NOAA's Need for a CI for Ocean Remote Sensing
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As NOAA assesses its future need for a Cooperative Institute for Ocean Remote Sensing (CI-ORS), it should consider the nation's increasing use of the coastal and deep ocean, requiring ocean-related data products and services. These needs represent both challenges and opportunities, which can most economically be met through partnerships combining NOAA's resources with those of Universities, other Federal and State agencies and private research corporations.

A future NESDIS CI-ORS is needed to nurture these partnerships and focus their efforts to gain the greatest benefits from the new U.S. and International satellite sensors that will come on-line in the next decade. Information from multiple sensors and satellites (polar orbiting and geostationary) must be integrated with data from in situ ocean observing systems, assimilating these observations into ocean circulation and ecosystem models. Ocean remote sensing is steadily advancing but will always be limited to the upper ocean, with data gaps caused by clouds (visible and infrared) or nearby land (passive microwave and radar). In situ data provide subsurface information, but the spatial coverage is sparse. Ocean circulation models have also advanced greatly during the past decade and now produce realistic circulation features and water properties. However, these features often occur at the wrong locations and times in "free-running" models. Only by assimilating real-time satellite and in situ data into realistic models can NOAA provide the accurate, three-dimensional fields of ocean currents and water properties needed for operational oceanography. Using the broad perspective provided by satellites, a NESDIS CI can play a leadership role in coordinating research that integrates the components of an ocean observing-modeling system, bridging multiple NOAA offices and other government, academic and private institutions.

Over its ten-year life-span, a CI-ORS will create new opportunities for NOAA, using a suite of U.S. and International satellite sensors. VIIRS and GOES-R will provide new U.S. capabilities in SST and ocean bio-optics, while higher-resolution sensors for the same variables will be carried by international satellites (MERIS, OCM-2, GOCI). In the near future, the only available scatterometers (ASCAT and OSCAT) will also be carried by international satellites, while U.S. and International satellites will carry conventional and advanced altimeters and SAR (Altika SARAL, JASON-3, JASON-CS, CryoSat-2). Toward the end of this decade, the next generation of U.S. scatterometers (the Dual Frequency Scatterometer) and swath altimeters (SWOT) will become a reality. New ocean remote sensing initiatives will also emerge and need evaluation, as demonstrated by the proposed NASA, NOAA and USGS Geostationary Coastal and Air Pollution Events (GEO-CAPE) mission. Continued access to academic, NASA, ONR and private enterprise scientists involved in developing and perfecting these technologies is imperative for NESDIS' continued conversion of research into operational products and services. A dedicated Ocean Remote Sensing CI will provide an effective mechanism to enhance that access, including access to oceanographic data collected by other agencies that are needed in cal/val activities to gain the greatest benefit from the suite of new sensors. The same CI can spread the benefits of NESDIS data products and services to other NOAA offices, especially by developing new data products and by sharing expertise in data assimilation with ocean modelers throughout NOAA.

Below are examples of successful partnerships that allow NOAA access to external research scientists, data and models through a Cooperative Institute for Ocean Remote Sensing. Although these examples are taken from CIOSS' experience, they are representative of the type of collaborations that will result from the establishment of a CI-ORS anywhere in the U.S., with benefits on regional, national and international levels. In addition to the benefits from specific projects, however, there are benefits that derive from the commitment to a long-term relationship between NOAA and the Universities involved in a Cooperative Institute. Those benefits are harder to quantify, but are no-less real, often arising from interactions between Federal, Academic and Private Research Institute scientists, who would not be talking to each other as often (or at all) if the CI did not exist.

Enhancing SST and Bio-Optics:
An example of the immediate challenges and opportunities within NESDIS is the VIIRS sensor on the recently-launched NPP satellite. As the first of a new generation of sensors providing SST and ocean bio-optical data, VIIRS requires ongoing calibration and validation (cal/val) efforts, which are presently being coordinated by a multi-agency team co-led by SOCD's Menghua Wang, CIOSS Fellow C. Davis and their ONR colleague, R. Arnone. Satellite data from the European MERIS and ONR HICO sensors are being added to the VIIRS cal/val efforts, as are in situ data from the Hawaiian Ocean Time Series station, from coordinated coastal cruises off the U.S. West Coast and from a national network of SEAPRISM installations. These examples demonstrate the type of diverse and changing capabilities that are needed by STAR but cannot be "hired" with the same versatility and efficiency with which they can be accessed through a CI. By leveraging data collection efforts funded by other agencies, the benefits accrued through use of NESDIS resources are greatly increased.

COAST – Coastal Ocean Applications and Science Team:
An example of the type of large project that a CI makes possible is the experience of CIOSS in quickly bringing together a team of national experts on hyperspectral sensors for inclusion in the GOES-R series. Shortly after the creation of CIOSS, Paul Menzel and Stan Wilson in NOAA asked CIOSS to coordinate activities of a national team of bio-optics specialists, in order to define the characteristics needed in a hyperspectral ocean color sensor for a Coastal Waters Imager. This became the Hyperspectral Environmental Sensor-Coastal Waters Imager (HES-CW). To do this, CIOSS brought Dr. Curt Davis to OSU from NRL to assemble and lead a consortium of Federal, academic and private institute scientists in the COAST project. Through a series of workshops, this team defined the sensor characteristics, published these in a brochure format and then planned a series of field experiments to collect data for use in the development and testing of algorithms for that sensor. Although the first of the field experiments was carried out in Monterey Bay in 2006, the HES-CW program was cancelled by NOAA shortly thereafter, bringing the COAST project to a close. Some of the results of these planning and design efforts were later incorporated into a hyperspectral ocean color sensor that was funded by NRL, launched and attached to the International Space Station – the Hyperspectral Imager for Coastal Oceans (HICO). Curt Davis (CIOSS) is the HICO Project Scientist working with a group of scientists at NRL and universities to lead the HICO efforts. Curt Davis also advises NASA on the design requirements for an ocean color imager on GEO-CAPE under study for launch in the 2020 timeframe. Besides demonstrating how a CI can rapidly organize a national team to address a NOAA need, it also shows that the efforts of such teams is not lost if the NOAA need goes

away. Because their livelihoods depend on the efficient use of their time, scientists on soft money have a vested interest in the use of their previous work on future projects. In this way, the activities of the COAST project, although terminated prematurely in NOAA, were incorporated into the NRL HICO project, rather than simply being put on a shelf. The HICO data are now available for the benefit of NOAA cal/val needs for VIIRS.

Scatterometer, Coastal Altimetry and Other Workshops:
On a smaller scale, a CI can help NOAA focus on specific issues by hosting workshops on applied topics. In the case of CIOSS, two workshops were held on the use of scatterometer data for marine forecasts. These workshops increased the awareness of the benefits of scatterometer data for those forecasts. At the second of these workshops, the participants defined the desired characteristics of the next generation of scatterometers. These requirements were translated into the specifications of the XOVWS scatterometer, although the resources needed to move forward with such an instrument have not yet been found. Likewise, CIOSS teamed with the NESDIS/SOCD Laboratory for Satellite Altimetry to organize and host the first Coastal Altimetry Workshop. This has evolved into an ongoing series of workshops on the same topic, supported by U.S. and European funding agencies. Other workshops have been supported and hosted by CIOSS on topics including utilizing international ocean color sensors in US coastal regions (outgrowth of the COAST effort described above), satellite Climate Data Records, assimilation of satellite data into coastal and basin-scale ocean circulation models and on the needs for monitoring and modeling programs in the California Current Large Marine Ecosystem. (See http://cioss.coas.oregonstate.edu/CIOSS/meetings.html for the proceedings of these and other workshops.)

Ocean and Ecosystem Modeling:
Funding from both NESDIS and the NOAA Integrated Ocean Observing System (IOOS) has been combined by CIOSS modelers to develop and implement data-assimilating models of ocean circulation and water properties off the U.S. West Coast during the past 9 years. These continue to be improved, with efforts directed toward ecosystem and biochemical components that will allow predictions of phytoplankton bloom trajectories and hypoxic conditions. Physical fields from the real-time Oregon forecast model are used to hindcast particle trajectories that inform spatio-temporal patterns of retention time on the Oregon shelf, and more recently to track ocean pathways of non-passive organisms to examine connectivity among the marine reserves and protected areas within the Oregon territorial seas. The connectivity and time-spans of connectivity are important considerations for effective Coastal and Marine Spatial Planning (CMSP). The latter Lagrangian studies that include organism behavior were initiated with NESDIS funding and are supported also by Oregon Sea Grant. NCEP's recently announced implementation of a global RTOFS (Real-Time Ocean Forecast System) will allow even greater interactions between a CI-ORS and NOAA modelers (coastal and basin-scale). The global RTOFS, coupled with the data collection from the IOOS supported gliders on the Oregon shelf will provide greatly improved boundary conditions to the regional models, and thereby result in improved hindcasts and predictions of shelf hypoxia.

Outreach:
The NOAA-funded CIOSS/OSU-SMILE Program partnership exemplifies how best to define and reach the vision and goals stated in NOAA's 2009 Education Strategic plan, as well as within

the Principals for Ocean Literacy. As stated in the plan's vision, the SMILE program involves teachers, students and academic partners in enhancing their ocean science literacy, with the explicit goal of showing that this increased knowledge makes a difference in people's lives. SMILE collaborates in the design and delivery of teacher professional development workshops that increase teacher knowledge and support their use of ocean science activities in their classrooms and afterschool SMILE clubs. Within the context of the clubs, we are creating and continuing to refine our contextual framework for linking ocean science content activities learned in the clubs to "college connection" activities. Our annual Ocean Sciences Challenge engages rural and minority high school students in the contextual application of their content knowledge to address real world concerns that face our communities. Scenarios used in past High School Challenges include: oil spills and environmental remediation; the support for coastal fishing communities in a changing environment; and the understanding of the human role in monitoring and preparing for increased coastal hazards. In each Challenge scenario, we incorporate satellite research and involve faculty and graduate students to enhance the teachers' and students' knowledge. This increased knowledge supports the community members in their application to address the problems or concerns. The partnership also increases students' awareness of, and aspiration to continue on to STEM careers linked to ocean sciences. The program framework has now been disseminated to Suitland Maryland as part of the Climate, Oceans and Weather program in St. Georges County, serving underrepresented youth.

CoastWatch and IOOS:

CoastWatch provides products derived from ocean remote sensing instruments to the public, with an emphasis on near real time data. In doing this, it needs to provide confidence in those products, which sometimes is in the form of refereed papers that use the same data sets for research. The successful use of those data in peer-reviewed science papers provides a level of pedigree for the data set. During the past ~8 years, the West Coast node of CoastWatch has used papers written by CIOSS Fellows in this manner. One example is provided by the frontal location product, developed originally by Tim Mavor in NESDIS/STAR. Two papers by CIOSS Fellow Jack Barth and his student, Renato Castellao, used these data in coastal regions along the U.S. West Coast and in the coastal ocean off Brazil, providing peer-reviewed references that CoastWatch could site when they made the data available. In some regions, the local CoastWatch node works with the local Regional Associations of NOAA's Integtrated Ocean Observing System (IOOS). Most of these RA's are engaged in collecting data in the coastal ocean and are also clients for the CoastWatch remote sensing data. In particular, most of the RA's support coastal High Frequency Radar surface current mapping systems. These data sets complement satellite fields that describe aspects of the surface circulation patterns next to the coast. Products that combine the CoastWatch satellite fields with these and other IOOS data sets are a natural area of collaboration between research scientists in NESDIS/STAR, Universities and private institutes. Facilitation of these types of partnership is one of the purposes of a CI.