A nested integrated regional ocean observatory

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Coastal ocean observatories are being proposed throughout the world. Their purpose is to monitor the underwater weather 3-dimensionally in highly utilized coastal regions, communicate the present state of the ocean to multiple users in real-time, and provide the data to ocean forecasters generating predictions of future ocean states. These observatories intend to meet their objective by combining spatially extensive remote sensing surface data with more sparse subsurface data collected from fixed moorings and mobile platforms. The hope is that the construction of coastal observatories will provide the observational/modeling infrastructure for understanding the underlying processes behind observed environmental patterns because these dynamic ecosystems are poorly sampled using traditional oceanographic approaches. Understanding the physical forcing of the aquatic ecosystems has been acknowledged to be key in developing principles for effective coastal management. Currently the coastal observatories all differ in design and stage of development. As part of the growing national network of coastal observatories, the Long-term Ecosystem Observatory (LEO) was established in 1996. This manuscript will describe the infrastructure of LEO and provide a case example of using this multiplatform system to study coastal upwelling.

The LEO observatory is located off the New Jersey coast in the Middle Atlantic Bight and is a coupled system where the data is assimilated into forecast models. Model forecasts in turn are used to adjust the sampling patterns of the field assets. Specific components to LEO network include:

1. Meteorology.

A dedicated meteorological tower outfitted with a suite of sensors providing a standard set of local meteorological measurements. The meteorological system also a pair of acoustic atmospheric profilers that sample the lower 5000 meters of the atmosphere for wind speed and direction. The on-shore assets are complemented with a meteorological buoy located 15 km offshore. The buoy is outfitted for wind speed and direction, air temperature, and barometric pressure. The buoy has a Freewave radio modem allowing two-way communication and automated data retrieval.

2. Remote Sensing.

Remote sensing technologies are used to provide spatially extensive surface maps of both physical and biological properties. Near-real time thermal infrared (Advanced Very High Resolution Radiometer) and ocean color (SeaWiFS) sensors provide estimates of sea-surface temperature and chlorophyll concentration, respectively, for data assimilation and model validation. The LEO site is a calibration site for the new generation of ocean color algorithms that provide estimates of the inherent optical properties. The advantage of having estimates of the inherent optical properties is that they are easy to interpret and can be decomposed into the individual constituents. Future efforts will focus on receiving data from the growing international constellation of ocean color satellites. Delay-mode RADARSAT data is currently provided through NOAA-NESDIS.

Complementing the satellite imagery, the CODAR SeaSonde High-Frequency Radar System measures real-time surface current fields. Two different classes of CODAR are part of the network. An intermediate scale CODAR system that provides a surface current vector map every hour in near real-time. Each map extends about 50 km alongshore and 40 km offshore with a grid resolution of 1.5 km. In addition to the intermediate scale system a single long range CODAR site installed in summer 2000, provides radial coverage over 190 km with a spatial resolution of 6 km. Three more long-range sites will be installed during the fall of 2000 and spring 2001. This 4-site CODAR system will provide continuous surface current measurements for the entire MAB from the outer edge of Long Island to below Delaware Bay.

3. Cabled Autonomous Nodes.

To provide a permanent presence in coastal waters a network of cabled instrumented nodes has been constructed. The cabled network consists of two robotic nodes 10 km off the southern coast of New Jersey connected to shore via an electro fiber-optic cable. Each node has a vertical profiler outfitted for conductivity-temperature-depth, optical backscatter, light, and chlorophyll fluorometer. A third optical node was constructed and tested during the 1999 to provide a complete characterization of the inherent optical properties in the water column, allowing for vicarious calibration of ocean color imagery.

4. Shipboard Adaptive Sampling.

To provide a spatial extension around the cabled observatory in situ data is collected with ships and autonomous underwater vehicles. One category of ships is designed to conduct rapid high-resolution surveys providing real-time data to the rest of the research fleet. These vessels are equipped with towed/undulating systems. Typically the instrumentation includes a surface-towed and undulating towed equipment packages. Data from this vessel is beamed, via Freewave modem, back to shore in real-time to guide other ships to adjust sampling transects "on the fly". The second category of research vessel is outfitted with a full suite of profiling instruments characterizing the apparent and inherent optical properties for remote sensing studies.

5. Vehicles.Au tonomous Underwater.

Two types of Autonomous Underwater Vehicles (AUV) have been operated at LEO. The Remote Environmental Monitoring UnitS (REMUS) are propeller-driven AUVs that have been successfully operated at LEO-15 since 1997. REMUS Survey AUVs are modular, allowing instruments to be added for specific mission requirements. REMUS systems at LEO have been equipped suite of physical and optical sensors. The navigation by the REMUS is facilitated by two-way communication with a series of transponders that are laid out along the AUV flight path. By summer 2000, the REMUS flew 11 missions in an undulating manner covering 444 km.

The nonpropeller Webb Slocum Electric Glider was deployed for ten days offshore Tuckerton, New Jersey for its first untethered open ocean flight during the 2000 summer experiment. The Glider is an autonomous vehicle that moves up and down in the ocean by changing its buoyancy. Wings allow steerable gliding, thus horizontal propulsion. This vehicle traces a sawtooth profile, observing temperature, conductivity, etc. versus depth. At the surface, cellular telephone links are established allowing the glider to fix its position via GPS and communicate with scientists onshore. Over the 10-day period, the Glider collected 5,190 vertical casts with an average 45-minute data delay without ever returning to the dock. The Glider, like the REMUS, is modular so instrument payloads can be customized for individual scientific needs.

6. Models.

Observational data streams feed the regional data assimilative atmospheric and ocean model systems. Typically, three- to four-day duration ocean forecasts are generated twice a week for a total of 8 forecast cycles during each of the CPSE experiments using the Regional Ocean Modeling System (ROMS). The ocean forecasts are forced with standard products from the Navy Operational Regional (NORAPS), and Global (NOGAPS) Atmospheric Prediction Systems, and Regional Atmospheric Modeling Systems (RAMS). Assimilated data include satellite SST, CODAR surface currents, and subsurface CTD data and CODAR surface currents via nudging. In this observationally rich environment, forecast errors are dominated by uncertainties in the model physics or future boundary conditions rather than initial conditions. Therefore, ensemble forecasts with differing model parameterizations provide a unique opportunity for model refinement and validation. The ROMS circulation model continues to be advanced and will be coupled to an optically-based ecosystem food web model in the near future.

To facilitate data dissemination the Rutgers Ocean Data Access Network (RODAN) has been developed. RODAN is operated by a web server that has access to LEO databases and the associated meta-data, analysis modules and visualization software. The web-based interface for RODAN accesses available data and process it using the available analysis modules. For example, if a plot is requested, the controller will plot the data and send it back to the user for display on their screen. If only datafiles are requested, they can be downloaded and stored on the user's computer. The system is an open access to all users through the World Wide Web.

Conclusions

The coastal observatories provide the potential to characterize highly dynamic coastal waters. This will fill a critical void and will serve a suite of applied and scientific needs. Currently each observatory has its own unique scientific flavor as they are being designed for studying specific scientific questions; however, ideally these high-resolution regional sites will be unified through a coherent suite of broadband measurements. The resulting system would provide a nested observation grid capable of defining the basic patterns in hydrography and biology for the majority of the coastal ocean.