CIOSS
Cooperative Institute for Oceanographic Satellite Studies

Studying the Ocean from Space
What CIOSS Does

CIOSS is a partnership between Oregon State University and the National Oceanic and Atmospheric Administration (NOAA), designed to help the NOAA/NESDIS (National Environmental Satellite, Data and Information Service) fulfill its mission goals by improving satellite products for the ocean, atmosphere and air–sea interface.

CIOSS has a special focus on the coastal ocean, along with an interest in global climate data records. Basic research uses combinations of satellite fields, in situ data, and ocean and atmosphere models to increase our understanding of the physical and bio-optical processes in the ocean and atmosphere. CIOSS analyses also aid the design of future satellite sensors.

CIOSS projects within the context of the U.S. Integrated Ocean Observing System (IOOS) are improving NESDIS’s ability to fulfill its role as the lead agency for remote sensing. CIOSS Fellows are also active in the IOOS components for direct ocean observations and nowcast/forecast models of the coastal ocean.

After its successful external review during its fourth year, CIOSS was renewed for a second 5–year period, extending from 2008–2013.

Most of the academic Fellows are housed in the College of Oceanic and Atmospheric Sciences at Oregon State University. The college is also one of the partners in the recently reformed (2009) Cooperative Institute for Climate and Satellites, with its primary node at the University of Maryland, providing another context for climate studies.

CIOSS projects address five themes:

- Satellite Sensors and Techniques
- Ocean–Atmosphere Fields and Fluxes
- Models and Data Assimilation
- Ocean–Atmosphere Analyses
- Outreach
Highlights

CIOSS Fellow Curtiss Davis* is a project scientists on the Hyperspectral Imager for the Coastal Ocean (HICO). HICO is an advanced space-borne sensor created specifically for observing the coastal ocean.

CIOSS Fellows Curtiss Davis and Ricardo Letelier work on the VIIRS Ocean Environmental Data Records calibration and validation plan, for color products for the coastal and open ocean.

Science workshop topics include ocean color, ocean surface vector winds, modeling and assimilation of satellite data in coastal oceans, and coastal altimetry. Outreach includes the SMILE high school program and support for REU students.

A project led by CIOSS Fellow Dudley Chelton investigates the wind response to sea surface temperature from the surface to the top of the troposphere.

CIOSS researchers Angelique White and Morgaine McKibben are evaluating CoastWatch bloom products that track chlorophyll to improve prediction and in-situ monitoring of HABs and then to transfer that knowledge to Oregon state agencies.

A NOAA-supported computer model of ocean conditions is run by Alexander Kurapov to help West Coast sport fishermen conserve fuel by finding shorter routes to tuna locations.

CIOSS research helps prepare for future ocean-color sensors will include those on ACE (Aerosol Cloud Ecosystems), HyspIRI, Sentinel-3 (European, MERIS design), and others.

CIOSS products are being transitioned to the web, such as near-coast gridded QuickSCAT wind fields with enhanced coastal coverage for the U.S. West Coast, developed by Michael Freilich and Barry Vanhoff.

CIOSS Fellow Dudley Chelton and NOAA scientist Richard Reynolds are working to identify the regions where high-resolution SST analysis is trustworthy.

The Salmon Stock Assessment Report uses CIOSS research to promote sustainable fisheries. To understand past collapses and forecast future salmon stocks, NOAA biologists such as Bill Peterson are using CIOSS products to look back at ocean currents close to shore in earlier years.

*Throughout this document, the names of CIOSS Fellows are bolded.
Hyperspectral Imager for the Coastal Ocean

A sophisticated new imaging system developed by the Naval Research Laboratory has been installed aboard the International Space Station, where it scans selected regions of coastal oceans and nearby land masses.

The Hyperspectral Imager for the Coastal Ocean, or HICO, is the first space-borne sensor created specifically for observing the coastal ocean in the last 30 years. It allows scientists to better analyze human impacts and climate change effects on the world's coastal regions. The applications include oil spills, plankton growth, harmful algal blooms, and sediment plumes from major rivers.

The HICO science data is archived at Oregon State University, the repository for distribution to researchers in the United States and internationally through the website http://hico.coas.oregonstate.edu.

"The timing couldn’t be better," said Curtiss Davis, project scientist. "The development of different Earth observation systems, for whatever reason, has stalled. All of the current NASA ocean color sensors are beyond the end of their planned lifetimes. At a time when observation and analysis of the world’s oceans is critical to monitor climate change, we were losing our ability to do so."

What the HICO system will do, Davis said, is provide much higher-resolution imaging and a full spectrum of color. Previous imaging systems had a resolution of about one km and about nine spectral channels. HICO’s scale is at 90 m and it has 90 spectral channels, which is “a tremendous leap forward in resolution,” he pointed out.

With HICO images, Davis explained, “We can separate phytoplankton blooms from sediment plumes from rivers, and better measure chlorophyll levels in the ocean, which are associated with phytoplankton production.”

Using the International Space Station for such observation is new. Its orbit is not “sun-synchronous” and thus the station platform offers a wide range of illumination angles and sampling times not available via satellite observation.

“HICO can look in detail at selected sites and its strength is to monitor specific areas facing environmental pressures, such as the Florida Keys, the plume from the Mississippi River that creates a hypoxic zone in the Gulf of Mexico, or the harmful algal blooms off our own Pacific coast,” Davis said.
Future Ocean Color Sensors

The extended SeaWiFS mission has ended and the two present operational NASA systems for optical remote sensing, MODIS Terra and Aqua, are both beyond their planned lifetimes. NASA and NOAA are working to fly several new systems with differing needs, from near real-time operational uses to long-term, consistently calibrated climate data records.

Visible/Infrared Radiometer

The Visible/Infrared Imager Radiometer Suite (VIIRS) is planned to be the next operational sensor for ocean color, sea surface temperature, land and atmospheric products for NOAA and NASA.

However there are concerns that the ocean color requirements for radiometric accuracy and precision that have been established over the past decades may not be met by this new sensor. To help assure the best quality data, Curtiss Davis and Ricardo Letelier are working as part of the VIIRS Ocean Calibration and Validation team.

The first VIIRS sensor is due to be launched in early 2012 on the NPP satellite. Davis and Letelier will be matching the VIIRS products with in situ validation data in real time to assess the quality of satellite data. Improvements in algorithms will produce the best possible quality data from this sensor.

Lessons learned from working with this first VIIRS instrument will then be applied to improve the data and products from future VIIRS instruments scheduled to be launched in 2014 and beyond.

Other Future Sensors

Looking further into the future, Davis works on ocean color instrument design and specifications with NASA, NOAA, the U.S. Navy, and the international community. Sensors he is evaluating include the following.

ACE: Aerosol Cloud Ecosystems mission includes an ocean color sensor. Davis describes it as, “Very much like an advanced replacement for SeaWiFS—a dedicated ocean instrument with more channels, high signal to noise ratio, very stable.”

HyspIRI is a hyperspectral imager similar to HICO, only with higher resolution for land imaging and the coastal ocean on a dedicated satellite and designed for long-term operation.

According to Davis, “The spatial resolution might be 40 m. Bottom features of the coastal ocean are like land features where you need this high resolution to resolve them so it could be very useful for coral reefs and other shallow environments.”

GEO-CAPE is a new satellite in the planning stage that would be the first U.S. satellite to make ocean color measurements for coastal waters from a geostationary orbit.

Davis notes, “This is the ocean equivalent of the geostationary weather satellites that provide the weather data we see each night on the news. You need the ability to stay over one coastal area and do rapid imaging to see features that might move 10–30 km in a day in the strong coastal currents. In the coastal region, there are large phytoplankton bloom events, storm runoff events, hurricanes, and so on. The spatial resolution will probably be 300–400 m and provide an exciting new view of the coastal ocean.”

Earth Surface Images from HICO. Images are subsets of HICO images that are 43 km wide by 190 km long. Images below, from left: (1) Florida Keys near Key Largo, Sept 27, 2009. Orientation is from SW at bottom to NE at top. (2) Complex river plume features just west of the mouth of the Mississippi River, LA, Dec 9, 2010. Orientation is from SE at bottom to NW at top. (3) OSU product highlighting the Columbia River Plume off Oregon, July 13, 2010. Orientation is from SW at the bottom to NE at the top.
Transition of CIOSS Results to Web

The standard 25 km QuikSCAT ocean vector wind product includes an arbitrarily imposed 30 km land mask. This is a region where there are strong gradients in the wind field that are dynamically important for ocean circulation. Michael Freilich and Barry Vanhoff 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), 10-year (01 August 1999 to 31 July 2009) data set was created that includes the new geometry-dependent land mask. This data set spans the California Current System 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.

Ted Strub and Craig Risien compared the CIOSS u and v wind fields with a 3-month, 0.125 latitude x 0.125 longitude, science-quality data set provided by Dave Foley (NOAA CoastWatch, http://coastwatch.noaa.gov/). In addition, CIOSS worked with David Moroni to transition these data products to the NASA data archive centers at http://podaac.jpl.nasa.gov/.

Near-Coast Gridded QuikSCAT Fields, with Enhanced Coastal Coverage: US West Coast

Daily composites of QuikSCAT wind speed and direction for three ocean vector wind products for 26 April 2009. Left: Jet Propulsion Lab’s 0.25° data set. Middle: JPL 12.5 km data set gridded to a 0.10° grid. Right: 0.10° CIOSS near-coast gridded wind product. Clearly visible in the JPL 0.25° (0.10°) fields is the 30 km land mask. In contrast, the geometry dependent land mask used in the CIOSS 0.10° dataset allows for wind retrievals within 5–10 km of the Santa Catalina and San Clemente Islands.

Harmful Algal Blooms (HABs)

Phytoplankton blooms are a normal ocean process, critical to maintaining the marine food web. But certain species of phytoplankton have the ability to produce toxins that can be harmful to humans.

Angelicque White and graduate student Morgaine McKibben are evaluating CoastWatch satellite bloom products that track chlorophyll along the U.S. West Coast in 8-day periods, in a NOAA-funded project. The project will build up Oregon HAB-monitoring by improving prediction of blooms, developing an efficient process for in situ monitoring of suspected toxic blooms, and then transferring that knowledge to state agencies. Early work in this project will:

• Evaluate the current satellite bloom product for accuracy by comparing it to in situ fluorescence data from a mooring off the central Oregon coast.
• Vary the bloom product algorithm to determine if shorter or longer windows for present and previous conditions would better identify blooms observed in situ.
• Extend the analysis to other regions of the Oregon coast using data collected on cruises from 2006 to present.

To be able to predict HABs, McKibben is building a statistical model that constrains the environmental predictors of toxin production on Oregon beaches. To build this multiyear database, McKibben is including data from other OSU researchers such as nutrients, sea-surface temperature, current speed/direction, and wind vectors). The researchers are conducting extensive phytoplankton sampling on the research vessel Elakha and will compare that data with
How CoastWatch Uses CIOSS Science to Protect Fish

CoastWatch provides real-time satellite data to state, federal, municipal researchers; more recently it has evolved to also serve data for primary/secondary education and the public. Six CoastWatch nodes (Alaska, California, Hawaii, Great Lakes, Chesapeake Bay, Florida) develop products specific to those regions.

The West Coast node is located in Pacific Grove, CA, at the Environmental Research Division. Its primary concern is to promote sustainable or protected fisheries; it also supports response to hazards such as oil spills and harmful algal blooms.

CoastWatch Coordinator, Dave Foley, described the role that CIOSS plays as providing the scientific support behind the data products. “We can serve products, however we can’t convince managers to engage without scientific support behind products. CIOSS researchers leverage their expertise to help develop products and publish science results in peer-reviewed journals so that they are recognized as valid. They have our back, scientifically.”

An example of using CIOSS research to promote sustainable fisheries is that of the Salmon Stock Assessment Report. In 2007 and 2008, there was a catastrophic collapse of the salmon fishery. To understand what happened and to be able to forecast future salmon stocks, biologists need to look back at ocean currents close to shore in earlier years.

Young salmon, or smolts, emerge from streams or rivers into the open ocean, where they remain until they are sexually mature and return to their natal streams. There is a strong correlation between the direction of currents next to the coast when the smolts emerge and the five-year return rate of those same salmon.

NOAA has some buoys near shore that can measure current. However the number of buoys is limited. Earlier satellite products of coastal altimetry had a wide landmask close to shore and the algorithms previously in use could not give accurate answers about nearshore currents.

Based on CIOSS research, the nearshore altimeter sea surface height (SSH) fields have been improved by interpolating between offshore SSH data from altimeters and coastal SSH data from tide gauges. This allows a clearer picture of nearshore currents and gives NOAA an additional tool to extend its existing buoy readings to all other West Coast regions.

This expanded scientific knowledge eventually impacts management decisions. In California, the Pacific Fishery Management Council governs the salmon fishery, an industry of $50–60 million in the past, for commercial and recreational users, in the ocean and in the rivers.

The science behind these West Coast products is also shared with other regions in the nation, so they can modify the concepts and methods to their own regional uses.

Above: Chinook salmon smolts. (Courtesy of the Bonneville Power Administration, U.S. Department of Energy)
Coastal and Marine Spatial Planning

A network of Marine Protected Areas (MPA) or Marine Reserves (MR) is being developed for Oregon’s territorial seas. A hoped-for benefit is to replenish depleted West Coast fish stocks and provide for sustained economies of coastal communities. The network concept of connectivity among MPAs is being assessed using pelagic trajectories derived from high-resolution physical models and particle-tracking models.

From particle trajectories in the simulated flow fields, Harold Batchelder has been able to characterize the spatial and temporal variability in local residence time and identify regions that function as potential sources or sinks at weekly time scales. He examined potential seasonal connectivity among six existing or proposed MPA/MR sites along the Oregon coast. Connectivity is a function of the duration of the pelagic phase of individual species.

This analysis focused on pelagic durations extending to 1–2 weeks. Batchelder quantified the fraction of the released particles that transited through each MR site within seven days of release and the mean duration (in hours) that a particle remained in that site.

Reserve size and spacing in this analysis varied greatly (see map). Cape Blanco is a significant barrier to dispersal from northern reserves to southern reserves in the summer, but is less of a barrier to dispersal from southern to northern reserves in winter. This is because alongshore connectivity among reserves is greater during winter than summer because the downwelling favorable winds of winter maintain propagules near the coast, while summer upwelling moves propagules offshore.

Larger reserves are more likely to be connected to other regions because of their size than are smaller reserves.

Map on right: Existing and proposed Oregon territorial seas Marine Protected Areas and Marine Reserves (MRs) used in the model analysis. The color contoured region is the geographic extent of the Regional California Current System (RCCS) model off Oregon. The MRs from north to south are Cape Falcon, Cascade Head, Otter Rock, Cape Perpetua, Cape Arago, Redfish Rocks Inner, and Redfish Rocks Outer. The latter two are adjacent to one another south of Cape Blanco. The circulation model extends north only to about Tillimook Bay. The proposed MR at Cape Falcon (northernmost polygon) is north of the northern edge of the RCCS physical model. (RCCS model courtesy of Dr. Enrique Curchitser, Rutgers University.)

Oregon Coastal Ocean Simulator

Recent low bottom oxygen conditions (hypoxia) on the Oregon shelf during late summer have caused massive die-offs of near-bottom dwelling fish and invertebrate populations, especially in 2006, when low oxygen hypoxia was widespread and prolonged over much of the OR–WA shelf. Yvette Spitz and Hal Batchelder use a coupled ecosystem–circulation–oxygen model to hindcast the physical and biological processes that might have led to the low oxygen conditions. They hypothesize that the development of hypoxia is due to the combination of several factors: (1) the offshore presence of low dissolved oxygen (DO) source waters, which are advected onto the shelf during upwelling, (2) higher primary production over the shelf and sinking of organic material to the seafloor, and (3) long residence times before deeper water gets replenished by new, higher DO waters. They focus on the impact of offshore and north–south fluxes of nutrients and oxygen onto the shelf ecosystem.

In 2002, oxygen concentrations at the offshore Newport Line station were significantly lower than climatological values obtained from observations made between 1997–2004. As seen in the accompanying figure, the initial spring conditions have a significant impact on the summer 2002 bottom oxygen concentration. Hypoxia occurs much earlier and is more widespread using observed April 2002 DO than using climatological April conditions. Other simulations show that the influence of nitrate and oxygen conditions at the northern boundary (Washington shelf) on DO and hypoxia off Oregon can be large in some years.

Modeled percent of the shelf area (top panel) and number of days (bottom panels) with hypoxic bottom water (DO <1.4 ml/l) in 2002 for different initial April conditions.
Temperature Forecast Helps Tuna Fisheries

A NOAA–supported computer model using ocean temperatures developed at Oregon State University, is helping West Coast sport fishermen predict the best route to take to reach tuna habitat.

Tuna prefer warmer ocean waters above 59 degrees Fahrenheit. As ocean waters swirl and mix, the precise area where water temperatures are optimum for tuna may change on a daily basis. NOAA–supported OSU scientists, led by Alexander Kurapov, have developed 24-hour and 48-hour predictions of ocean temperatures derived from their computer model. The forecast is available online and tailored for tuna fishers by Craig Risien, a physical oceanographer from OSU.

“The word has spread among the sport fishing fleet and this web site has become quite popular. We use this site to decide how far to go to fish for tuna, where to go, or whether to go at all. It is invaluable, especially in light of the cost of fuel,” says Ron Seip, owner of the fishing vessel Sweet Witch of Coos Bay, Ore.

The forecast model starts with a five-day record of winds over the Oregon coast derived from a weather forecast model. Each day, the model takes this record and combines it with previous estimates of ocean conditions from two days before, and runs them through a series of mathematical equations. The result is a “nowcast” of present conditions and forecasts each day. Estimates of currents, temperature, salinity, sea surface height and other information are produced.

“Ecological forecasts become increasingly important as our ocean changes. This forecast is an example of NOAA’s Integrated Ocean Observing System (IOOS) and the academic research community working together to create useful models and make them operational,” says John H. Dunnigan, NOAA’s assistant administrator for the National Ocean Service.

OSU supported the transition of the model from research to quasi-operational status through CIOSS. It is funded through NOAA’s Global Ocean Ecosystem Dynamics program and the Northwest Association of Networked Ocean Observing Systems through IOOS. IOOS is a tool delivering the data and information needed to increase understanding of our coastal waters so decision makers can take action to improve safety, enhance our economy, and protect our environment.
Ocean–Atmosphere Analysis

Gulf Stream Influence on Overlying Wind Field

The influence of the warm waters of the Gulf Stream on the winds in the atmospheric boundary layer (the lowest 1 to 1.5 km of the atmosphere) has been recognized for several decades. A recent study suggested that the influence of this ocean–atmosphere interaction might extend throughout the entire troposphere that reaches to a height of about 12 km. This would have important implications for weather forecasting and climate modeling.

A project led by Dudley Chelton investigates the wind response to sea surface temperature (SST) from the surface to the top of the troposphere from satellite observations and compares the results with the wind fields from weather forecast models.

Chelton notes, “In combination with models and other observations, we’re trying to figure out how the influence of SST penetrates deep into the troposphere and affects weather patterns. Over the Gulf Stream, it is clear that SST does influence winds, probably more so than anywhere else in the world ocean. This is a very important place, because many storms form in the region, possibly because of this ocean–atmosphere interaction.”

Satellite measurements of ocean surface winds by the QuikSCAT scatterometer are combined with tropospheric winds inferred from atmospheric temperature profiles measured by the Advanced Microwave Sounder Unit. These measurements document wind response to SST over the Gulf Stream at various atmospheric pressure levels from the surface to the top of the troposphere.

As the first step in this study, attention is focused on the period of February 2007, during which winds blew strongly off the North American continent and approximately perpendicularly across the Gulf Stream (see figure on page 2).

The preliminary analysis provides strong observational evidence that the SST front associated with the Gulf Stream may indeed exert a strong influence on winds throughout the troposphere. As shown in the figure, vertical velocity has high vertical coherence, sometimes extending all the way from the surface to the top of the troposphere at about 200 mbar (12 km). This vertical velocity communicates the SST influence high into the atmosphere.

This observed SST influence on atmospheric winds is grossly underestimated in weather forecast models and, by inference, in coupled climate models. Improving the accuracies of tropospheric winds in the models may therefore lead to improved weather forecasts and more accurate climate predictions.

The average vertical velocity during February 2007 estimated from the AMSU (Advanced Microwave Sounder Unit) data.

The vertical velocity in atmospheric pressure coordinates of mbar/sec is shown in map form at atmospheric pressure levels of 900 and 400 mbar (about 1 and 7 km, respectively).

The bottom panel is a vertical section along the diagonal line shown in the two maps.

Red/yellow and blue/purple correspond, respectively, to upward and downward velocity.

Contours of SST in °C are overlaid on the top panels.
NOAA uses SST in many data products. Examples include the following.

- Historic SST analysis using only in situ data (e.g., from ships and more recently from buoys), 1854 to present on a monthly 2-degree grid.
- Weekly SST using in situ and infrared satellite data, November 1981 to present on a 1-degree grid. (This product was developed by Richard Reynolds in the late 1980s.)
- Daily SST using in situ, infrared (and microwave since 2002) satellite data, September 1981 to present on a 1/4-degree grid. (This daily product was developed in 2007 by Richard Reynolds and colleagues at NOAA and in collaboration with Dudley Chelton.)

The products are used for different purposes. Monthly fields are used to look at long-term climate change.

Weekly fields are good for looking at signals over periods of several years, such as El Niño. The weekly product is also used as the ocean boundary condition in the NOAA National Centers for Environmental Prediction (NCEP) global weather forecast model.

Daily fields can be used for a variety of purposes, such as tracking fisheries or showing the wake of a hurricane as it passes through an area. This higher resolution product also has the potential to improve the accuracy of the NCEP global weather forecast model, although it has not yet been incorporated into that model.

Richard Reynolds of CICS (NOAA’s Cooperative Institute for Climate and Satellites) has been working with Dudley Chelton to improve the spatial resolution of high-resolution SST analysis.

Reynolds explains, “Every time you try to improve the resolution in time and space, the results get ‘noisier.’ We want to identify problems with the data and put out [products] that people can use, with less noisy data.”

The daily, high-resolution product is calculated in a two-stage procedure. The first stage consists of computing the daily 1/4-degree SST product mentioned above, based on combined infrared and microwave measurements of SST. This product is then used as the first guess in the second stage of the procedure, which incorporates only the high-resolution infrared measurements to produce a very high-resolution SST analysis in the regions that are cloud free.

Recently, Chelton and Reynolds noticed large SST gradients near the edges of clouds. Reynolds describes the finding, “It’s as if all the SST features were being jammed up against where all the clouds started. We’ve been discovering that there are problems with the retrievals near the edges of the clouds. When you look at the temperature of the ocean and see all of these features right where the data stops, that’s suspicious.”

Reynolds and Chelton are working on the cloud-cover problem to identify the regions where the high-resolution SST analysis is trustworthy. The next steps will be to screen out the unreliable areas to let people know where there are problems in the high-resolution product. The goal is to differentiate those areas in which high resolution is possible from areas in which only the coarser resolution of the daily 1/4-degree gridded product is achievable.
Career Pathways

Angelicque White

Angelicque White is an OSU Assistant Professor investigating photosynthetic microbes. Throughout her education, she was interested in biology. She began looking at low-oxygen events in freshwater estuaries during her Masters degree at the University of Alabama, Huntsville. She notes, “In Alabama, we call those events Jubilees, not dead zones. As the fish are suffocating for lack of oxygen, they jump out of the water, so you can just walk down to the shore with a net.”

After her Master’s degree, she came to Oregon State and has been here nine years as a graduate student, postdoctoral researcher, and now professor. As a postdoc, White’s projects looked at various angles of how certain nutrients and the ratio of these nutrients (phosphorus and nitrogen) control the abundance, growth and diversity of phytoplankton. White has now branched out in a different type of chemical analysis. “With a colleague at UCSC (Adina Paytan) and recent funding from NSF, we’re investigating the production of organic matter that occurs as phytoplankton decompose. Basically, instead of studying the birth of blooms we’re now looking at what happens when blooms fade. Different phytoplankton groups have characteristic cellular nutrient ratios and differing molecular composition. When these organisms die and are broken down by bacteria, the inorganic and organic compounds within their cellular structure are released. In some cases this decomposition results in the production of methane or ethane—both potent greenhouse gases.”

Craig Risien

In his fourth year as an undergraduate at the University of Capetown in South Africa, Risien worked in satellite oceanography for an honors project. He followed that interest through in his MS degree in Oceanography at the University of Capetown, studying wind stress variability over the Benguela upwelling system.

Risien recalls, “When I came to OSU, I started in physical oceanography with Dudley Chelton. However, I always wanted to do something that was practical and applied. When I switched to a Marine Resource Management degree, Dudley said he’d be willing to fund me if I came up with a project in which he was interested. So I came up with an idea to try to use wind data from the QuickSCAT satellite in an oil-spill trajectory forecasting model. While working on my MRM degree, I had thought I would end up at a coastal services center, but ended up getting a job here at OSU doing product development, which I love.”

Morgaine McKibben

Morgaine McKibben is now a Master’s candidate in Biological Oceanography, working on harmful algal blooms research with Angelicque White. Since the age of four, McKibben knew that she wanted to work with the ocean. She went to UC Santa Cruz in Marine Biology. “I volunteered in the lab of a marine biology professor who specialized in tropical coral reefs. When asking his advice on how I could best prepare for grad school, he said I should decide on an ecosystem and group of organisms I’d like to focus on. I tried over the next couple of months, but nothing stood out to me, which got me a little worried.”

Oceanography 101 exposed McKibben to oceanography. “I learned that oceanography for a biologist was more concentrated on how phytoplankton and other microscopic organisms affect the physical environment of the oceans and vice versa. The huge part these tiny organisms play in ocean ecosystems and our planet’s climate is fascinating to me.”

McKibben plans to continue with a PhD and then move into research, ideally combining research with teaching.
Partnerships

Researchers at academic institutions and NOAA often collaborate to solve science problems important to society and to maintain useful public data products. Academic researchers often have depth and experience in a scientific area. However, their short-term funding means that they are unable to assemble a dataset, maintain it, improve it and then serve it out over a long time. Federal and state agencies have breadth and continuity; they can commit to maintaining a valuable data set.

An academic–government partnership provides collaboration to define problems important to society; perform cutting-edge research; and make research more valuable by providing stable continuity to data products and established processes.

CIOSS–NOAA

An example of such collaboration is work on sea surface temperatures (SSTs). Richard W. Reynolds works with NOAA’s Cooperative Institute for Climate and Satellites, analyzing data on SSTs. He is currently working with Dudley Chelton, Distinguished Professor at Oregon State University, on improving the spatial resolution of satellite-based global SST products, with particular emphasis on the coastal regions where small-scale features are often found in the SST field.

Although Reynolds has spent his career analyzing SST, he notes that Chelton contributes different expertise and experience. “He looks at a lot of data sources, such as winds from QuickSCAT, and he will see things that I wouldn’t notice. He noticed that near the edges of clouds there were always big SST changes. In our shared inquiry, we’ve been finding out that there are problems with the retrievals near the edges of the clouds.”

Reynolds also credits Chelton as being a motivator to tackle the vexing problem of higher-resolution daily analysis of SST. “Dudley has always been interested in microwave satellite data. We’ve been talking about it and collaborating for five or six years. I’d been meaning to do this higher-resolution daily analysis and he just kept pushing it. His research showing the importance of the influence of small-scale features in the SST field on the overlying wind field made this a higher priority.”

Chelton says that oceanographers’ understanding of the spatial and temporal variability of the SST field has gone through a remarkable evolution over the past decade since the availability of satellite microwave measurements of SST. The advantage of microwave remote sensing is that it can measure the SST through clouds. The availability of this new perspective in combination with satellite measurements of the surface wind field has revealed that the SST has a very strong influence on atmospheric winds. This has opened exciting research opportunities for studying how SST may affect weather and climate variability.

The federal government can make a long-term commitment to distributing and maintaining a product, which is not possible at the universities. In describing this collaboration, Reynolds notes, “At a university, it’s hard to maintain a product. After a grant is completed, a researcher has to move on to do more science of interest. In the partnership, the academic researcher is able to provide insight into how to make a product as accurate as possible and then hand over the product to the federal agency and have it continue.”

CIOSS–State of Oregon

Researcher Angelique White and graduate student Morgaine McKibben are working with the Oregon Department of Fish and Wildlife (ODFW) to track harmful algal blooms (HABs). The academic–government partnership includes the transfer of knowledge from scientists to the agency who will be maintaining the project. For this research, the transfer has two parts:

- Building statistical models for predicting HABs.
- Building a rapid-response monitoring system.

“One way we are trying to do this is by incorporating remote sensing measurements and in situ parameters into a common database that is automatically updated as new data stream in. From this near real-time data we can generate predictions of whether or not current conditions are favorable for HABs. ODFW can utilize these predictions to adapt their sampling routines and we can continue to evaluate the effectiveness of our models.”

White describes how developing the rapid-response system can help the state: “ODFW is tasked with regulation of shellfish harvest and protecting Oregonians from HAB outbreaks. Projects like ours add to their existing knowledge base and give them additional information to help maximize sampling efforts along our coast, identify HAB hot spots and maximize the chances for making sure contaminated shellfish don’t make it onto someone’s dinner plate.”
Outreach, Education, and Training

The SMILE Program

The Science and Math Investigative Learning Experiences (SMILE) program is a pre-college science and math enrichment program for elementary, middle, and high school students in about a dozen school districts throughout Oregon. The purpose of the program is to encourage educationally under-served students and those from schools with low high school graduation rates to pursue a higher education and career in science, math, health, engineering or teaching fields. Teachers in SMILE communities lead weekly after-school clubs for SMILE students.

Each year, the high school SMILE students attend an overnight ocean sciences challenge event at Oregon State University and Western Oregon University. The purpose of the challenge is to connect 9th- to 12th-grade students with the university environment and to provide enrichment activities in a supportive, team-based atmosphere, so that students feel like they have accomplished something substantial at college and can start making plans for their future in college.

The curricular focus is scenario-based ocean science, and is partially funded through CIOSS. Approximately 100 students from 11 schools attend the challenge event.

Challenges from past years include:
2010 What About Whales?
2009 Tsunamis
2008 Ocean Rescue

REU: Research Experience for Undergraduates

The REU program is an opportunity for undergraduates to participate in research at sea or in world-class analytical laboratories at Oregon State University. Nationally, there is a shortage of high-quality applicants to graduate programs in oceanography and atmospheric sciences. Some of the talented and highly motivated undergraduates in the OSU Honors College may find a career in this direction following exposure through an REU program.

The REU program matches Honors students each academic year with faculty mentors to conduct research programs with support from federal agencies (primarily from NSF).

Supplemental funding requested by faculty support student participation. Students can then be assured of:
• Employment.
• Research experience, presentation and writing skills.
• Topic and faculty advising for a senior thesis.

CIOSS regularly sponsors one or more REU students.
CIOSS Workshops

CIOSS Outreach and Education efforts include workshops on ocean remote sensing and modeling.

Ocean Color
An early research topic was the use of ocean color data. The initial focus was a major effort to help NOAA plan for hyper-spectral (visible) observations from the next generation of geostationary satellites.

A series of workshops held by CIOSS and partners from NOAA/NESDIS, NASA and the U.S. Navy, formed a team of national experts in marine optics (COAST, the Coastal Ocean Applications and Science Team, led by Curtiss Davis) who defined sensor characteristics needed for coastal applications.

Curtiss Davis and Ricardo Letelier also led workshops that developed characteristics for new in-water calibration efforts, ocean color climate data records and integration of data from U.S. and international satellites, such as Europe’s MERIS sensor.

Davis is now engaged in preparing for the next NOAA–NASA color sensors (VIIRS) on the Joint Polar Satellite System.

Ocean Surface Vector Winds
A pair of CIOSS workshops (organized by Dudley Chelton and Mike Freilich at OSU and by Paul Chang in NESDIS) brought together experts in ocean surface vector wind (OSVW) measurements and demonstrated the value of satellite-measured OSVW fields in marine forecasts.

Participants at the second workshop defined NOAA’s near-future operational needs for OSVW measurements; a new set of requirements was published in the 2006 workshop report found on the CIOSS website. A letter from over 750 scientists (organized by Freilich and Chelton) to the NRC Earth Sciences Decadal Survey in 2006 led to the Survey’s recommendation that NOAA plan and launch an improved scatterometer.

Modeling and Assimilation of Satellite Data in Coastal Oceans
Modeling and the assimilation of satellite data in coastal oceans have been the focus of two CIOSS-supported workshops. An April 2007 workshop organized by Alexander Kurapov brought together coastal modelers from NOAA, ONR and academia. Resulting papers were published in Dynamics of Atmospheres and Oceans: vol 48 (1-3), 2009, Modeling and Data Assimilation in Support of Coastal Ocean Observing Systems.

CIOSS helped organize and support a September 2010 coastal modeling workshop in Portland, OR. Assimilation of satellite data into ocean models remains a way to extend fields derived from the satellites to regions beneath the surface, under clouds and closer to the coast.

Coastal Altimetry Workshops (CAW)
Another set of ongoing international workshops was initiated in Silver Spring, MD, during February 2008, through a partnership between CIOSS and the NESDIS/STAR/SOCD Laboratory for Satellite Altimetry (led by Laury Miller). These workshops are improving the techniques needed to retrieve alongtrack altimeter sea surface heights in coastal regions. Using an “error budget” framework, participants identified the sources of SSH errors and developed suggestions for research needed to understand and reduce the largest of these errors.

Progress in retrieving altimeter data in coastal regions has been reported at follow-up workshops held in Europe (Pisa, Italy, November 2008; Frascati, Italy, October 2009; Porto, Portugal, October 2010).

At the fourth CAW in 2010, CIOSS again partnered with Laury Miller in NESDIS/SOCD/LSA to fund student attendees. One student was Laxmikant Dhage, an Indian undergraduate student who worked with altimeter data during summer 2010 at OSU with Ted Strub. Due to this experience, Mr. Dhage has changed his area of interest and will begin graduate studies in physical oceanography at OSU in Fall 2011.

SMILE Teacher Workshops
In the context of its support for the OSU SMILE program, an after-school “club” program for districts with large populations of under-represented students, CIOSS has supported and participated in SMILE’s teacher workshops. These several-day workshops are held three times each year and present the teachers with materials used in their after-school clubs and in the annual team challenge.

Short Courses
Short courses (approximately one week) have been used to help NOAA research scientists make better use of satellite data. Cara Wilson (NMFS/ERD) and Dave Foley (CoastWatch West Coast) have organized and led these courses at OSU four times (August 2006, March 2007, March 2008, March 2011).

Besides helping to arrange for the availability of lab space with computers for each student (through a GIS lab run by OSU Geosciences), CIOSS has provided much of the instruction in the background of ocean remote sensing. NOAA scientists (many from NMFS, some from other line offices) bring one or two projects with them and get started on those projects during the course. The course has been very well received within NOAA.
CIOSS Fellows

* Dr. Ted Strub: Professor, COAS; Director of CIOSS
* Dr. Mark Abbott: Professor and Dean, COAS; Chair of CIOSS Executive Board
  Dr. John Allen: Emeritus Professor, COAS
  Dr. Jack Barth: Professor, COAS
* Dr. Harold Batchelder: Professor, COAS
* Dr. Paul Chang: Research Scientist, NOAA/NESDIS/STAR/SOCD
  Dr. Dudley Chelton: Professor, COAS
  Dr. Pablo Clemente-Colon: Research Scientist, NOAA/NESDIS/STAR/SOCD
  Dr. James Coakley: Professor, COAS
  Mr. Ryan Collay: Program Coordinator for SMILE, OSU
* Dr. Curtiss Davis: Senior Research Professor, COAS; Chair of CIOSS Council of Fellows
* Dr. Paul DiGiacomo: Chief, CIOSS Science Director, NOAA/NESDIS/STAR/SOCD
  Dr. Gary Egbert: Professor, COAS
  Dr. Steven Esbensen: Emeritus Professor, COAS
  Mr. Dave Foley, CoastWatch Coordinator; NOAA/NESDIS
* Dr. Michael Freilich: Professor, COAS
  Dr. Kent Hughes: Research Scientist, NOAA/NESDIS/STAR/SOCD
* Dr. Alexander Ignatov: Chief, Ocean Sensors Branch, NOAA/NESDIS/STAR/SOCD
  Dr. Michael Kosro: Professor, COAS
  Dr. Alexander Kurapov: Associate Professor, COAS
* Dr. Ricardo Letelier: Professor, COAS
* Dr. Laury Miller: Chief, Satellite Altimetry Laboratory, NOAA/NESDIS/STAR/SOCD
  Dr. Robert Miller: Professor, COAS
  Dr. Michael Ondrusek: Research Scientist, NOAA/NESDIS/STAR/SOCD
  Dr. William Pichel: Research Scientist, NOAA/NESDIS/STAR/SOCD
* Dr. Roger Samelson: Professor, COAS
  Dr. Eric Skyllingstad: Professor, COAS
  Dr. Yvette Spitz: Associate Professor, COAS
* Dr. Menghua Wang: Chief, Marine Ecosystems and Climate Branch; NOAA/NESDIS/STAR/SOCD
  Dr. Angelique White: Assistant Professor, COAS
  Dr. Cara Wilson: Research Oceanographer, NOAA/NMFS

* Members of the Council of Fellows

A phytoplankton bloom captured in the north-east corner of Monterey Bay by the aircraft-mounted hyperspectral SAMSON sensor. The bloom, indicated in red, is identified using the 709 nm band, with adjacent yellow regions also having high levels of phytoplankton. This banded structure shows the individual swaths from sequential aircraft passes.

During the SMILE High School Challenge at Oregon State University, students studying the use of satellite fields to depict marine mammal habitat confront a life-size model of their subject matter.

Southern California Bight surface winds from Scatterometer and clouds from MODIS.

The launch of TOPEX/Poseidon in August 1992 began an uninterrupted series of precision altimeters.

Altimeters monitor the global ocean, showing an equatorial band of high sea levels (red and white) during El Niño conditions and low sea levels (blue and purple) during La Niña conditions.

True color image of river plumes off Oregon and Washington.