A Short History of the Long Term Ecosystem Observatory (LEO)

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Coming from the field of deep-sea ecology, Frederick Grassle appreciated the limited time scientists have to observe natural phenomena in the ocean and that this fundamentally inhibited understanding. When Frederick Grassle joined Rutgers to develop the Institute of Marine and Coastal Sciences, he carried his vision for developing a "permanent window to the sea." It was a goal that entrained many of us in the 1990's. Rutgers re-occupied a designated research area offshore of Tuckerton, New Jersey that had been abandoned since the mid-1970s, but was still found on NOAA navigation charts. The approximately 3 by 3 km area was the proposed site of an offshore floating nuclear power plant in a plan developed in response to that decade's energy crisis. With support from the National Science Foundation and the State of New Jersey, Rutgers and Woods Hole Oceanographic Institution (WHOI) deployed an electro-optic cable (Figure 1) extending from an exisiting shore lab to about 15 meters water depth. The strategy was based on science-engineering partnerships where the scientist provided the motivation, the engineer developed the new tools, and the team collaborated on implementation. This model has been central to the growth of the New Jersey observation network, where science-engineering partnerships have focused on the development of satellite data-processing algorithms (Moline et al., 2003), surface current radars (Kohut et al., 1999; 2003), autonomous underwater gliders (Schofield et al., 2002; Glenn and Schofield, 2003), ship-towed systems (Creed et al., 1998; 2000), and bio-optical instrumentation (Kirkpatrick et al., 2003).

Figure 1 The 11 ton and 10 kilometer spool of LEO-15 electro-optic cable.

Figure 2 The observational array mustered for the LEO Coastal Predictive Skill Experiments.

The cable has successfully delivered power to instruments since its deployment in 1996, notably conducting a series of studies focused on sediment transport processes on sand ridges. Science motivation focused on the differences in the physical forcing around the ridges. It was known through theoretical studies (Trowbridge, 1995) that even small perturbations in the flow induced by the ridge might cause variations in the sediment transport that could produce a feedback loop that reinforces the ridge. The cable allowed experiments to move beyond self-contained units that were limited by battery power and data storage capacity to deployments on the LEO-15 cabled observatory, so that limitations were now instrument calibration and bio-fouling environment. The high data bandwidth allowing for the installation of video cameras was one of the unexpected successes. The cameras observed that under low flow conditions, fish liked to school around the instruments. Thus, the low flow condition reflected flow around an organism as much as over a sand ridge.

Other notable successes include seasonal deployments of a flow cytometer by WHOI, turbulence sensors by Old Dominion University, and oxygen measurements by Lamont Doherty Earth Observatory. The NOAA National Undersea Research Program facilitated access to the cable by a diverse group of scientists. A clear peer-review process allowing access for any scientist was critical to the success of the cable. Maintaining access for the widest number of scientists is increasingly difficult as the *in situ* equipment on either end of the cable ages and requires extra care to remain functional. The spatial ocean observing components were developed parallel to the cable.

These larger ocean observatory projects grew from efforts funded by the Office of Naval Research and the National Ocean Partnership Program. In the late 1990s spatial sampling capabilities offshore of New Jersey expanded from kilometer-scale to tens of kilometers-scale for a series of Coastal Predictive Skill Experiments (CPSEs). This spatial expansion was driven by a scientific focus on the topographic steering of coastal upwelling and resulting impact on near

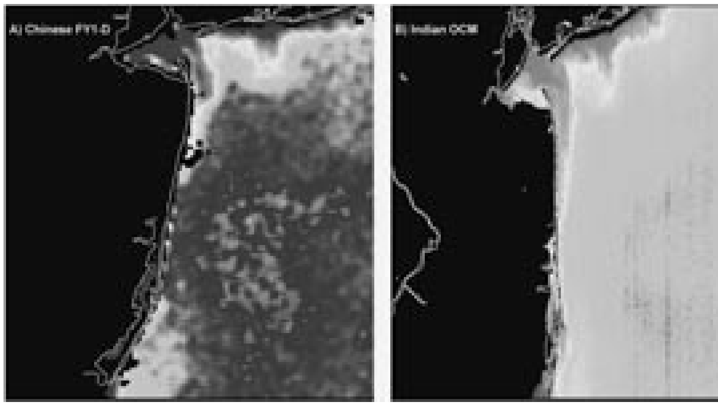

Figure 3 Maps of relative chlorophyll concentrations (dark = high concentrations) for the Hudson River and New York Bight measured by the A) Chinese FY-1D and B) Indian OceanSat satellite systems. Tapping into the international constellation of satellites allows for broad coverage in both space and time.

shore optics and biology (Figure 2). Engineering efforts focused on developing a flexible ocean sampling network that was coupled to a numerical nowcast/forecast model allowing researchers to adaptively plan field projects with the guidance of biweekly evening forecast briefings. Field observations consisted of real-time satellite remote sensing, standard and long-range surface current radar measurements, ships, and two classes of underwater vehicles (Schofield et al., 2002). A major addition to the observation system was a wireless communication network based on radio frequency modems that allowed the scientists onshore and on the ships to access data from each other - allowing them to adjust sampling patterns and track features being advected within the sampling grid. The cabled observatory itself has maintained a steady stream of scientific users for nearly a decade; however, the largest influx of researchers was associated with the availability of the spatial datasets and the model forecasts.

The 30 by 30 km area, while powerful, had a relatively small footprint in space, greatly limiting what science questions it could address, especially processes operating over days to weeks. Most of the questions that are driving our research interests operate over a larger space/time domain. Enabling technologies that have facilitated the construction of the 300 by 300 km New Jersey Shelf Observing System (NJ SOS) included: (1) a growing international constellation of high-resolution (spatial and spectral) satellites providing thermal and ocean color maps (Figure 3); (2) multistatic long-range high frequency radars generating hourly surface current maps over distances approaching 200 km (Figure 4); and (3) long-duration remotely-controlled Glider-type Autonomous Underwater Vehicles for mobile subsurface physical/bio-optical observations (Figure 5). The advantage of these three technologies is that they can be operated 24 hours a day, 7 days a week, provide spatially coherent maps appropriate for empowering modeling efforts, and engage both the general public and scientific communities.

After seven years of building and expanding the ocean observing network off New Jersey, we have learned that scientists need to be actively engaged and in leadership positions to ensure that the fledlging ocean technology continues to evolve. This control can create a natural tension between operators who maintain the facility and those who use it. Our experience is that there will be a conflict unless the operator's metric for success is novel scientific experiments, which might be more risky to the infrastructure, as opposed to the number of days that sensors are wet.

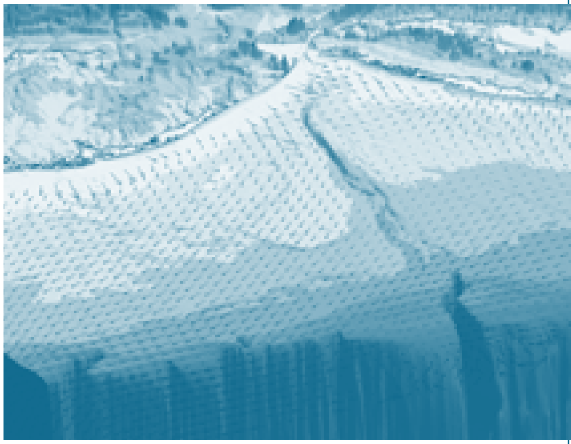

Figure 4 Topographic map with overlayed shelf wide currents measured with a multi-static CODAR network.

When scientists can maintain a continuous presence in the ocean, many surprises await. For example, recent seasonal deployments by turbulence sensors reveal the presence of super charged Langmuir cells capable of resuspending sediments and biological material from the seafloor (Ann Gargett personal communication). These data were corroborated by the autonomous gliders offshore, suggesting a new alternative resuspension process that may be a significant feature on the continental shelf.

Spatial data in real-time are a highly valued scientific commodity and are the key for adaptive sampling. Spatial data sets have been assimilated into models, and time series point measurements have been used for model validation purposes only. Technologies providing spatial time series will be the key to success and will likely be central to most biological and chemical research that depend on separating advective changes from local growth or transformation.

Finally, the people are the most important commodity for an observatory. Talented operators, cutting edge scientific users, and engaged leadership are required to sustain an innovative environment. The observatory should facilitate communication between scientists and provide a platform that can stimulate rigorous data-based debate. If this debate begins on a national scale through the ORION and similar offices, oceanography in the coming decades will be very exciting.//

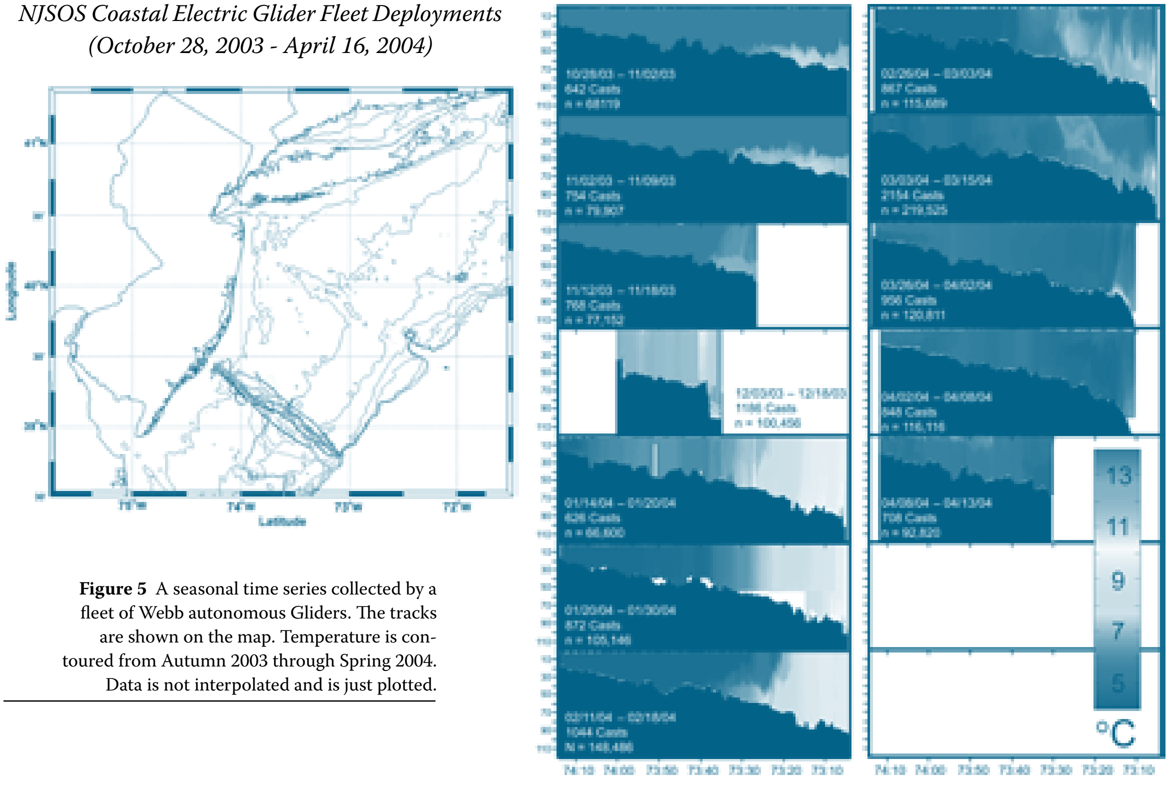

Figure 5 A seasonal time series collected by a fleet of Webb autonomous Gliders. The tracks are shown on the map. Temperature is contoured from Autumn 2003 through Spring 2004. Data is not interpolated and is just plotted.

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