# Remote Sensing of the Marine Ecosystem

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Due to several recent natural and man-made disasters, the monitoring of the marine environment has gained considerable attention by state and national agencies. This can be attributed to several factors, including the number of people who either live nearby or visit coastal regions, the delicate nature of the marine ecosystem which can impact the habitat in the region, and the strong economic dependence of local and regional industry on these ecosystems. Advanced remote sensing techniques, such as the use of multi-spectral satellite measurements, can contribute to the monitoring of the marine environment. Sensors such as NOAA's Advanced Very High Resolution Radiometer (AVHRR) and NASA's Moderate Resolution Imaging Spectrometer (MODIS) all contribute information (refer to Table 1 for a more complete summary of sensors). This article will present two applications of satellite remote sensing in the monitoring of the marine ecosystem.

The Chesapeake Bay contributes hundreds of millions of dollars to the state economies of Maryland, Delaware, and Virginia through commercial and recreational fishing and tourism,. Those who are familiar with the area can only describe the consumption of softshell Blue Crabs as a dining experience unique to Chesapeake Bay! Farming is also a major industry on the Delmarva Peninsula. However, pollutants from these farms (fertilizers, animal waste, etc.) run off into the Bay and can have a catastrophic effect on the bay's ecosystem and fisheries.

Through a project that represents collaboration between local universities and NOAA scientists, a prototype ecological forecast system was developed for the Chesapeake Bay. The system, which routinely generates predictions of several noxious marine organisms, was deemed necessary because various noxious marine biota, such as jellyfish and harmful algal blooms, periodically afflict the waters of the Chesapeake Bay. Knowing where and when to expect these biotic events may help one to avoid or react to them. Harmful algal blooms (HABs), such as the dinoflagellate *Karlodinium veneficum*, have contributed to several fish kills at an aquaculture facility on the Eastern Shore of Maryland. Prediction of these HABs may allow the aquaculture facility to prepare for their arrival and transfer the fish to other areas or to relocate the fish pens. Avoiding areas known to harbor sea nettles also has an obvious advantage if one wishes to go swimming in the bay. As any boater on the bay knows, the best way to cool off during those long, hot summer days is to jump into the water. That is, unless there are sea nettles nearby. A "sting" by their tentacles can be excruciatingly painful and will take the joy out of a dip in the bay.

Table 1. A listing of remotely sensed oceanographic parameters, their observational / instrument class and representative sensors. Modified from Brown et al., 2005.

| Variable | Observational Category | Example Sensors |
|---|---|---|
| Bio-Optical | Visible – Near Infrared | MERIS, MODIS, OrbView-2 (SeaWiFS), Landsat, SPOT |
| Sea-Surface Temperature | Thermal Infrared<br>Microwave Radiometers | AVHRR<br>SSM/I, WindSat |
| Salinity | Microwave Radiometers & Scatterometers | Aquarious (planned) |
| Sea-Surface Roughness, Waves & Tides | Synthetic Aperture Radar<br>Microwave Scatterometers & Altimeters | ERS-1 & -2, QuikSCAT |
| Sea-Surface Height | Altimeters | Topex/Poseidon, Jason-1 |
| Sea Ice | Visible – Near Infrared<br>Microwave Radiometers, Scatterometers & Altimeters<br>Synthetic Aperture Radar | AVHRR<br>SSM/I<br>AMSR-E |
| Surface Currents & Circulation | Visible – Near Infrared<br>Microwave Scatterometers & Altimeters | AVHRR, DMSP |

The prediction technique is relatively straight forward and exploits our knowledge of the environmental conditions associated with sea nettles and our ability to acquire relevant environmental variables in near-real time. Daily nowcasts of sea nettles are generated by applying a statistical habitat suitability model to near-real time estimates of salinity and temperature in the Chesapeake Bay. The habitat model, developed using historically collected data, quantitatively relates these ambient conditions to the likelihood of encountering sea nettles in Chesapeake Bay (Decker et al., 2007). Ambient salinity is estimated from a numerical hydrographic model of Chesapeake Bay and sea-surface temperature is derived either from the same hydrographic model or from NOAA satellite imagery. An example of this product is shown in Figure 1. The sea nettle predictions are available at http://coastwatch.noaa.gov/seanettles.

Remotely sensed data also permit us to assess the health and functioning of marine ecosystems by monitoring marine algae, both noxious and helpful, at coastal and global scales. These microscopic "plants" constitute the base of the oceanic food web and play a significant role in the Earth's carbon cycle. In some cases, specific types of phytoplankton can be identified from space. For example, high concentrations or "blooms" of the phytoplankton *Emilliania huxleyi*, which belongs to a group of phytoplankton that produces and surrounds itself in calcareous plates (Fig. 2, insert),can significantly affect a region by acting as a source of organic sulfur (i.e. dimethyl sulfide) to the atmosphere and calcium carbonate to the sediments, and by altering the optical properties of the marine surface layer. Documenting the occurrence of its blooms in time and space is therefore essential in characterizing the biogeochemical environment of a region. Furthermore, their distribution pattern can be employed to define the environmental conditions favorable for their occurrence. *E. huxleyi* blooms can be distinguished from most other conditions in visible satellite imagery by their milky white to turquoise appearance. This relatively unique spectral signature can be used to detect the presence of these blooms in satellite ocean color imagery. (Ocean color is defined as the spectrum of water-leaving radiances in the visible (400 – 700 nm) and near infrared (0.7 – 1.0 μm) exiting the water column. Ocean color observations are acquired by measuring the radiances of different visible to near infrared wavelengths at the sensor, computing and subtracting components of this total radiance due to specular reflection and the atmospheric contributions, and converting the resulting water-leaving radiances into meaningful geophysical parameters, such as chlorophyll and suspended sediment concentrations.) Figure 2 presents an example of this product derived from GeoEye's OrbView-2 (also known as SeaWiFS). Tracking the location, magnitude and timing of these blooms, as well as phytoplankton in general, over a sufficient period of time will be useful in detecting whether changes in their distribution pattern have occurred , and by association, assessing the marine ecosystem's response to climate change.

The importance of the marine ecosystem cannot be overstated. Satellite remote sensing data help scientists to study and monitor the health of the marine ecosystem and may be used in coupled ocean-atmosphere-ecological models. Within the US, both NASA and NOAA satellites routinely provide satellite imagery for monitoring and investigating the physical, chemical, geological and biological aspects of the world's ecosystems. Hopefully, this capability will continue. Although a hyperspectral sensor capable of retrieving ocean color products was in the original design for the GOES-R satellite series, it has since been removed from the satellite due to budgetary constraints. An operational ocean color capable sensor, the Visible/Infrared Imager Radiometer Suite (VIIRS), will be carried on the National Polar-orbiting Operational Environmental Satellite System (NPOESS), the next generation of polar-orbiting operational satellite system. With an eye on detail and adequate planning, this and other satellite sensors will allow us to monitor the ocean's ecosystems in coming years.

## References

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**Acronyms**

AMSR-E – Advanced Microwave Scanning Radiometer on EOS Aqua Satellite
AVHRR – Advanced Very High Resolution Radiometer
DMSP – Defense Meteorological Satellite Program
ERS- European Remote-Sensing Satellite
Jason-1 – Name of a joint US/French altimeter mission
LANDSAT- Land remote sensing Satellite
MERIS - Medium Resolution Imaging Spectrometer
MODIS - Moderate Resolution Imaging Spectrometer
QuikSCAT – Quick Scatterometer
SeaWiFs - Sea-viewing Wide Field-of-view Sensor
SSM/I – Special Sensor Microwave/Imager
SPOT - Systeme Probatoire d’Observation de la Terre satellite
TOPEX – Topography Experiment, the US altimeter on TOPEX/Poseidon
Topex/Poseidon - Name of a joint US/French altimeter mission;

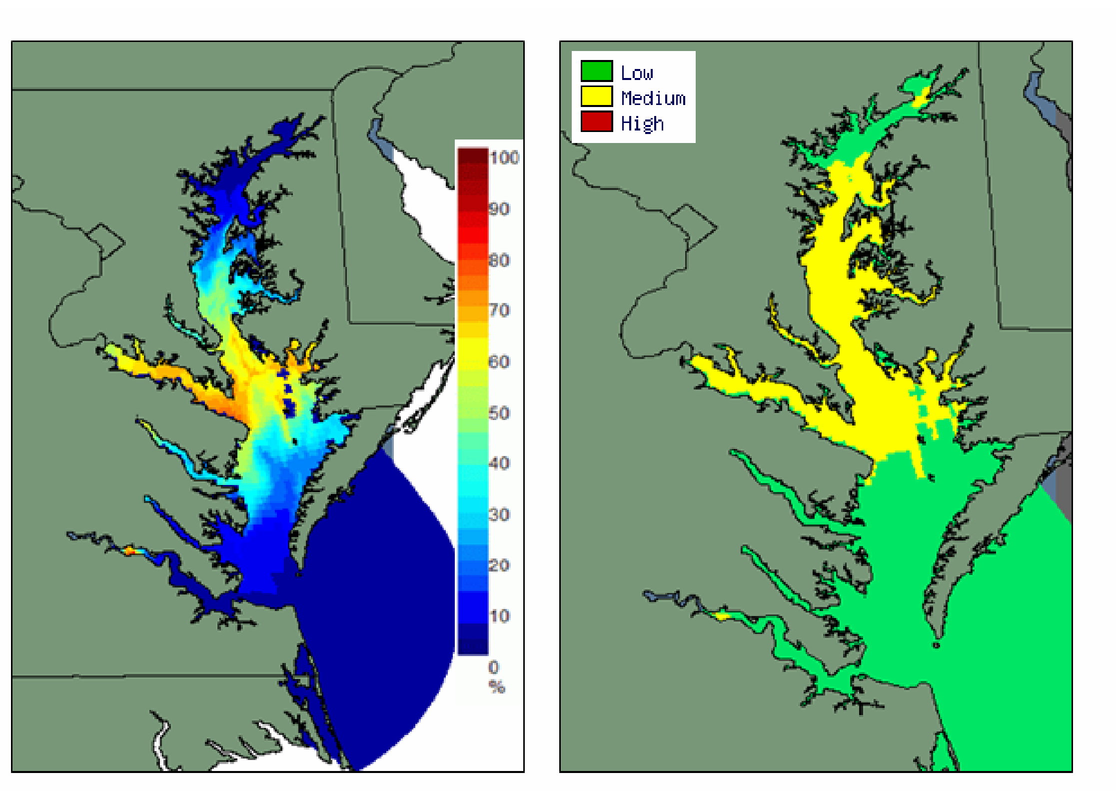


**Figure 1 -** Predicted likelihood of encountering sea nettle, a species of stinging jellyfish, (left) and the relative abundance of *Karlodinium veneficum*, a species of phytoplankton attributed to fish kills(right) on August 17, 2007.

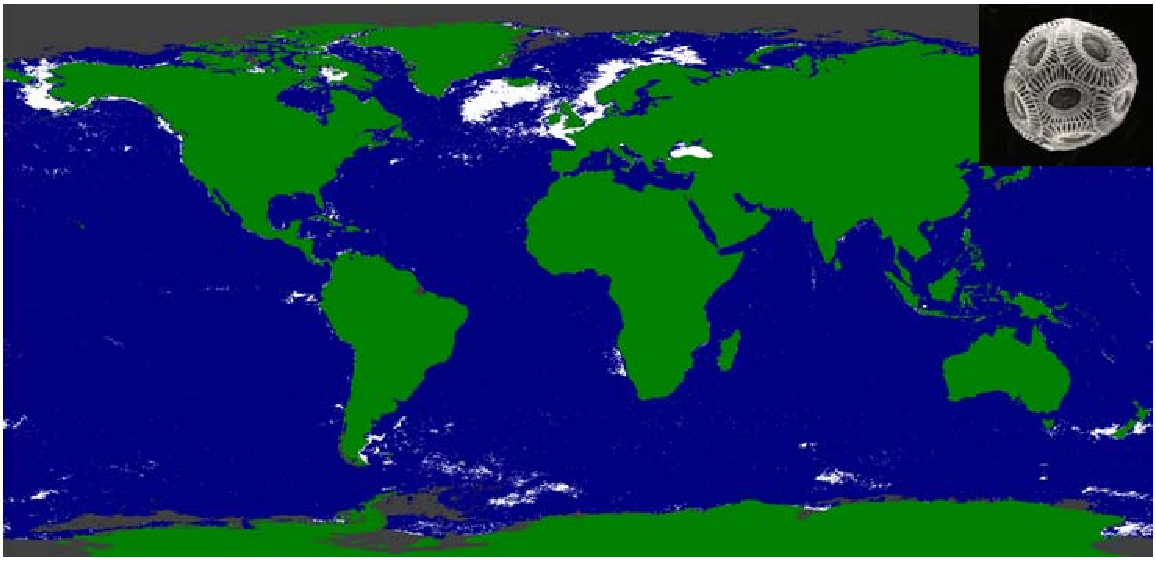

**Figure 2 –** Annual composite of detected coccolithophorid blooms in SeaWiFS imagery during 1998. Their blooms are colored white in the image. Blue represents regions where blooms were not detected and grey indicates locations where data are lacking. The inset in the upper right is an enlarged photo of the *Emiliania huxlei*.