COMMENTARY

Epilogue to SEACOOS

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As we bring closure to this volume and to SEACOOS, an experiment in developing a regional coastal ocean observing system (RCOOS), it is useful to reflect on some of the lessons learned and what a path forward might be. The origin of SEACOOS and the transition of SEACOOS into SECOORA are provided in the prologue. To that introduction, covering the formalities and mechanisms by which SEACOOS came into being and the multi-agency support, both conceptual and financial, it is important to add the human element that made SEACOOS successful. The framework brought the partners together, but our cohesion grew out of mutual respect for intellectual contributions over a broad range of matters, from the science behind the observing and modeling, to the information management, to the need for enlightened outreach. This began with the most fundamental aspect of the program design, the question: what should the SEACOOS domain be?

Thus our earliest programmatic decision was science-based. Given that the Loop Current-Florida Current-Gulf Stream System connects the eastern Gulf of Mexico with the southeastern United States, thereby affecting all coastal ocean state variables, we realized that SEACOOS had to incorporate the entire State of Florida, including its broad West Florida Continental Shelf, and its adjacent boundary Loop Current. A SEACOOS defined by defensible science, not geography, was our initial consensus decision, and this initial decision, which carried forward into SECOORA, is amongst our most important contributions to the RCOOS concept. After all, RCOOS products will likely fall short of their expressed societal goals if the observations and models from which they are derived are not scientifically defensible. Indeed, one of the success stories reported at the SECOORA summer 2008 workshop was an explanation for the differences between red tides observed in 2006 and 2007. The first of these years saw a fairly normal bloom on the West Florida Shelf, with no blooms on the east coast, whereas the second of these years saw anomalously strong blooms on the east coast extending to the Carolinas, with only a nominal occurrence on the West Florida Shelf. Bloom initiation occurred on the West Florida Shelf in both years, but 2007 experienced export (via the Loop Current), whereas 2006 experienced retention.

Numerous scientific lessons on the workings of the coastal ocean were learned, but the details of these are best left for the refereed professional literature. Here we will be concerned with some general and programmatic lessons. We begin with the recognition that the RA societal goals are inherently multi-disciplinary and interconnected. For instance, ecology begins with uniting nutrients and light. Since nutrient concentrations are high at depth and light intensity is high near the surface, the circulation is an inherent part of ocean primary productivity. Complex chemical, biological, species and habitat interactions then ensue, aided and abetted by the currents through the distribution and concentration of matter across the coastal ocean. Hence the concept of ecologically-based management must be viewed in the broadest multi-disciplinary, inter-connected sense.

For SEACOOS (and SECOORA) the *K. brevis* red tide organism provides a challenge for such multi-disciplinary RCOOS applications, and since *K. brevis* kills fish it also bears upon fisheries applications. Fortunately, the same tools for red tide study apply equally to most of the RA societal goals. In essence, the lesson is that we must engage in multi-disciplinary, ocean state variable estimation though coordinated observing and modeling programs. Models are required since there are never enough observations, but models without adequate observations (for initialization, boundary conditions and veracity testing) are insufficient. Ocean state variable estimation, whether for currents, waves, *K. brevis*, the intermediary nutrients, or any other ocean state variable must be approached in a similar manner, and that approach is what provided a focal point for the RCOOS developments within the various SEACOOS sub-regional groups. The challenge was large, but as with any challenge we achieved incremental successes, one step at a time. A corollary is that multi-disciplinary RCOOS applications of societal importance can begin in advance of having all of the pieces in place. Analogy is drawn to numerical weather forecasting. It was not very good when it started; some might argue that it is not very good today; yet it is of great societal importance, and progress steadily continues as observations, models, and their integration though data assimilation all improve.

The above sounds good in principle. In practice, there are many impediments to achieving progress. People are the most significant limiting commodity, and people require sustained funding. Instruments and systems fail, and this necessitates spares, maintenance and calibration support, plus logistical support to service platforms and sensors. Bandwidth and power at sea are also limiting so care must be taken to ensure that data requirements and instrument placements are science-driven, not bandwidth and power-driven.

Overcoming these impediments requires economies of scale and multi-tier collaborations among federal, state, and local government, academic, and private sector partners. But like any application of the scientific method, we must challenge the assumptions that go into the partnerships. What has worked for SEACOOS and similar programs around the nation can provide practical lessons on how these partnerships can evolve. The important point is that SEACOOS (and similar programs) have demonstrated that we can advance now, and not wait until such time as issues are all resolved. For instance, who may introduce and maintain an instrumentation system now may differ from who may do so, or operate such a system, in the future. More important than the details is that we build a scientifically defensible RCOOS and that we learn relevant societal lessons along the way.

Advancement often comes through doing, and numerical weather forecasting again provides an analogy. Thus it is argued that the actual RCOOS practice provides a path forward, and good examples of the fruits of multiple-tier collaborations reside at the NDBC websites on both HF radar and observations from moored buoys. In each case, resources deployed by various organizations are merged into a common presentation format by the NOAA/NDBC, regardless of the data provider. Similarly, private sector providers have seamlessly packaged SEACOOS (and other RCOOS) data to the benefit of a broader community.

Whereas some sensing systems are easier to integrate than others, there exists no single measurement system that is adequate to describe the state of the coastal ocean. Required are: moorings, HF radar, drifters, profilers and gliders, satellites, and ships supporting multi-disciplinary suites of sensors. The observing system must be designed for full water column observations distributed over dynamically distinct regions, spanning the inner shelf to the shelf break and beyond, to account for the interactions between the shelf and deep-ocean and between the shelf and the estuaries. A similar statement applies to the models. Required is the coupling of atmosphere and ocean circulation models along with wave and biological models. But as with the observations, no single model or model framework is fully sufficient, owing to the scales that must be resolved. For instance, modeling hurricane storm surge requires resolution down to the scale of individual inlets and bayous, plus flooding and drying provisions for land. Moreover, ensemble modeling, as advanced for numerical weather prediction, and perhaps most notably for hurricane prediction, should also be advanced for the coastal ocean. But large suites of observations and models, supported with information management and disseminated through outreach, all require that same limiting commodity mentioned earlier—people, and people cannot be educated and retained without sustained funding.

Although SEACOOS was founded in science, the previous discussions serve to demonstrate that its success also derived from bringing together different constituencies to serve a common purpose and work towards common goals. These included academic researchers in pursuit of understandings on complex phenomena; federal, state, and local agency employees more organizationally constrained by specific missions and management applications; a variety of educators focused on learning and public awareness opportunities; and a small group of private sector entrepreneurs who saw potential value in the RCOOS operations. As SEACOOS found its feet, it fostered new dialogues, conversations of shared problem-solving, collaborative partnering, and relationships among these very diverse participants, and our thematic workshops helped to promote such dialogue.

The collaborative structure that emerged out of SEACOOS illustrates a means by which we can address many of today's coastal ocean science problems. Addressing climate change, pollution, and water resource issues and how these bear upon coastal ocean ecology, maritime safety, commerce, and quality of life all require multi-disciplinary collaborations amongst scientists, engineers, environmental managers, operational forecasters, educators, and entrepreneurs. Through the merging of cultures, SEACOOS succeeded in lowering barriers to collaborations, and functional capacity was built, both in the water and intellectually. But maintaining such capacity requires new and sustained resources.

In summary, the SEACOOS investigators are all fortunate to have engaged in this five-year, RCOOS development experiment. While not business as usual, we found that working together, using diverse sets of resources toward achieving complementary goals, was rewarding. Instead of seeking a least common denominator, we pushed each other to achieve a higher level of performance. Not everything was as successful as we had hoped, but the successes advanced the RCOOS concept, and these successes justify a continuation of effort to see an RCOOS to fruition. However, assumptions must be challenged, leadership must evolve, and better partnering amongst the academic, federal, state, and local government, and private sector participants must occur, if we are to collectively achieve the RA and RCOOS goals of addressing matters of societal concern in that littoral domain where society literally meets the ocean. Excellent observing, modeling, data management, and outreach capabilities exist around the nation, and the RA and the RCOOS concept provides a framework for advancing these capabilities. Small shifts in emphasis from managerial planning to more action in sustaining and enhancing ongoing efforts by practitioners will bring us a long way toward realizing the societal goals espoused. Empowering performance, thereby sustaining capacity investments while continuing to plan and improve, is a valid pathway forward. Short of empowering performance, the SEACOOS five-year experiment in RCOOS development may have been just that.

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