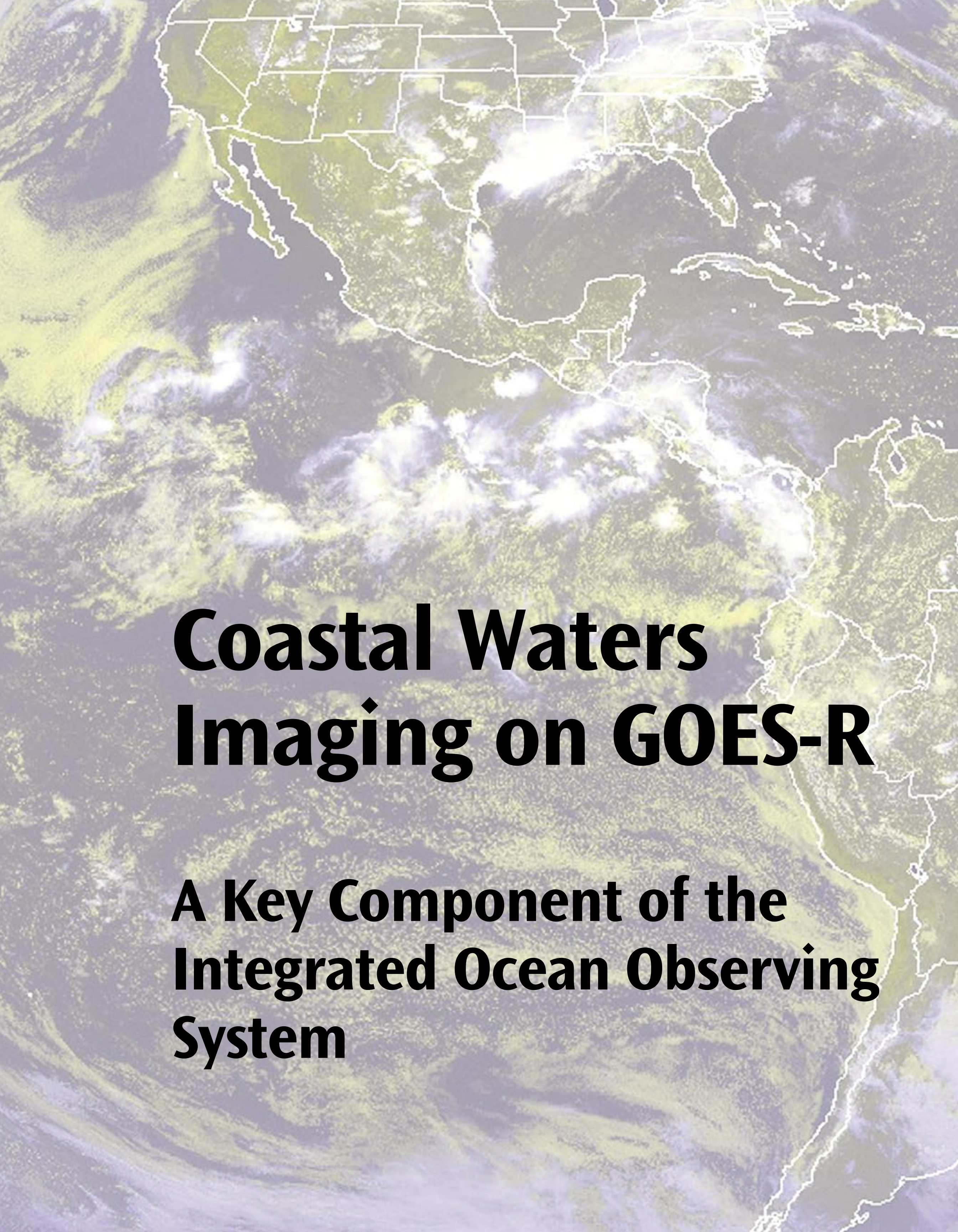


Coastal Waters Imaging on GOES-R

A Key Component of the Integrated Ocean Observing System

Coastal Monitoring in the Next Generation of GOES

For over 30 years, geostationary weather satellites have been used by the National Weather Service (NWS) for daily weather forecasting and for tracking severe storm events. Geostationary Operational Environmental Satellites (GOES) have played a key part in the nation's weather prediction capabilities and have been used to successfully detect every hurricane that has made landfall in the United States during this time. Similar technology is needed to monitor the ocean.

The National Oceanic and Atmospheric Administration (NOAA) plans to include an imaging capability for coastal waters on the next generation of GOES satellites, scheduled for launch in 2012. A Hyperspectral Environmental Suite that includes a coastal waters imaging capability (HES-CW) and atmospheric sounding sensors is proposed for the GOES-R platform. These sensors will revolutionize the understanding and management of U.S. coastal waters in the same way that GOES imaging has changed weather prediction over the last 30 years.

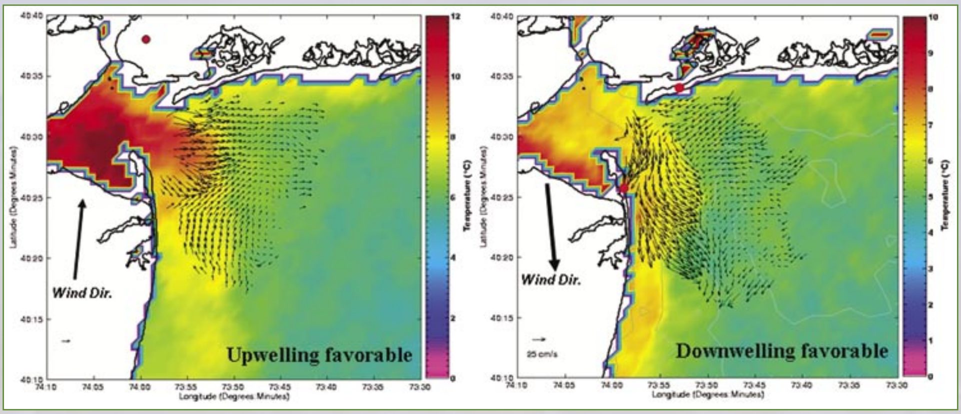
> *"Space-borne sensors can provide comprehensive, real-time, widespread coverage of ocean conditions and features and their data will form an integral part of the national IOOS."*
>
> — An Ocean Blueprint for the 21st Century, Final Report of the U.S. Commission on Ocean Policy, Washington, D.C., September 2004.

In its report to Congress, the U.S. Commission on Ocean Policy expressed growing concern about the health and future of coastal waters and recommended the development and implementation of an Integrated Ocean Observing

Cover: GOES-11 image acquired June 2004, NOAA Satellites and Information Services

System (IOOS), a national monitoring network that will include coverage of coastal areas. In response to this recommendation, the IOOS has been identified in the U.S. Ocean Action Plan as a source of critical observations needed to improve the basis for coastal management. The IOOS is critically dependent on both remote sensing for spatially synoptic observations of the ocean's surface, and in situ measurements for observing the ocean's interior. The fusion of remote and in situ sensing provides a powerful means to rapidly assess current states of oceanic and coastal systems in all four dimensions of space and time, thereby representing an unprecedented ability to test physical and biological models of upper-ocean processes.

Integrating Imagery and Ocean Observations



Courtesy of Coastal Ocean Observation Laboratory, Rutgers University

The Integrated Ocean Observing System will provide observations that are essential to developing a forecasting capability for the coastal ocean. The flow of the Hudson River into New York Harbor and out to sea or, depending on the wind, onto the New Jersey shore is an example of the variability that occurs. Surface currents, measured hourly with high frequency radar, can assist with predictions; the addition of imagery will provide a more complete picture.

Satellite Imagery for Coastal Resource Management

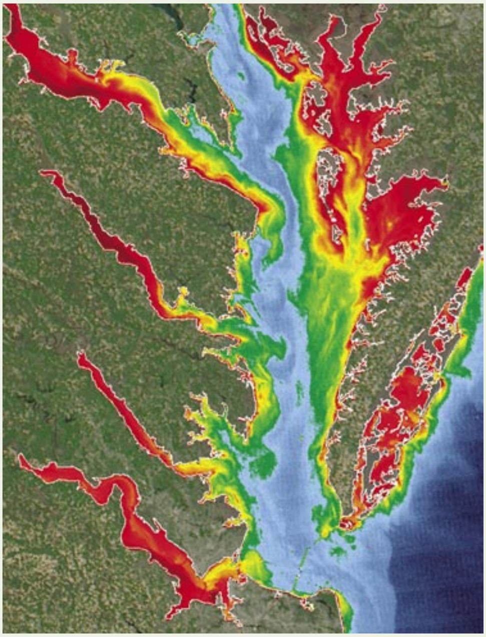
Providing Imagery at an Improved Scale

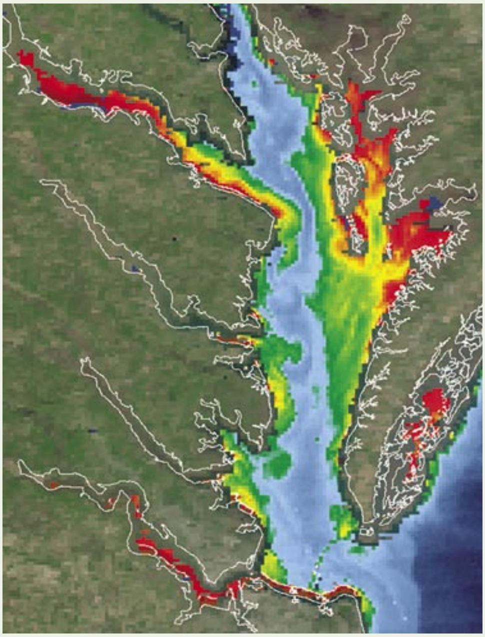
The U.S. coastline is highly irregular with many sounds, bays, and estuaries. Analogous to the way high-definition television compares to conventional television, the 300-meter spatial resolution planned for HES-CW is 10 times better than is presently available from most polar-orbiting satellites. One advantage of a sensor on a geostationary satellite is that it can focus on an area of interest for an extended period to obtain high signal-to-noise imagery. Higher quality images characteristic of geostationary satellites combined with higher spatial resolution will greatly enhance the ability to image and monitor complex areas like Chesapeake Bay, Puget Sound, San Francisco Bay, and the Great Lakes.

"Six years ago, we were working with a coastal water quality control group who was going out by ship and taking samples. At that time, they didn't do water quality sampling in the sanctuary because they thought, 'Nothing is going to affect the islands.' We just happened to get a NOAA satellite image that clearly indicated a sediment plume from a river on the mainland was traveling 25 miles out into the ocean and impacting the Channel Islands. We printed that out and went down to our meeting with them and that was the first year they did sampling around the islands. That was a perfect example of a picture being worth a thousand words."

— Ben Waltenberger
Channel Islands National Marine Sanctuary

Monitoring Clarity in the Bay





Courtesy of Naval Research Laboratory

Water clarity is being monitored as a performance indicator for restoration efforts in the Chesapeake Bay. These images of the lower Chesapeake Bay illustrate the improvement in spatial resolution needed for coastal waters. The higher spatial resolution of the 250-meter Moderate resolution Imaging Spectroradiometer (MODIS) image (left) provides greater detail (turbid waters are shown in red; clear waters in blue) in the rivers and the main body of the Chesapeake than the 1-kilometer image from the same sensor (right). The next step is to routinely provide higher resolution imagery, and the geostationary platform is a novel approach to accomplish this goal.

Providing Imagery When It's Most Useful

Tides, winds (such as the land/sea breeze), river runoff, upwelling, and storms drive coastal currents to speeds that can reach several knots. Furthermore, currents driven by tides can reverse approximately every six hours. These waters can transport harmful algal blooms, pollution, oil spills or other features that can rapidly affect coastal resources. Current sensors acquire one image per day and clouds can obscure the view of an area. By sampling every three hours, the HES-CW will provide coastal managers and scientists with access to coastal ocean imagery throughout the day, and the capability to choose or combine images to provide a view that is free of clouds. Identifying and closely tracking these types of features as they approach the shore will greatly improve our ability to manage coastal resources just as GOES imagery has improved our ability to monitor and forecast the weather.

"We find the images to be an invaluable tool that gives us a bigger picture of possible red tide or other harmful algal blooms that may affect our beaches and local waterways. By simply monitoring the water at our local beaches, we had no way of knowing if red tide existed offshore and could potentially impact our coastline."

— Frank Halas, Collier County Commission

Monitoring Harmful Algal Events

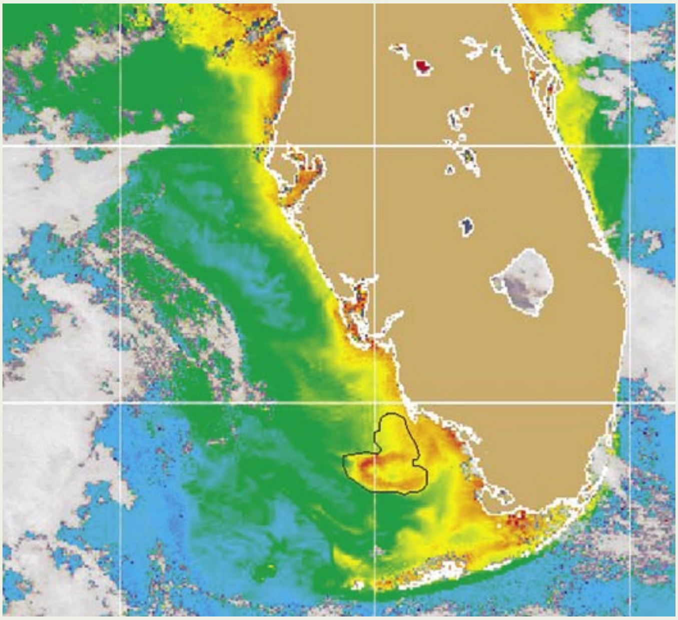


Photo courtesy of Mote Marine Laboratory

Images courtesy of NOAA CoastWatch and OrbImage

In the Gulf of Mexico, blooms of the toxic algae *Karenia brevis* result in fish kills (photo), shellfish bed closures, and lost tourism that cost the state of Florida millions of dollars each year. Ocean color images from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS on OrbView-2) with 1-kilometer resolution are currently being used to estimate the size and extent of these blooms to help state agencies adapt their monitoring strategies. With frequent sampling provided by HES-CW, coastal managers will have access to an up-to-date cloud free image to effectively track the movement of the bloom, adjust their sampling strategy, and make more informed decisions about managing these blooms on a daily basis. Improved spatial resolution of 300 meters will provide better imagery in the nearshore areas where the proximity to tourist activities and shellfish harvesting areas are highly impacted by harmful algal bloom events.

Providing Imagery that Encourages Innovation

The ocean's color in the coastal zone is a combination of signals from phytoplankton, colored dissolved organic matter, suspended sediment, and bottom features. The HES-CW will be configured to provide products similar to the polar-orbiting sensors to allow continuity of information; however, the configuration will also enable new and improved products that are not possible from present and planned polar-orbiting sensors. For example, it will be designed to provide a fluorescence-based chlorophyll product that allows for better separation between phytoplankton from other components in the water. This information can be used to develop new products that estimate primary production and the physiological condition of phytoplankton in coastal waters — powerful indicators of ecosystem health and stability. Having this information will help move our nation's coastal programs from a reactive into a proactive mode.

"Having remote sensing data is really important after large scale storms, oil spills and hazardous spills, or groundings. It's the first thing you're asked; 'Do you have any imagery so we can tell the extent of the damage?'"

— Henry Norris, Florida Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission

Assessing Storm Events

Courtesy of NASA and OrbImage

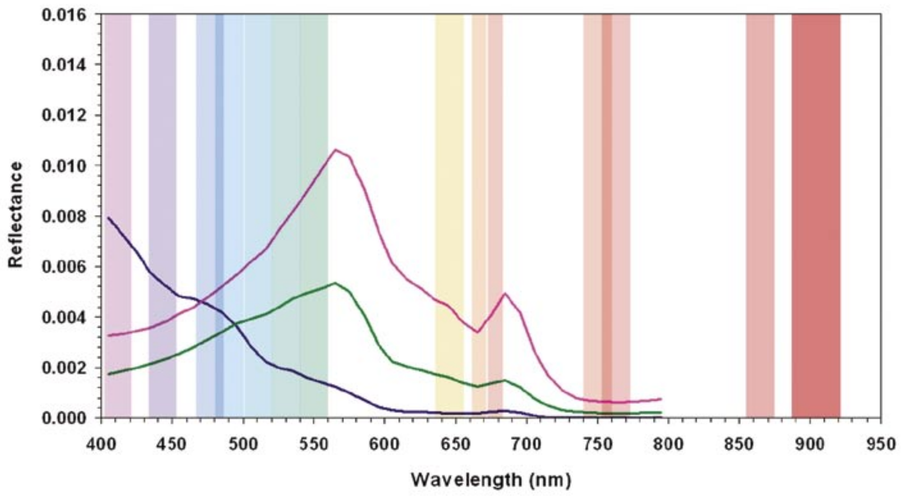
Storm events such as hurricanes can rapidly affect coastal water quality by suspending sediments and flooding rivers and estuaries with nutrients and land-based pollution. The turbid plumes generated by the storms and flooding of Hurricane Floyd are evident in the photo (right) and SeaWiFS image (above) as dark murky areas within the Pamlico-Albemarle Sound and as a plume being carried from North Carolina by the Gulf Stream. A HES-CW sensor will have an optimal design to distinguish between chlorophyll, suspended sediments, and dissolved organic matter at high resolution. A geostationary platform will provide an improved capability to gather imagery when clouds are in the area.

Courtesy of NOAA National Ocean Service

Technical Requirements and Specifications

A pointable sensor on a geostationary platform, the HES-CW will image U.S. coastal waters every three hours and hourly at selected sites. The ability to acquire a large number of scenes increases the chance of obtaining high-quality, cloud-free images that are so important for monitoring coastal processes.

The configuration and 300-meter spatial resolution of the HES-CW will support the development of algorithms for shallow, nearshore waters and provide continuity to satellite missions with sensors that meet or exceed present ocean color specifications for spectral and spatial resolution.



The HES-CW is being designed to accommodate a minimum of 14 wavelengths in the visible and near-infrared part of the spectrum. The placement is optimized to detect changes in ocean reflectance caused by varying concentrations of phytoplankton, sediments, and dissolved organic material and to resolve the effects of the atmosphere. Examples shown here are for open ocean (blue line), coastal areas with lower chlorophyll (green), and coastal areas with higher chlorophyll (pink). Some of the channels are the same as present ocean color sensor specifications so that the HES-CW will extend the climatological data set for those products. Additional channels and smaller bandwidths are being considered.

Where Do We Go from Here?

Imagery is being incorporated into management tools for a variety of coastal issues; demand is growing for improved imagery. The technology is now available to make this leap for the coastal resource management community. GOES-R has begun to accomplish this task by:

- Designing the imaging capability to specifically address the complexities of coastal waters.
- Establishing the Coastal Ocean Applications and Science Team (COAST) to ensure that the expertise of the oceanographic community is brought to bear on this critical issue of national importance.

These efforts will demonstrate to both public and private sectors that the GOES-R capabilities will significantly contribute to managing coastal resources in an efficient, effective, and timely manner — paving the way for a subsequent smooth operational implementation.

Courtesy of NASA-Johnson Space Center

For Additional Information about the GOES-R Program

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Date of Publication: February 2005