and for geographical image registration (Svedlow et al., 1978). The method of cloud-tracking was extended to extract sea-ice motion (Ninnis et al., 1986) and advective sea surface velocities from SST and ocean color satellite imagery (Emery et al., 1986; Collins and Emery, 1988; Kamachi, 1989; Tokmakian et al., 1990; Emery et al., 1992; Kelly and Strub, 1992; Kuo and Yan, 1994; Ghisolfi, 1995; Gao and Lythe, 1996; Domingues et al., 2000). Kelly and Strub (1992) evaluated the use of sequences of (polar-orbiting) satellite-derived SST fields to estimate surface velocities using the MCC method of “Feature Tracking” (Emery et al., 1986),
comparing the results to a method developed by Kelly (1989) that inverted the heat advection equation; they found little difference in the accuracy of the two methods.

The studies cited above used SST or ocean color fields from polar-orbiting satellites. Prior to 1995, GOES SST fields were not used for the retrieval of surface velocities in the ocean, due to their greater noise and courser spatial sampling compared to SST fields from polar-orbiting AVHRR and (later) MODIS sensors. Beginning with GOES-8 in 1995, improvements in the GOES imagers have allowed SST retrievals with horizontal resolutions of ~ 1/20 degree (5.5 km) and accuracies of 0.7-1.0K. In the future, the improved spectral channels on GOES-R should provide SST fields with higher accuracy, less noise due to water vapor and aerosols, and higher spatial resolution of ~ 2 km.

In preparation for GOES-R, our approach is to use the high resolution (1 km) SST fields from numerical models of the coastal circulation off Oregon to simulate the fields expected from existing and planned GOES sensors. Applying cloud masks from actual GOES fields to eliminate data in the model fields allows us to create more accurate proxies for satellite SST fields, resulting in more realistic evaluations of the expected performance of the methods when GOES-R data become available.

![Figure 1](image.png)

Figure 1. Study area and schematic depiction of the MCC procedure. Data in the template box (solid square) in the first image are correlated with data in identical sized boxes centered at all pixels in the search window (dashed box) in the second image. The displacement of the water underneath the template box is taken to be to the central pixel of the template box in the second image which produces the greatest correlation coefficient.

Figure 1 shows an example of the MCC procedure. The “template” window (solid box) contains the SST field from the first image that is to be correlated with data found in identical boxes in the second image. The “search” window (larger dashed box) defines the maximum displacement distance to be tested. The displaced position of the template window in the second image is taken to be centered on the box that produces the maximum correlation coefficient; the velocity is calculated from the displacement. The results change when one changes the sizes of the search and template windows: the size of the template window is related to the spatial decorrelation scale for SST, while the size of the search window must be large enough to accommodate the largest allowable advective distance. Searching in too large a window, however, produces spurious large
(but random) correlations. Note that a velocity of 1 m/s produces displacements of 11, 22, 43 and 86 km over 3, 6, 12 and 24 hours. Thus, the use of shorter periods of separation has at least two advantages: (1) search windows needed to allow velocities of 1-2 ms\(^{-1}\) can be smaller, reducing the computational time; and (2) shorter time periods also reduce the amount of distortion, rotation, heating and cooling in the features that are tracked. We also note, however, that errors in image registration cause errors in displacement, which translate into errors in velocities that are increased by the use of short periods between images.

To demonstrate the method, the MCC procedure is applied to sequential, model-derived SST fields, at periods of separation between images of one to 24 hours. The model SST fields are computed using the Regional Ocean Modeling System (ROMS), with horizontal resolution of 1 km (Osborne et al., 2012). Derived velocities for the one-hour separation are shown in Figure 2, overlain on the second of the pair of SST fields used in the calculation. After the velocities are calculated over the entire domain of interest, several methods can be used to edit the individual velocities. One method uses the value for the maximum correlation that corresponds to the chosen displacement and velocity. A velocity can be rejected if its correlation coefficient is less than some threshold. Another method (used here) calculates the horizontal mean velocity and its standard deviation over the entire region of interest, using these to eliminate individual vectors that differ from the mean by more than one standard deviation. Where possible, missing values are then replaced by 3x3 means of the valid surrounding vectors.

Figure 2 shows that the MCC-derived currents calculated with only 1-hour of separation between images (left) captures many of the features of the actual (model) velocity field (right). As the time separation increases, the degree of distortion and rotation increases and differences between the retrieved and actual model velocity field increase. Even in this example, with no compositing, no clouds and 1km resolution, the derived velocities are often weaker than the model velocities.

The objective of our study is to quantify the expected errors in the derived velocities. The first stage of the evaluation uses model fields such as these with increasing separation times. The second phase of the study will average the model data to represent the 5.5 km GOES data that are available now, removing cloud contaminated pixels using cloud masks from present GOES images. Results will be compared to velocity fields derived from present GOES data. In the final stage of the research, we will simulate future GOES-R data and retrieve velocity fields from these improved images. Our results will be compared to model velocity fields that assimilate the GOES SST data, which are described in the report for Project 9b.
Figure 2. (Left) MCC velocity field derived from model SST fields separated by one hour. Individual velocities have been edited as described in the text. (Right) Model velocity fields averaged over the hour separating the images. Both vector fields are overlaid on the Model SST field from the second pair of images.

References:


PROJECT 10

Title: Support for the Installation of a Direct Broadcast Satellite Dish

Principal Investigator: Ricardo Letelier

Name and NOAA Office of the Primary Technical Contact: Paul DiGiacomo, NESDIS/STAR/SOCD

NOAA Collaborator on the Project: Kent Hughes, NESDIS/STAR

CIOSS Research Theme:
Theme 1 – Satellite Sensors and Techniques

Related NOAA Goal from the NOAA Strategic Plan:
Goal 1 – Ecosystems

Total Period of Performance
May 1, 2011 – December 31, 2011

Project Description

Background

Between 2001 and 2009, our group maintained and administered an X-band direct broadcast station in Corvallis, Oregon. Ocean color data were received from the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite sensor, processed, and made available to the public in near real time. End-users rely on our data for projects such as pollution monitoring, prediction of Harmful Algal Blooms, scientific cruise planning, and fisheries management. In 2009 our satellite dish lost its operational capability.

In October 2011, a new ocean color sensor was launched called the Visible Infrared Imager Radiometer Suite (VIIRS). This sensor is a follow-on to MODIS and will provide chlorophyll-a concentration and sea-surface temperature data. The direct broadcast stream from this new sensor is expected to begin in January 2012.

Software to process direct broadcast data from VIIRS (called the International Polar Orbiter Processing Package; IPOPP) is in development at the Direct Readout Laboratory (DRL, NASA). As an IPOPP alpha test site, our research group has been extensively involved in the initial stages of the software testing and use. Currently, this software will process MODIS data only – the code for VIIRS processing is still in development at the DRL.
Ocean color direct broadcast data may also soon be available from the Indian Ocean Color Monitor (OCM-2) satellite sensor. This sensor was launched in September 2009 as part of the OCEANSAT-2 mission. An agreement between NOAA, NASA, and the Indian Space Research Organization (ISRO) regarding the collection of direct broadcast data is in progress.

The proposal sought support to replace our inoperable direct broadcast satellite dish to enable the near real-time processing and distribution of ocean color data transmitted from MODIS, VIIRS, OCM-2, and future sensors.

**Progress**

In September 2011, a new satellite receiving station was installed on the Oregon State University campus in Corvallis, Oregon (Fig. 1). This 3-meter dish is capable of receiving both X and L-band satellite data. Manufactured and installed by Orbital Systems Inc., the EOS X-L reception system has been continuously operational since the day of installation.

The system is currently collecting satellite data from MODIS (aboard the TERRA and AQUA satellites), METOP, and HRPT (NOAA-18 & 19). In addition, the dish is tracking and attempting reception from VIIRS and OCM-2 (however these two sensors are not currently downlinking any direct broadcast data). The coverage area for our station is illustrated in Fig. 2.

MODIS data (Fig. 3) are processed in real time with IPOPP to provide ocean, land, and atmosphere products. The images and data are available from [http://sugar.coas.oregonstate.edu/MODIS/IPOPP/](http://sugar.coas.oregonstate.edu/MODIS/IPOPP/).

METOP and HRPT data are archived on our system.

VIIRS engineering packets have been successfully downlinked to our station. Once the VIIRS direct broadcast downlink is turned on, we are in a position to immediately capture the data. The VIIRS processing software, IPOPP, is still in development at NASA. When a new version of IPOPP (with VIIRS processing capabilities) becomes available, real-time processing of VIIRS data will commence at our station. At that point, VIIRS data will be made available in the same manner as MODIS is currently.
The OCM-2 data downlink is not currently turned on. Once an agreement is reached between NOAA, NASA, and ISRO, it is expected that direct broadcast will become available over the Oregon station. Our satellite dish is already tracking OCM-2, and is prepared to capture the data when available. At that point, the OCM-2 will be delivered in near real-time to interested parties at NOAA via ftp.

The new receiving station has performed admirably over the past few months, providing scenes from a range of satellite sensors. We are looking forward to being able to provide both VIIRS and OCM-2 data in the very near future as they become available.

Figure 2: An example of the coverage area of a single MODIS-AQUA pass over the direct broadcast station in Corvallis, Oregon. The location of the station is shown as “Pedestal_1”. Three satellites can be seen in this example – AQUA (in the process of being collected), NOAA-19 (next to be collected as soon as AQUA is out of range), and TERRA (out of range). The Corvallis station can collect data from as far east as the Great Lakes, and a similar distance to the west.

Figure 3: A MODIS-AQUA scene collected by the new satellite receiving station in Corvallis, Oregon. This scene corresponds to the swath shown in Fig. 2. The scene was collected on January 5 2012, at 20:56 GMT (12:56 local time).
PROJECT 11

Title: Use of long-term open ocean time-series bio-optical data for the validation and refinement of ocean-color algorithms

Principal Investigator: Ricardo Letelier

Name and NOAA Office of the Primary Technical Contact: Paul DiGiacomo, NESDIS/STAR

NOAA Collaborators on the Project: Dave Foley, NOAA/CoastWatch, Mike Ondrusek, NESDIS/STAR

CIOSS Research Theme:
Theme 1 – Satellite Sensors and Techniques

Related NOAA Goal:
Goal 2 – Climate

Project Description

Background and Objectives

The consistent long-term validation of ocean color imagery and derived data products is a fundamental requirement for the development of ocean Climate Data Records. To date a significant effort has focused on vicarious calibration of the SeaWiFS and MODIS sensors using optical measurements from the Marine Optical Buoy (MOBY) to derive normalized water leaving radiances. In addition, a large global bio-optical dataset has been gathered by NASA in the SeaWIFS Bio-optical and Storage System (SeaBASS). These two efforts comprise the backbone for the validation and refinement of ocean color product algorithms and have served to assess how the composition of phytoplankton assemblages may affect the retrieval of ocean color products across oceanic regions (Trees et al. 2000). However, datasets in SeaBASS were collected for specific cruises by different research groups using diverse sampling and analytical protocols. MOBY provides a long time series at a specific location but it only measures Apparent Optical Properties which are propagated to the surface for use in vicarious calibrations; there is no associated HPLC or other measurements necessary to assess ocean product algorithms. Uniquely the HOT data set provides a uniformly sampled long time series data set that is essential for assessing the uncertainties in ocean color algorithms for the open ocean as a function of microbial diversity and physiological variability in the marine environment.

Independently from the MOBY and SeaBASS efforts, the NSF funded Hawaii Ocean Time-series (HOT) program has been characterizing the physical, chemical, biological and bio-optical properties of the upper water column at the oligotrophic open ocean Station ALOHA (22°45’N, 158°W) at nearly monthly intervals since 1988. Station
ALOHA is located in the geographical vicinity of MOBY and ocean color satellite sensors usually capture the MOBY and ALOHA sites during the same pass. The HOT has produced one of the most comprehensive and consistently sampled and analyzed open ocean bio-optical datasets. HOT data products include particle chemical composition and size distribution, phytoplankton pigment composition, and the vertical distribution of apparent optical properties, as well as the total and the dissolved components of the inherent optical properties.

In the context of Climate Change, and based on the satellite-derived chlorophyll concentration in surface waters, several recent reports have suggested that oceanic oligotrophic regions in the subtropical North Pacific are expanding (Behrenfeld et al. 2006; Polovina et al. 2008) as a result of upper water stratification. However, observations from the HOT program display opposite trends (Corno et al. 2007) and suggest that the satellite derived trends could be the result of photo-adaptive processes (Letelier et al. 1993; Winn et al. 1995). These apparent inconsistencies in long-term trends point to the need of assessing the sensitivity of ocean color algorithms in the subtropical gyres. The extent and consistency of the HOT bio-optical datasets allows us to evaluate how seasonal and long-term changes in photosynthetic pigment distribution and microbial assemblages may contribute to changes in the parameterization of ocean color product algorithms in these vast regions. The goal of this proposed work is to use the rich HOT bio-optical dataset to constrain the ocean color algorithm uncertainties for SeaWiFS, MODIS and MERIS, and to develop the procedures to integrate the HOT database in the evaluation of VIIRS algorithms. Specific outputs of this effort will be the quantification of the uncertainties associated with the derivation of sea surface chlorophyll and particulate organic carbon from current remote sensing ocean color algorithms.

**Approach**

**Datasets:** The HOT physical, chemical and biological database (including HPLC pigments) can be accessed online ([http://hahana.soest.hawaii.edu/hot/hot-dogs/interface.html](http://hahana.soest.hawaii.edu/hot/hot-dogs/interface.html)). The ancillary bio-optical data, also part of the HOT program, including radiance reflectance, absorption and attenuation profiles, are available at our OSU website ([http://picasso.oce.orst.edu/ORSOO](http://picasso.oce.orst.edu/ORSOO)). The data set includes particulate, detrital and phytoplankton spectral absorption for samples collected at Station ALOHA since February 2006. Also as part of our HOT instrument upgrade, the 7 wavelength radiance reflectance profiler (Biospherical) was replaced in April 2009 with a hyperspectral profiling system (HyperPRO-II, Satlantic Inc.).

Through our direct broadcast effort, we receive and process SeaWiFS and MODIS Aqua ocean color data corresponding to Station ALOHA ([http://picasso.oce.orst.edu/ORSOO/hawaii/satellite](http://picasso.oce.orst.edu/ORSOO/hawaii/satellite)). MERIS data is downloaded from the ESA Earth Observation portal. VIIRS on NPP was launched in October 2011 and is currently in the instrument checkout phase. As soon as it becomes operational VIIRS data will be downloaded from GRAVITE and added to the comparison data set for product evaluation.
Algorithm evaluation: Our primary task will be to use the time series of HPLC chlorophyll and particulate organic carbon and match-up SeaWiFS, MODIS, MERIS and when available VIIRS data at different spatial resolution to assess the sensitivity of the different sensors and algorithms to the seasonal and long-term in situ variability observed at Sta. ALOHA. The durations of the HOT, SeaWiFS and MODIS datasets will allow us to assess if there are seasonal and long-term changes in the relationship between the in situ observations and the derived remote sensing products.

Following this effort, we will use additional taxon specific pigments and the ratio of chl-a to total particulate organic carbon (POC) in surface waters of Station ALOHA to characterize the seasonal and long-term changes in phytoplankton assemblages and their relative absorption characteristics. This effort will be aimed at quantifying to what extent changes in the microbial assemblage affect the retrieval of chlorophyll concentrations and the interpretation of the reported seasonal and long term trends in these oligotrophic regions.

This effort will help advance the development of consistent ocean color Climate Data Records and will strongly complement the coastal effort led by Curt Davis. It will also serve as the basis for the validation of future open ocean color products derived from VIIRS as they become available.

2010 research activities:

We have updated our Hawaii Ocean Time-series matchup database including near monthly in situ hyperspectral radiometry (Hyperpro II profiles), phytoplankton pigments by HPLC and fluorometry, particle absorption spectra by filter pad technique, as well as ocean color remote sensing from SeaWiFS, MODIS-Aqua and, more recently, MERIS.

![Fig. 1: Comparison between SeaWiFS OC4V4 derived and in situ fluorometric chl a at Station ALOHA. (Filled blue symbols correspond to summer months when the relative abundance of Trichodesmium spp and diatoms increases.) Samples collected at 5 m depth within 24 hours of the remote sensing scene.](image)
As observed last year, when comparing remote sensing derived with in situ chlorophyll values, the mean annual chlorophyll for the study region appears to be reproduced by both remote sensing algorithms. However, the regression slope is significantly lower than expected, generating an overestimation of the in situ chl concentration for in situ values < 0.1 mg m^{-3} and an underestimation at greater concentrations (Fig. 1 displays results for SeaWiFS OC4V4). We proposed several hypotheses that could explain this deviation from a 1:1 slope, including seasonal changes in the relative composition of the taxonomic assemblage affecting the spectral absorption and backscatter, as well as the chl a specific absorption.

![temporal variability in the ratio of 443 to 676 nm phytoplankton absorption derived from filter pad analysis in samples collected at 5 m depth at station ALOHA. The red lines correspond to January 1.](image)

**Fig. 2:** Temporal variability in the ratio of 443 to 676 nm phytoplankton absorption derived from filter pad analysis in samples collected at 5 m depth at station ALOHA. The red lines correspond to January 1.

As seen in Fig 2, phytoplankton spectral absorption displays significant variability with a strong seasonal pattern when normalized to 676 nm. This variability is also observed in the chlorophyll specific absorption at 676 nm (data not shown) suggesting a strong seasonal pattern in chlorophyll packaging effect, which is not considered in current chlorophyll remote sensing algorithms. Our present analyses also suggests that, in this oligotrophic environment, changes in chlorophyll concentration due to physiological adaptation are the main driver in the observed phytoplankton pigment variability and that seasonal and long term trends in remotely sensed chlorophyll concentrations may reflect changes in light availability rather than phytoplankton biomass. Furthermore, the packaging effect derived from our absorption pad measurement imposes some constrains to the detection limits of chlorophyll concentration in these regions.

In order to account and correct for the effect of chlorophyll packaging effect observed in our samples when using ocean color remote sensing algorithms, we will explore the
relationship between $a^*(676)$ and the spectral composition of our samples. We expect that the packaging effect will be associated with a decrease in the ratio of photoprotective to photosynthetic pigments, leading to a decrease in the ratio of $(a_{488}-a_{532})/(a_{676}*(488-532))$.

In order to test this relationship over the next few months we propose to compare the ratio of photosynthetic to photoprotective pigments derived from HPLC to our filter pad derived $a^*_{676}$ and to assess the extent to which this relationship can be described using SeaWiFS and MODIS ocean color bands. In 2011 this project was merged with Project 5 to become ‘The use and validation of MERIS projects for the West Coast and Hawaiian Waters’. 2011 results are included in section 5 of the annual report.

References


PROJECT 12

Title: Coupled Real-Time Coastal Ocean Biophysical Simulations for Forecasting Production Processes, Oxygen Dynamics and Potential Hypoxia on the Oregon Shelf

Principal Investigators: Yvette Spitz, Harold Batchelder, and Alexander Kurapov

Name and NOAA Office of the Primary Technical Contact: Paul DiGiacomo, NESDIS/STAR/SOCD

NOAA Collaborator on the Project: C. Brown, NESDIS/STAR, L. Miller, NESDIS/STAR, D. Foley, NESDIS/CoastWatch, W.T. Peterson, NMFS

CIOSS Research Themes:
Theme 3 – Ocean-Atmosphere Models and Data-Assimilation
Theme 2 – Ocean-Atmosphere Fields and Fluxes
Theme 4 – Ocean-Atmosphere Analyses

Related NOAA Goals from the NOAA Strategic Plan:
Goal 1 – Ecosystem management
Goal 3 – Serve society's needs for weather and water information

Background and Project goals

Frequent summertime episodes of low dissolved oxygen (hypoxic; < 1.43 ml DO/L; DO=Dissolved Oxygen) bottom waters have been observed since 2002 on the Oregon shelf system. Severity and duration of the events, as measured by the level of low-oxygen, as well as the spatial extent of the hypoxia vary from year-to-year. These events have a strong influence on the benthic fauna, including many harvested rockfish species, and the invertebrates that serve as their principal prey. Oxygen levels during Aug-Sep 2006 were so low that at some places anoxic (absence of DO in the water) conditions were reached, leading to death of fish, crab and other benthic species. Low oxygen conditions on the shelf are the cumulative, or synergistic, result of many processes; among the most important are (1) the amount of total primary production, (2) the retention (or residence) time of water before it is flushed from a local region, and (3) the initial DO content of the source waters that upwell onto the shelf.

In this project, our goal is to extend the real-time physical coastal ocean simulation (developed by Kurapov with the support of CIOSS and NANOOS) to include (1) a simple ecosystem model, and (2) biogeochemical oxygen dynamics. This coupled model will provide short-term forecasts of biological productivity, export of biogenic material to the bottom waters, and oxygen concentration.

Research in Progress

Model Development: A simple NAPZD-DO model (nitrate, ammonium, phytoplankton, zooplankton, detritus, oxygen) based on Spitz et al. (2005) has been coupled to the
ROMS physical model with a set-up described in Koch et al. (2010). Oxygen is calculated from respiration, regeneration and production processes using a constant O:N ratio. In addition, alteration of oxygen in the coastal ocean by air-sea exchange and ventilation processes is controlled by wind speed, gas solubility, and temperature and salinity dependence of the Schmidt number, and is calculated using the equations in Wanninkhof (1992). The chlorophyll-a component was added to the model as follows:

$$\frac{\partial Chla}{\partial t} = V_m f(I) Q P Chla CN_p MW_C - m Chla - G Chla$$

$$- \text{advection + diffusion}$$

The first term on the right hand-side corresponds to the growth term in the phytoplankton (P) equation, the second term is the mortality and the third term is the grazing by zooplankton. $CN_p$ is the phytoplankton carbon to nitrogen ratio and $MW_C$ is the carbon molecular weight. $\rho_{Chla}$ is the fraction of nitrogen assimilated by the phytoplankton that is used to make more chl-a and is defined based on Geider et al. (1996) as

$$\rho_{Chla} = \frac{\theta_m V_m f(I) Q}{\alpha \theta I}$$

where $\alpha$ is the initial slope of the P/I curve, and $\theta_m$ and $\theta$ are the maximum and actual chlorophyll-a to carbon ratios, respectively. Calibration of this part of the model remains to be done.

**Simulations and conclusions:** The simulations for this project were realized for domain (Figure 1) spanning over (129°-124° W) in meridional and over (40.5° - 47.5° N) in zonal directions. Horizontal grid has 3 km resolution, vertical resolution is provided by 40 sigma-levels with finer resolution in the surface and bottom boundary layers. The grid bathymetry is a hybrid of ETOPO-5 global Earth topography (offshore) and NGDC 12" bathymetry array (over the slope and the shelf parts) with some smoothing to avoid numerical instability due to sharp gradients in the topography. The physical model is forced by daily-averaged COAMPS winds with 9-km horizontal resolution and monthly-averaged, 2.5 degrees horizontal resolution NCEP/NCAR fields for heat-flux computation (short-wave solar radiation, air temperature, air pressure, relative humidity, precipitation). Initial and open boundary conditions for 2D and 3D velocities, T, S and SSH are from daily NCOM-CCS. For the ecosystem boundary conditions we used NCOM-CCS simulations with nitrate fields adjusted to better match observed offshore nitrate climatologies along the Oregon Coast. The boundary conditions for DO are based on a relationship between NO$_3$ and DO determined from in situ observations over the last decade. Figure 2 shows that the modeled and observed nitrate and oxygen profiles at the Newport Line are in good agreement in July 2002, which corresponds to a period roughly 3 months after the start of the simulation.

During this phase of the project, we continued to assess the impact of the offshore and north-south fluxes of nutrient and oxygen on the shelf ecosystem and focused more
specifically on the timing and duration of hypoxic events. We considered three years (2002, 2006, 2008) where the initialization and extent of the hypoxic event are contrasting (Figure 3). In 2002, the hypoxic event started earlier and became widespread on the shelf. In 2006, the severity of the event was the strongest during August. In 2008, the hypoxic events were weaker and did not cover the entire shelf especially in late-August.

During the upwelling season (June-August), we see a net decrease of oxygen over the shelf (Table 1). The net biological forcing yields an increase of oxygen on the shelf, whereas the physical processes lead to a net decrease of oxygen. Net biological and physical forcing were larger in 2006 than 2002 and resulted in a stronger decrease of shelf oxygen during the 2006 upwelling season. To define the relative contributions of the three open boundaries (northern, western and southern) to the DO budget over the shelf (defined as the region shallower than 200m), we computed the DO fluxes normal to these boundaries and integrated them over the upwelling period (June-August) of 2002 and 2006. The 2006 influx of oxygen through the northern boundary is approximately 70% of the 2002 influx and the outflux through the western boundary was slightly larger in 2006 than in 2002. The southern boundary fluxes were quite different between the two years. While there was a net outflux through that boundary in 2002 (equivalent to about 28% of the northern boundary influx), there was a small influx in 2006 (ca. 10% of the northern influx). From this phase of the project we can conclude that local and remote forcing are important to predict hypoxic events on the Oregon Shelf. These findings and a complete analysis of the shelf fluxes of nutrient and oxygen will be given in a manuscript that is in preparation.

**Research Planned**

Work will continue toward achieving the project objectives and near-real time forecasting. Emphasis will be placed first on calibrating the chlorophyll-a component of the model and its relationship with hypoxia intensity and extent. This should allow us to use remotely sensed observations in combination with the coupled ecosystem/circulation model to forecast hypoxic events. We will also assess the impact of uncertainty in the physical flow field on the modeled NPZD-DO fields.
References


Participation in regional, national and international meetings

Batchelder, H. P., Lagrangian and Eulerian Modeling of Shelf Ecosystems, November 29-30, 2011, Workshop on the “Science of Coastal and Marine Spatial Planning”, held at Oregon State University

Spitz, Y.H., Hypoxic Condition Prediction in Upwelling Systems, June 26 - July 1, 2011, Mount Holyoke College, South Hadley, MA.

Manuscripts


Figures

Figure 1: Model domain from NCOM and ROMS (black box) simulations. The boundary conditions for our coupled models are prescribed along the edges of the black box.

Figure 2: NO3 (blue) and DO (red) profiles along the Newport (NH) line ($44.65^\circ$N) during 10-12 July 2002. NH-##: ##=offshore distance in miles. The pale and thick lines represent the observations, bright and thin lines are the model outputs.
Figure 3: Time series of shelf water volume with hypoxia (<1.4 ml/l DO concentration) in % of the total shelf volume (top panel) and the percentage of cross-shelf area with hypoxic conditions as a function of time (bottom panel) for (a) 2002, (b) 2006 and (c) 2008.

Table

Table 1. DO shelf budget (ml O₂ *10¹⁶) due to different processes over the upwelling season (June-August).

<table>
<thead>
<tr>
<th>Factor/Time interval</th>
<th>June-August 2002</th>
<th>June-August 2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical=Advection+Diffusion</td>
<td>-0.3339</td>
<td>-0.4563</td>
</tr>
<tr>
<td>Air-Sea Flux</td>
<td>-0.0829</td>
<td>-0.0655</td>
</tr>
<tr>
<td>Physical+Air-Sea Flux</td>
<td>-0.4168</td>
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<tr>
<td>Biological Source</td>
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<tr>
<td>Biological Sink</td>
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<tr>
<td>Biological Net</td>
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<tr>
<td>Net</td>
<td>-0.1190</td>
<td>-0.1679</td>
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</tbody>
</table>
PROJECT 13

Title: CIOSS Graduate Student Fellowship in Ocean Remote Sensing

Principal Investigator: P. Ted Strub

Name and NOAA Office of the Primary Technical Contact: Paul DiGiacomo, NESDIS/STAR/SOCD

NOAA Collaborator on the Project: Paul DiGiacomo, NESDIS/STAR/SOCD

CIOSS Research Theme:
Theme 1 – Satellite Sensors and Techniques
Theme 2 – Ocean-Atmosphere Fields and Fluxes
Theme 5 – Outreach: Formal Education in Ocean Remote Sensing

Related NOAA Goal from the NOAA Strategic Plan:
Goal 3 – Weather and Water

Project Description
The goal of this project is to support a graduate student in the CEOAS (College of Earth, Ocean and Atmospheric Sciences) graduate program, pursuing a graduate degree (MS or PhD), with a research thesis topic in one of the CIOSS Themes in ocean remote sensing. The graduate student will be advised by a CIOSS Fellow and will become familiar with research conducted at SOCD headquarters, as well as in CEOAS. The student should also use the CoRP Exchange Program to visit other STAR CI’s, NOAA labs and centers.

Progress
A student from India is being supported during his first year of graduate study at OSU. Mr. Laxmikant Dhage received his B.S. from the Guwahati campus of the Indian Institute of Technology (IIT) in Spring, 2011. During the summers of 2009 and 2010, Mr. Dhage worked with satellite altimeter data: in 2009 with Dr. Y. K. Somayajulu at the Indian National Institute of Oceanography in Goa, India; and in 2010 with Dr. P.T. Strub in CEOAS. Dr. Strub also helped Mr. Dhage attend the 4th Coastal Altimetry Workshop in Porto, Portugal, where he presented results of his work during summer 2010. Mr. Dhage applied to graduate schools in the U.S. in the field of Physical Oceanography and was accepted at OSU (and several other universities), where he began his study in Fall 2011 and has done well during his first term.

Mr. Dhage’s research project will extend work that he started during his initial visit as a summer intern in 2010, looking at the alongtrack altimeter data in the Indian Ocean. Although he was formally admitted to OSU as an MS student, he will have the opportunity to take written comprehensive qualifying exams during July 2012, after his first year at OSU. If he passes those exams, he will be advanced to candidacy and can either finish an MS thesis or move directly on to a PhD thesis. In either case, we will be asking for a second year of funding to continue his work at OSU.
Although his initial analysis will be on the alongtrack altimeter data from the Jason and TOPEX altimeter series, Mr. Dhage will also work with the other primary types of ocean remote sensing data: scatterometer winds, sea surface temperature (SST) and surface chlorophyll-a concentrations (CHL). To do this, he will use data from two new Indian satellites, as well as the more well understood U.S. and European satellites. The Indian Space Research Organization (ISRO) launched the Oceansat-2 Satellite (http://www.isro.org/satellites/oceansat-2.aspx) in September 2009. This satellite carries an “Ocean Colour Monitor” (OCM-2) sensor and a Ku-band pencil beam scatterometer (OSCAT). Data from these sensors have not yet been made public but we will eventually receive these data (OCM-2 in real time from our own receiver; OSCAT data through NASA) and collaborate with Indian colleagues on their analysis. SARAL/Altika (http://smsc.cnes.fr/SARAL/) is another Indian satellite that will be launched early in 2012, carrying a new altimeter in a partnership between India and France. We again plan to work with Indian colleagues in the analysis of these data. Although these collaborations do not depend on Mr. Dhage’s participation, it may well prove useful to have a student at OSU who has strong ties to the Indian science community and we look forward to growing relationships between U.S. and Indian ocean-remote-sensing experts over the next several years.
PROJECT 14

Title: Transition of CIOSS Results to the Web

Principal Investigators: P. Ted Strub and Craig Risien

Name and NOAA Office of the Primary Technical Contact: Paul DiGiacomo, NESDIS/STAR/SOCD

NOAA Collaborator on the Project: Dave Foley, NESDIS/CoastWatch

CIOSS Research Themes:
Theme 2 – Ocean-Atmosphere Fields and Fluxes
Theme 5 – Education and Outreach

Related NOAA Goals from the NOAA Strategic Plan:
Goal 3 – Weather and Water

Project Description
The goal of this project is to develop new and improved data products, using currently available CIOSS data sets, and to transition these products to NOAA CoastWatch and NASA’s Physical Oceanography Distributed Active Archive Center (PO.DAAC), thus allowing managers, businesses, policy-makers, and scientists access to this information in a more efficient and timely manner. Specific data sets we will work with include altimeter-derived surface height and velocity fields and scatterometer-derived surface vector wind fields along the U.S. West Coast. In developing these value added fields, we have worked with the Northwest Association of Networked Ocean Observing Systems (NANOOS), the NOAA West Coast CoastWatch node in Pacific Grove, California and the NASA Jet Propulsion Lab in Pasadena, California. The improvement of altimeter and scatterometer products fills a gap in the CoastWatch suite of data sets, which have historically emphasized satellite-derived sea surface temperature and ocean color.

Progress
SLA/TG Fields
Gridded AVISO quarter degree DT UPD MSLA version 3.0 fields\(^1\) were merged with NOAA CO-OPS tide gauge (TG) data\(^2\) to produce high-resolution fields of SSH in the nearshore region of the California Current System (CCS). This data set is unique in that it covers the 50-75 km wide region next to the coast that is not sampled by altimeters. To create the merged data set we used methods similar to those described in Saraceno et al. (2008). Important differences include:

1. The data for this product are derived from AVISO Version 3 fields.

\(^2\) http://tidesandcurrents.noaa.gov/
2. This product uses an inverse weighted interpolation instead of the Delaunay triangulation method.

3. This product covers expanded spatial and temporal domains that include 35.25 - 48.5 °N, 227.75 - 248.5 °E and 14 October 1992 – 04 November 2009.

0.25 latitude x 0.25 longitude gridded AVISO data were used for distances greater than 0.75 degrees from the coast. Tide gauge data were interpolated to a regular grid along the coast in between tide gauges, creating a “virtual” array of tide gauges (Figure 1). The 0.75 degree wide region next to the coast was then filled in by interpolating between the offshore AVISO and virtual tide gauge SSH values. Finally, geostrophic velocities were calculated from these interpolated SSH fields (Figure 2). These data, which are available as weekly composites for the period 14 October 1992 – 04 November 2009 and the region 35.25 - 48.5°N and 227.75 - 248.5°E, were compared with GLOBEC moored current measurements at NH-10, Coos Bay (CB), and the Rogue River (RR). Table one summarizes the results of this study, which compare well with the findings of Saraceno et al. (2008).

<table>
<thead>
<tr>
<th></th>
<th>NH-10</th>
<th>CB</th>
<th>RR</th>
<th></th>
<th>NH-10</th>
<th>CB</th>
<th>RR</th>
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<tr>
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<td>-0.281</td>
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<td></td>
<td>4.78</td>
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<tr>
<td>RMS Diff</td>
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<td>9.92</td>
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<td></td>
<td>8.69</td>
<td>6.31</td>
<td>5.24</td>
</tr>
</tbody>
</table>

Note: Rogue River data starts in Fall 2000.
Note: Moored data have been smoothed with a 20-day boxcar filter, similar to Saraceno et al.

**Table 1.** Comparison of currents from the SLA/TG with three GLOBEC moorings.
Mooring measurement depths: NH-10: 10m, CB: 10m, RR: 15m. Data from April 2000 to September 2004.

The statistics described in Table 1 and the time series presented in Figure 3 (left panels) show that the meridional geostrophic velocities derived from the SLA/TG data set are well correlated with the GLOBEC mooring data. Figure 3 (right panels) and the low correlations in Table 1 show, however, that the zonal geostrophic velocities are not well determined by the CIOSS SLA/TG product.

We have worked with Jessica Hausman (JPL) to transition this data product to JPL PO.DAAC. It is now available online at ftp://podaac.jpl.nasa.gov/allData/coastal_alt/preview/L4/OSU_COAS/. Since March 2011 this data product has been accessed, via the JPL FTP site, by 567 users who have downloaded 2470 files.
**Ocean Vector Wind Fields**

The standard 25 km QuikSCAT Ocean Vector Wind (OVW) product includes an arbitrarily imposed 30 km land mask, a region where there are strong gradients in the wind field that are dynamically important for ocean circulation. Dr. Michael Freilich and Dr. Barry Vanhoff have developed a narrower land mask that allows for wind retrievals within 5 -10 km of land. This wind retrieval method uses the long record of QuikSCAT data and is based on the fact that radar backscatter due to land is relatively time insensitive for a given viewing geometry. Thus, by calculating backscatter variability on a fine spatial grid an empirical land mask can be generated. Regions of low backscatter variability are likely contaminated by land while regions of high variability are not. Using 12.5 km QuikSCAT wind fields a high-resolution (0.10 latitude x 0.10 longitude), data set was created that covers the entire QuikSCAT mission (19 July 1999 - 21 November 2009) and includes the new geometry dependent land mask. This data set spans the California Current System (CCS) between 30 and 50°N and 115 and 135°W and consists of 12 wind variables including wind speed, wind speed squared, wind speed cubed, zonal and meridional wind components, wind curl (vorticity) and divergence, wind stress magnitude, zonal and meridional wind stress components, and wind stress curl and divergence. We compared the CIOSS u and v wind fields with a 3-month, 0.125 latitude x 0.125 longitude, science quality data set that was provided by Dave Foley (NOAA CoastWatch). Figure 4 shows an example of how the 0.1° CIOSS fields compare with the 0.125° NOAA CoastWatch and standard 0.25° QuikSCAT fields. These results were presented at the 2009 Eastern Pacific Ocean Conference (http://agate.coas.oregonstate.edu/EPOC2009.pdf). More recently this data product was highlighted as NOAA Cooperative Institutes “Hot Item” (http://www.nrc.noaa.gov/ci/hotitems/2010/CIOSS-Aug2010.pdf).

We have worked with David Moroni (JPL) to transition this OVW data product, which includes a user guide (Vanhoff et al., 2011) that was developed in conjunction with JPL, to JPL PO.DAAC. It is now available online at http://podaac.jpl.nasa.gov/dataset/QSCAT_OSUCHAS_L3_OW_USWestCoast. Since March 2011 this data product has been accessed, via a JPL FTP site, by 140 users who have downloaded more than 13 GB of data. Note that these fields are also made available via a JPL OPeNDAP server and that JPL does not track data accessed via this service.
References


Figure 1. (top) Low-pass filtered time series of sea level (m) as measured by twelve NOAA CO-OPS tide gauges. (bottom) Results of the interpolation of the twelve tide gauges’ time series to a 0.125 degree alongshore grid.
Figure 2. An example of the interpolation of the sea level (m) measured by tide gauge stations with the sea level measured by satellite altimetry, for the week centered on 15 May 2002. (left) Gridded sea level as provided by AVISO in color with vectors overlaid to depict estimated geostrophic current velocities. (middle) Sea level observations from AVISO that are within 0.75 degrees of the coast are removed and sea level observations, derived from an array of virtual tide gauges, are mapped to the coast line. Overlaid vectors depict estimated geostrophic current velocities. (right) The sea level result obtained from the interpolation of the tide gauge observations with the satellite data in color with vectors overlaid to depict estimated geostrophic current velocities.
Figure 3. A comparison of geostrophic current data derived from the CIOSS SLA/TG data set with current data from three GLOBEC moorings located at NH-10, Coos Bay (CB), and the Rogue River (RR). Meridional and zonal current data are shown in the left and right panels, respectively. While the meridional SLA/TG currents are relatively well correlated with the GLOBEC observations, zonal geostrophic velocities are not well determined by the CIOSS SLA/TG product.
Figure 4. Daily composite maps of QuikSCAT wind speed and direction for 26 April 2009. Clearly visible in the 0.25° field (left panel) is the 30 km land mask associated with the standard processing. While, the land mask associated with the NOAA CoastWatch 0.125° data set (middle panel) allows for a greater number of wind retrievals closer to land, the geometry dependent land mask used in the 0.10° dataset (right panels) allows for wind retrievals within 5 - 10 km of the Santa Catalina and San Clemente Islands.
PROJECT 15

Title: Benchmark Characterization of Bloom Characteristics for Coastal Oregon: An In Situ Evaluation of Satellite-Based Bloom Detection Products

Principal Investigator: Angelique E. White

Name and NOAA Office of the Primary Technical Contact: Paul DiGiacomo, NESDIS/STAR/SOCD

NOAA Collaborator on the Project: Dave Foley, NESDIS/CoastWatch

CIOSS Research Themes:
Theme 2 – Ocean-Atmosphere Fields and Fluxes
Theme 1 – Satellite Sensors and Techniques
Theme 3 – Ocean-Atmosphere Analyses
Theme 5 – Outreach: Formal Education

Related NOAA Goal from the NOAA Strategic Plan:
Goal 1 – Ecosystems

Background and Project Description
NOAA’s Coastal Services Center currently disseminates several broadly utilized and effective harmful algal bloom (HAB) forecast products for the Gulf of Mexico [Stump et al. 2003; Carvalho et al. 2011]. In collaboration with the NOAA CoastWatch West Coast node (Dave Foley) we have actively sought to evaluate aspects of these HAB products for the Oregon coast region. The ultimate goal of this effort has been to assess the potential of these bloom products as a tool for early detection of HAB events that could be utilized by coastal managers. Unlike the Gulf of Mexico where the primary HAB-forming genus (Karenia brevis) has a unique optical signature [Cannizzaro et al., 2008; Hu et al., 2008], the HABs of concern off Oregon, including several species of Pseudo-nitzschia and Alexandrium, cannot be discriminated from bulk chlorophyll retrievals. To address this challenge, we have leveraged NOAA funded work (MOCHA, http://bioweb.coas.oregonstate.edu/~mocha/) to evaluate the temporal and spatial variability of HAB events and the relationship of these events to satellite retrievals of chlorophyll and the NOAA CoastWatch chlorophyll deviation bloom product. This product takes the last 8 days of SeaWiFS or MODIS chlorophyll and subtracts from it the previous month. Thus, a positive value means that a bloom developed in, or was advected into, a given pixel within the last 8 days relative to the previous month. This CIOSS and NOAA partnership has identified several preliminary findings relevant to efforts to develop operational HAB forecasts in Oregon:

1. At 1-km resolution, the mean data gap between positive retrievals in the Oregon region is 4-10 days. This heterogeneous spatial and temporal coverage has informed our efforts to adapt HAB forecast products for Oregon. Specifically, the
8 day window that represents the most recent conditions was chosen because it is the shortest time window for which we can obtain a relatively cloud free image.

2. Domoic acid events are associated with the spring transition albeit these events are not reliably or positively correlated with chlorophyll blooms.

3. Saxitoxin events occur nearly annually, are associated with late summer upwelling and appear to be more intense under El Nino conditions (Tweddle et al. 2010). Saxitoxin events are generally associated with an increase in bulk surface chlorophyll and hence more likely to be detected via remote sensing.

These results suggest that Oregon-HAB forecasts via remote sensing may be feasible on weekly-monthly time scales and the seasonal timing of positive bloom retrievals can be indicative of HAB taxonomy (particularly for saxitoxin events). In order to expand upon these preliminary results and evaluate the efficacy of remote sensing bloom products for the region, robust in situ characterizations of chlorophyll blooms are vital. Specifically, we are currently lacking a benchmark characterization of in situ bloom frequency and persistence. The project described herein would provide this benchmark analysis and complement ongoing HAB monitoring efforts to evaluate and enhance NOAA/NESDIS satellite-derived products.

The overarching goal of this project is to provide a detailed characterization of in situ chlorophyll bloom persistence, frequency, and spatial extent relative to the current NOAA west coast satellite bloom product. This analysis will rely on chlorophyll and CDOM measurements retrieved from long-term Slocum glider data and HAB event analyses derived from MOCHA. The Slocum glider data were chosen for this analysis due to their high-resolution temporal and spatial profiles of bio-optical parameters. The glider travels approximately 22 km per day along a due east (or due west) transect located at ~44.5ºN, just offshore of Newport, Oregon. Gliders descend and ascend through the water column, creating continuous vertical profiles from the coast, over the continental shelf, and out to approximately 50 km beyond the shelf-break. Transects typically span ~120 days, and deployments are made year-round, weather permitting. Slocum gliders provide a surface, or horizontal, resolution of approximately 100 - 800 meters out to a distance of approximately 50-120 km offshore, and a subsurface, or vertical, resolution of less than one meter. Chlorophyll-a fluorescence, CDOM fluorescence and backscatter are continuously measured along these transects. The lead PIs for the glider deployments (K. Shearman and J. Barth) have agreed to provide us with the calibrated and processed optical data.

From our perspective, this dataset provides a unique and timely opportunity to define the in situ bloom characteristics in HAB hot spot regions and provide a measure of bloom persistence and spatial extent as a benchmark for evaluation of satellite-derived predictions of toxic and non-toxic bloom events. Persistence in this case can be defined as the time period for which the bloom index is positive along a repeat transect. The additional CDOM and backscatter data streams from the gliders will also allow us to evaluate potential false positive bloom retrievals. Finally, we will compare the bi-weekly NOAA/MOCHA data records of phytoplankton community structure (HAB species included) and particulate and dissolved toxin levels to derived chlorophyll bloom proxies. In collaboration with NOAA/NESDIS and other CIOSS fellows (Davis, Letelier, etc.),
this effort will contribute to the broader goal of enhancing the monitoring and prediction of HAB events along the Oregon coast.

**Objectives/Accomplishments**
The objectives and preliminary outcomes for this project are as follows:

*Objective 1:* Evaluate the frequency and persistence of glider-based chlorophyll blooms (defined using an algorithm developed with previous CIOSS funding, see Figure 1).

*Outcome 1:* We have completed an evaluation of remote sensing bloom algorithms based on MODIS CHL and FLH for the Oregon coast. A manuscript describing these research findings is nearly-finalized. We anticipate submission to our target journal (Marine Ecology Progress Series) by the first of the year. This work establishes a protocol for evaluation of the temporal and spatial analyses of phytoplankton blooms that will be applied to the glider datasets. Morgaine McKibben, a graduate student funded by this project, is set to begin PhD research on this topic in the winter 2012 term.

*Objective 2:* Vary the *in situ* bloom product algorithm to determine if shorter or longer windows for the current and previous conditions would better identify blooms.

*Objective 3:* Quantify how CDOM and particulate concentrations vary in space and time, and how this variance in optical conditions affects the accuracy of the bloom product.

*Objective 4:* Compare the occurrence and frequency of toxin events (as defined by toxin levels in shellfish tissue samples and dissolved and particulate toxin levels in water samples collected during MOCHA research cruises) to *in situ* and satellite bloom detections.

*Outcome 2-4:* We will focus on 2009-2010 data initially as this was a period in which both domoic acid and saxitoxin events were recorded in the Newport region. The final measure of performance for this work will be ‘validation of an experimental product’. Essentially we aim to have evaluated and performed QA/QC routines of glider data and matched these results to MODIS bloom products. Again this research will be the topic of a PhD thesis by Morgaine McKibben, a graduate student that will begin her PhD research in January 2012.
Figure 1. An example of (A) MODIS CHL and (B) MODIS FLH- based bloom products for successive 8d composites spanning June 24-July 2.
Task II: Outreach with NOAA Collaboration

PROJECT 16

Title: CIOSS Outreach: Development of Oceanographic Remote Sensing Curriculum for the SMILE High School Program

Principal Investigator: Ryan Collay

Name and NOAA Office of the Primary Technical Contact: Paul DiGiacomo, NESDIS/STAR/SOCD

CIOSS Research Theme:
Theme 5 – Outreach

Related NOAA Goal from the NOAA Strategic Plan:
Goal 3 – Weather and Water

Background—Through the NOAA/CIOSS partnership with the Science & Math Investigative Learning Experiences (SMILE) Program, underserved and underrepresented high school students engaged in weekly afterschool clubs and a culminating scenario-based, problem-solving event based upon ocean sciences, modeling and oceanographic remote sensing lead by public school teachers who serve as SMILE club advisors. The ultimate goal was to increase student interest in and preparation for higher education and science-based careers. The annual thematic topics span the academic year. Consequently, for the current reporting period, the project addressed two thematic topics:
Ocean Theme for Year 8—How does climate change and ocean condition affect fisheries through long-term changes in the currents and nutrients that support biotic communities?

Ocean Theme for Year 9—How can we make predictions for changes in ocean conditions, as related to predicted climate change impacts, that will have implications for human health?

Project Goals—The short-term and long-term goals of the NOAA/CIOSS partnership with the SMILE Program were to:
- Engage researchers and graduate students in the development and delivery of club activities and the problem-based Ocean Challenge scenario in a context of ocean sciences;
- Support an increase in high school teachers in their knowledge of NOAA research and their ability to engage students through ongoing Teacher Professional Development;
- Increase awareness and interest in pursuing STEM careers among SMILE students, specifically linking students' ocean science knowledge to people and careers;
- Provide "College Connection" challenge events in ocean sciences to increase college readiness, connect students to people meeting a community's through research;
Involve undergraduate and graduate students as team mentors to facilitate team engagement and progress and to serve as college-student and career role models; Promote aspirations and preparation among SMILE students for higher education; and, Promote science and ocean literacy among students and teachers as defined by NOAA's Ocean Literacy framework.

**Teacher Workshops (TWS)**—In support of NOAA’s education plan, this project provided professional development learning opportunities for the fifteen high school teachers that serve as SMILE Club advisors. The workshop sessions are designed to help these teachers gain ocean science content knowledge, enhance their pedagogical content knowledge in fostering student engagement, and experience the activities they later conduct with students during club meetings. Workshops for teachers occurred three times during this period: Winter, Spring, and Summer. A portion of the funding for these workshops came from a US Dept. of Ed. grant through the University/Schools Partnerships Program. Many of these teachers have been with our program for over five years and have participated in over fifteen workshops. Oceans sciences are not commonly content areas in high school so one-third of each workshop sessions is designed to engage the teachers as learners. Not only does this increase their content competency, their learning and engagement helps them model "life-long learning" for their students. Additionally, at each workshop we provide the teaching materials they will use to engage students in the clubs.

**Afterschool SMILE Clubs**—SMILE Clubs, each consisting of approximately 20 students and two classroom teachers serving as club advisors, met weekly after school during the year. The clubs provide content and process skills enrichment through instructional materials linked to Oregon standards and benchmarks, as well as NOAA Ocean Literacy goals. In this setting, advisors engage students in activities that support their interest and knowledge in ocean science and in preparation for the spring college-connection event, the High School Ocean Sciences Challenge. Approximately, one-third to one-half of the club time is allocated to activities connected to the annual thematic focus. Students learned the underlying science and research methods that supported a broad understanding of the annual theme, as well as specific content and process skills students needed to successfully engage in the challenge.

The primary goal for our program, and central to our CIOSS partnership, is increasing the diversity of students who participate in science and mathematics and whose interest and career aspirations are enhanced. The program data demonstrates that we reach these students and that they persist in the clubs (62% three or more years), take math and science course in each year in high school (100%) and go on to college (85%). The enrollment for 2010-11 was 235 students:
<table>
<thead>
<tr>
<th>Female</th>
<th>Male</th>
<th>Latino</th>
<th>Native Am</th>
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<th>2nd year</th>
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So far, the 2011-12 high school club membership is 199 students: 77% from underrepresented groups, 62% are female. We are still collecting this year's applications.

**High School Ocean Science Challenge 2011: Ocean Conditions and Habitat--Understanding Where Our Seafood Comes From and Defining a Sustainable Fishery.**

Each year we pick a theme that supports student's learning about the science and research that helps us understand an issue. Then students apply their understanding to a problem or challenge.

The theme this year encompassed:
- How do satellites help us see ocean habitat as the product of variable conditions?
- How can we use remote sensing data to understand and locate fish habitat?
- How do we measure the productivity of an area in the ocean and how does this help us understand the health and sustainability of a fishery in that area?
- What can ocean satellite data and models tell us about plankton blooms?
- What is a sustainable fishery, and what factors affect its sustainability?
- What factors contribute to unhealthy seafood (toxin bioaccumulation in the food web, etc.)?

The HSC was built on the idea that markets track where their seafood comes from in order to help their consumers make informed choices about their seafood consumption, particularly as it relates to sustainability. In the 2010/2011 challenge, students used remote sensing data to determine the location and habitat characteristics (temperature, primary productivity, etc.) that support various fisheries. Using this information, as well as data about the sustainability of fishing stocks, the teams decided which fish to sell in their fish markets, and developed a plan to inform consumers: the source of the seafood, if it was sustainable a fishery as caught, and if consumption had health benefits. Key scientists who were involved in developing the challenge included: Ted Strub (CIOSS), Bill Peterson (NOAA), Dave Foley (NOAA), Grant Law (CMOP), and Sarah Mikulak (NANOOS). A full list of science faculty and graduate students who helped with this year’s challenge can be seen at the end of this report. Over 30 faculty and students from across OSU participated in the design and delivery of our events and workshops.
Planning for the 2011/2012 High School Challenge: Oceans, Climate, and Human Health

Increasingly, we are trying to understand the interactions between ocean conditions and human health, particularly as we see what affect climate change may have on these interactions. An increasing number of agencies and stakeholders are asking for this information in order to make predictions that may minimize negative impacts on human health. Keeping the general public informed about these issues can be challenging, as there are a variety of media outlets, not all of which present balanced and accurate information. Students in this year’s challenge will explore how this science gets communicated through various media outlets.

The theme this next year will encompass:

- Ocean & climate modeling and prediction; how do these work?
- What variables do we need to understand in order to make predictions about events that may impact human health?
- How is climate change expected to impact ocean conditions?
- How do we use remote sensing to predict and track algal blooms?
- What events may arise over the next 50 years, due to changing ocean and atmospheric conditions, that impact human health? What and how do we know about these changing conditions?

Project Timeline during Reporting Period

<table>
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<tr>
<th>Project Activity</th>
<th>Date</th>
<th>Outcomes</th>
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<tr>
<td>Winter Teacher's Workshop</td>
<td>January 2011</td>
<td>Building on the Summer TW, teachers focused on the content and skills students needed for the HSC. Teachers received packaged instructional materials to support club implementation. Teachers increased their ocean science knowledge.</td>
</tr>
<tr>
<td>Afterschool SMILE Clubs</td>
<td>January–June 2011</td>
<td>Students increased their knowledge of ocean sciences, and made connections to ocean and other STEM careers.</td>
</tr>
<tr>
<td>High School Ocean Sciences Challenge</td>
<td>April 2011</td>
<td>Students learned about large-scale factors that define ocean habitat and influence the health and sustainability of fisheries. Students developed marketing plans to inform consumers about their seafood.</td>
</tr>
<tr>
<td>Spring Teachers Workshop</td>
<td>May 2011</td>
<td>Teachers engaged as lifelong learners in engagement pedagogy. Project personnel and SMILE teachers evaluated the year and discussed plans for the partnership.</td>
</tr>
<tr>
<td>Summer Teachers Workshop</td>
<td>August 2011</td>
<td>Teachers increased their ocean science knowledge and engaged in activities to implement in clubs. Teachers received packaged instructional materials to support club implementation.</td>
</tr>
<tr>
<td>Afterschool SMILE Clubs</td>
<td>September-December 2011</td>
<td>Students increased their knowledge of ocean sciences, and made connections to ocean and other STEM careers.</td>
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</tbody>
</table>

Program Evaluation

Club End of the Year Assessments: SMILE uses end-of-year surveys from students, parents and teachers to collect data on the impact of the project-centered club activities and the on-campus challenge event on the students’ interest, knowledge and aspirations.
2011 HSC: The student event evaluations responses revealed the following:
- 75% reported that their club activities prepared them for the challenge;
- 74% reported an increase their understanding of the use of science in making choices;
- 66% reported a better sense of careers that require math and science and support for their specific career interest;
- 75% noted graduate students and professionals supported their career goals; and
- 62% reported the challenge encouraged them to get more involved in the future.

Additionally sixteen high teacher/ SMILE club advisors completed an evaluation
- 71% rated the HSC as good to excellent

2011 Winter, May and Summer TW’s: Teachers completed workshop evaluations in January, May, and August responded specifically to the quality of the session’s presentation(s) and provided additional comments on the usefulness of the activities and materials provided, as well the influence on teachers’ classroom practice.

Club Membership and Demographics
Enrollment and persistence in the clubs and school are key measures of the club's success and program's reach to students from the groups our program is designed to serve. This suggests that we have designed clubs and supported activities that students enjoy, that support their interests in content areas, school, and supports their and aspirations to college in STEM related fields.

Conclusion—The CIOSS-SMILE partnership accomplished its stated objectives by defining, designing and delivery high quality programming to support rural teachers and students and in working collaboratively to offer meaningful and high impact science education and outreach as part of a scientific research endeavor. Through SMILE, CIOSS continued to reach significant numbers of underrepresented students who demonstrate an interest in science and mathematics and related careers and rural classroom teachers of science and mathematics.
Science faculty, graduate students, extension agents, and community members involved in programming in 2011.

<table>
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<th>Teacher Workshop January 2010/2011</th>
<th>Affiliation</th>
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<tr>
<td>NANOOS</td>
<td>Amy Sprenger</td>
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<td>CIOSS &amp; MRM</td>
<td>Amy Vandehey</td>
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<td>NOAA</td>
<td>Bill Peterson</td>
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<td>Dave Foley</td>
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<td>Karl Clarke</td>
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<td>COAS</td>
<td>Morgaine McKibben</td>
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<tr>
<td>NANOOS</td>
<td>Sarah Mikulak</td>
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<tr>
<td>CIOSS</td>
<td>Ted Strub</td>
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<tr>
<td>CMOP</td>
<td>Grant Law</td>
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<td>SMED</td>
<td>Laura Dover</td>
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<th>Teacher Workshop January 2011/2012</th>
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<tr>
<td>COSIA/Sea Grant intern</td>
<td>Amy Dando</td>
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<tr>
<td>MRM</td>
<td>Katie Woollven</td>
<td></td>
</tr>
<tr>
<td>COAS/Oregon Climate Change Research Institute</td>
<td>Meghan Flink</td>
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</table>
PROJECT 17

Title: CIOSS Support to the NESDIS Cooperative Research Symposium and Exchange Program

Principal Investigator: P. Ted Strub

NOAA Technical Contact and Collaborator: Ingrid Guch, NESDIS/STAR/CoRP

CIOSS Research Theme:
Theme 5 – Outreach

Related NOAA Goal from the NOAA Strategic Plan:
Goal 5 – Supporting NOAA’s Mission

Project Description

The Annual NESDIS CoRP Symposium was held August 16-17, 2011 at CICS-NC in Asheville, North Carolina. The theme this year was “Using satellite observations and models to understand and communicate information on climate variability and change.” More information can be found on the Symposium website: http://www.cicsnc.org/corp/.

Presentation and poster titles for those given by CIOSS researchers are given below.

- Dudley Chelton – Satellite Observations and Numerical Model Simulations of the Influence of Sea-Surface Temperature on Surface Winds (presentation)
- Alexander Kurapov – Coastal-Interior Ocean Flux Estimates From a High-Resolution Data Assimilative Model (presentation)
- Meredith Payne – Ecoregional analysis of nearshore sea-surface temperature in the North Pacific (presentation – won best oral presentation award)

Student and Post-doc Exchange Program:

No one participated in the NESDIS Student Exchange Program this summer. Instead more CIOSS researchers were sponsored to attend the NESDIS CoRP Symposium.
PROJECT 18

Title: Coastal Altimetry Meetings Travel Funds

Principal Investigator: P. Ted Strub

NOAA Technical Contact and Collaborator: Laury Miller, NESDIS/STAR

CIOSS Research Theme:
Theme 5 – Outreach

Related NOAA Goal from the NOAA Strategic Plan:
Goal 5 – Supporting NOAA’s Mission

Project Description

With funding provided by Laury Miller in NESDIS’ Laboratory for Satellite Altimetry, CIOSS sponsored a group of attendees to two altimetry meetings that were held back-to-back in San Diego CA. Most of those supported were graduate students or other early career scientists; the purpose of the support was to encourage young scientists to become familiar with and use altimetric data in their work. The Fifth Coastal Altimetry Workshop (CAW-5, http://www.coastalaltimetry.org) was held in San Diego during October 16-18, 2011. This was followed by the international Ocean Surface Topography Science Team during October 19-21, 2011 at the same venue.

Those sponsored by CIOSS [with their guiding professor(s) in parentheses if applicable] are:

- Ioannis Androulidakis, RSMAS, Miami (V. Kourafalou)
- Subra Bulusu, Univ. S. Carolina
- Peter Gauke, Oregon State University (D. Chelton)
- Villy Kourafalou, RSMAS, Miami
- Matthieu Le Henaff, RSMAS, Miami (V. Kourafalou)
- Piero Mazzini, Oregon State University (J. Barth)
- Matthew Nienhaus, Univ. S. Carolina (S. Bulusu)
- Steven Kuo-Hsin Tseng, Ohio State Univ. (C. K. Shum)
- Roberto Venegas, Oregon State University
- Jenny Van Wakeman, Oregon State University (R. Matano, P.T. Strub)

Posters and presentations from the CAW-5 workshop can be found at http://www.coastalt.eu/sandiegoworkshop11.
III. APPENDICES

A. List of Awards Given to CIOSS Personnel

Mark Abbott – received the 2011 Jim Gray eScience Award, presented by Microsoft Research.

Meredith Payne – First place oral presentation winner at the 2011 CoRP Science Symposium.

B. Tables Showing Levels of NOAA Support

The following tables provide information on all research and administrative personnel associated with CIOSS. All of these people are formally employed by the State of Oregon/Oregon State University, and are supervised and evaluated according to State and University rules and procedures. While the CEOAS Dean thus has ultimate appointment and management responsibility, supervisory authority and substantive inputs regarding performance are delegated as follows:

1) CIOSS Administrative Specialist:
   Receives 1 FTE of salary from NOAA/CIOSS funding.
   Supervised directly by, and primary annual evaluation input delegated from the CEOAS Dean to, the CIOSS Director.
   Evaluation based solely on performance of CIOSS tasks.

2) CIOSS Post-Doctoral Assistants:
   Receive 50-100% FTE of salary from NOAA/CIOSS funding.
   Perform 50-100% of their research on CIOSS projects (commensurate with their NOAA/CIOSS FTE support)
   Supervised directly and primary annual evaluation input delegated from the CEOAS Dean to the specific faculty mentor of each Post-Doc.
   Evaluation based on performance of all research tasks, including but not limited to performance/contributions on CIOSS projects, commensurate with NOAA/CIOSS FTE support.

3) Faculty Research Assistants and Research Associates:
   Receive fractional FTE of salary from NOAA/CIOSS funding.
   Support some level of research for CIOSS projects (commensurate with their NOAA/CIOSS FTE support)
   Supervised directly and primary annual evaluation input delegated from the CEOAS Dean to the specific faculty PI of each Research Assistant/Associate.
   Evaluation based on performance of all assigned tasks, including but not limited to performance/contributions on CIOSS projects commensurate with NOAA/CIOSS FTE support.

4) Tenure-track and Research Faculty:
   Receive fractional FTE of salary from NOAA/CIOSS funding (typically less than 25% FTE).
   Conduct/lead research for CIOSS projects (commensurate with their NOAA/CIOSS FTE support)
   Supervised and primary annual evaluation by the CEOAS Dean, who may request input from the
CIOSS Director regarding faculty contributions to CIOSS research projects. Evaluation based on all research, teaching, and service activities, including but not limited to performance/contributions on CIOSS projects, commensurate with NOAA/CIOSS FTE support.

### Personnel - ≥50% NOAA Funding

<table>
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<tr>
<th>Category</th>
<th>Number</th>
<th>B.S.</th>
<th>M.S.</th>
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### Personnel - <50% NOAA Funding

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<td>Postdocs and Students supported on Subcontracts</td>
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Located at NOAA Facility (include name of facility) | 0      | 0    | 0    | 0     |
Obtained NOAA Employment within the last year       | 0      | 0    | 0    | 0     |
C. Tables of Publications by CIOSS, NOAA and Other Lead Authors

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D. List of Publications 2011 (CIOSS Fellows and associates in bold)

Peer Reviewed Publications by CIOSS Fellows and others associated with CIOSS


Books:


Non-Peer Reviewed Publications, Presentations and Outreach Activities by CIOSS Fellows and others associated with CIOSS (2011)

Published Proceedings:


Presentations and Outreach: (not included in tables of publications)

Hal Batchelder

Presentations at Science Conferences
Batchelder, H. P., and B. J. Lindsey. Comparison of IBM and concentration based approaches to modeling krill growth and population dynamics. 5th International Zooplankton Production Symposium, “Population Connections, Community Dynamics, and Climate Variability”. Pucon, Chile, 14-18 March 2011.


Workshops Chaired/Organized
Workshop on Zooplankton Individual Based Models. Pucon, Chile, 14 March 2011. (Co-convenor with Dougie Spiers (United Kingdom)).

Convenor and Local Host, Scoping Workshop on Semantics for Sustainability in the California Current Large Marine Ecosystem, Corvallis, OR, 8-9 September 2011.


Lead Convenor, PICES BIO Workshop on “MEMIP-IV: Quantitative comparison of ecosystem models applied to North Pacific shelf ecosystems—humble pie or glee? Khabarovsk, Russia, 14-15 October 2011 (Co-convened with Shin-ichi Ito (Japan), Angelica Peña (Canada) and Yvette Spitz (USA)).
**Participation in Regional, National and International Meetings**


**Curt Davis**

**Presentations**


**Alexander Kurapov**

**Presentations acknowledging NOAA support -**

COAS Physical Oceanography Seminar, February 2011

ROMS Users’ workshop, Hawaii, April 2011

2011 Assembly of the European Geophysical Ocean, Vienna, Austria, April 2011

GODAE-OceanView GSOP-CLIVAR Workshop, Santa Cruz, June 2011

Gordon Research Conference on Coastal Ocean Modeling, MA, June 2011

Presentation at the Satellite Operational Facility (SOF), MeteoFrance, Lannion, Brittany, France, July 2011

Presentation at NOAA-STAR, Camp Springs, MD, August 2011

NOAA/NESDIS Cooperative Research Program (CoRP) 8th Annual Science Symposium, August, 2011

(Invited speaker) PICES 2011 Annual Meeting “Mechanisms of Marine Ecosystem Reorganization in the North Pacific Ocean”, October 2011

ONR conference, Denver, November 2011
Craig Risien

Presentations


Yvette Spitz

Participation in regional, national and international meetings
Spitz, Y.H., Hypoxic Condition Prediction in Upwelling Systems, June 26 - July 1, 2011, Mount Holyoke College, South Hadley, MA.


Ted Strub

Outreach Activities
SMILE: Participated in planning for the 2011 SMILE High School Challenge, which took place in April, 2011. Participated in planning for the 2012 SMILE High School Challenge.

Jet Propulsion Laboratory Physical Oceanography Distributed Active Archive Center (PO.DAAC) Users’ Working Group: Participated in the on-site review (in March) and teleconference calls. Also helped to transition altimeter and scatterometer products to JPL.

OSU Marine Council: Lead on the Action Coordination Team for Coastal Disaster and Development.

Fifth Coastal Altimetry Workshop, San Diego, CA, October 2011. Member of the Organizing Committee.
Nick Tufillaro
Presentations
Talk presented at Alex Kurapov’s group seminar at Oregon State University, 11 November 2011. “The shape of ocean color,” Corvallis, OR.


Talk presented at Ricardo Letelier’s group seminar at Oregon State University, 15 June 2011. “Using optical flow to analyze ocean flow,” Corvallis, OR.

Attended SIAM conference on Applications of Dynamical Systems, 22-26 May 2011, Snowbird, UT.


Talk presented at Alex Kurapov’s group seminar at Oregon State University, 29 April 2011. “Current and new uses of ocean color remote sensing at OSU,” Corvallis, OR.

Public seminar on ‘Ocean Color’ as part of Southern Oregon University’s Free Friday Seminars, 22 April 2011 (Earth Day), Ashland, Oregon.


Talk presented at Oregon State University, 2 March 2011, Corvallis, OR. Sensing of coastal waters from the international space station and satellites.

Talk presented at AERONET-Ocean Color Workshop, 23-24 February 2011, Greenbelt, Maryland. The southern California SeaPRISM site.
Angelique White

Outreach

Saturday Academy Mentor (2011, A. White).


Press for marine plastics research (http://tinyurl.com/2byu667) covered by Earthsky.org, Coast to Coast AM, the Oregonian, Maclean’s magazine (Canada), San Jose Mercury News, thebenshi.com, Willamette Week (newspaper, Portland, Oregon), KVAL (television interview with CBS affiliate), Discovery news, Oregon Business magazine, Hawaii Public Radio, Oregon Public Radio and numerous other blogs, print, web and radio that picked up this press release (2011).


First ‘peek’ view of west coast ocean color from VIIRS: 8 December 2011, 21:10 GMT. (a) Northern Oregon Coast, (b) Southern Oregon Coast, (c) Northern California, (d) Expanded view of Bay Area, CA, (e) Southern CA, Los Angeles Harbor. (Figure from Curt Davis, CIOSS PROJECT 6).

The new 3-meter satellite dish from Orbital Systems in operation at Oregon State University, Corvallis, OR. (Figure from Ricardo Letelier, CIOSS PROJECT 10).

Near real time
Cloud Free West Coast Golden Regions
(HOT, Oregon, PNB, Monterey, Platform Eureka)

Delayed

Cruises
HOT
Newport
Opportunity
Glders
OSU (Oregon)
USC (LA)
SeaBASS
PNB, Monterey

Processing flow at OSU for data match ups. (Figure from Curt Davis, CIOSS PROJECT 6).