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Opportunities and Challenges of Establishing Coastal Observing Systems

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ABSTRACT: Some of the challenges to establishing and sustaining environmental monitoring are potentially overcome under the framework of global observing systems. Observing systems go beyond monitoring by enabling links between user needs and observations and by providing valued information products to user groups at appropriate spatial and temporal scales. The United Nations established three global observing systems; for climate, oceans, and land and freshwater. Initiatives have also begun to address important issues within coastal ecosystems. Recent socio-political awareness and technical advances have improved the opportunities for establishing these observing systems and ensuring their sustainability. Awareness and current technology alone are not enough, and ongoing implementation of these systems is still stymied by a variety of factors. We make several recommendations to promote their success now and in the future.

Introduction

In 1992, Duarte et al. (1992) assessed the status of marine monitoring programs and found that, while the number of programs initiated during the twentieth century had been increasing, over half had already been terminated with 40% halted in the 1980s. These programs were described by Duarte et al. (1992) as often being local in scale, responsive to specific events, based on funding with limited sustainability, in competition with more exciting science, and generally uncoordinated with other programs. We contend that monitoring programs have been difficult to sustain because they often do not have sufficient resolution in time and space to address issues of importance to decision makers; monitoring programs typically do not provide data and information at rates and in forms needed by decision makers; and the societal benefits of monitoring are often not realized or appreciated. Have conditions changed that make current initiatives more likely to succeed? We think they have, beginning in 1992 with the United Nations Conference on Environment and Development in Rio de Janeiro. The community of nations formally recognized the need for sustained, multidisciplinary observations across multiple scales from global to local ecosystems. This need is beginning to be met through the development of something more than monitoring programs, namely observing systems.

Observing systems are more than just monitoring because they are designed to link, at appropriate time and space scales, environmental observations to scientifically sound management of ecosystems and natural resources (Clark et al. 2001; Christian 2005). Coastal observing systems will help provide and communicate predictive models for such issues as eutrophication, sea-level rise, oil spill spread, hurricane and tsunami surge and impacts, habitat alteration due to urbanization, and harmful algal blooms. They are designed to build on ongoing monitoring and research programs where possible and extend capabilities where needed. Methods standardization and training are components of these systems. The prototype of a successful, operational and mature global observing system is the World Weather Watch (WWW) of the World

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Meteorological Organization (WMO). The WWW serves real-time data for numerical weather predictions, provides much of the data used for longer term climate predictions, and provides the foundation for the development of other multi-purpose observing systems.

Opportunities

Recognition of these needs has produced political opportunities for observing systems. The United Nations began supporting observing systems with the United Nations Conference on Environment and Development in Rio de Janeiro. These systems focus on the global ocean (Global Ocean Observing System [GOOS]), climate (Global Climate Observing System [GCOS]), and terrestrial (Global Terrestrial Observing System [GTOS]). In 2002, the World Summit on Sustainable Development highlighted the urgent need for integrated observations for assessing the state of the Earth (Johannesburg Summit 2002) and over thirty countries signed a declaration at the First Earth Observation Summit (2003). Since the First Earth Observation Summit, two summits have been held (2004, 2005); the Group on Earth Observations (GEO) has been formed with over 50 countries and over 40 international organizations (including the UN observing systems and their secretariats) signing on; the 10-Year Implementation Plan for Global Earth Observing System of Systems (GEOSS) was completed and endorsed; and the GEO has affirmed the intention to provide the support necessary to execute the Implementation Plan (National Oceanic and Atmospheric Administration 2005).

Implementation of GOOS, GCOS and GTOS is at various stages. GOOS is being implemented in two interdependent modules, global and coastal. The global module, in collaboration with GCOS, is focused on improving predictions of climate change (Global Climate Observing System 2004). Implementation began in the 1990's, and about half of the observing system has been implemented (Ocean.US 2005). GTOS has a well developed program on land cover and developing programs on terrestrial contributions to climate (with GCOS) and carbon flux. Importantly for this article GOOS and GTOS have developed coastal modules. The status of these coastal programs and access to information on extant observing systems can be obtained at the GOOS and GTOS web sites, given at the end of this article. The coastal GOOS (Intergovernmental Oceanographic Commission 2003, 2005) and GTOS (Food and Agriculture Organization of the United Nations 2005) plans were completed in collaboration that was formalized through the Integrated Global Observing Strategy (IGOS) Coastal Theme. The Coastal Theme addresses requirements for sustained observations across the land-sea interface, including observing system requirements for coral reefs (Integrated Global Observing Strategy 2006). All of these programs are dependent on local and national organizations to accomplish their goals and foster improved observing capabilities by the national and local organizations.

Advances in technology over the last decade have increased our ability to detect changes in environmental systems more rapidly and to forecast changes more effectively. Abilities have improved for remote and in situ sensing, real time data telemetry, data assimilation, and numerical models of ecosystem dynamics. These can and are being used to attract a widening spectrum of user groups and link advances in science with the development of operational capabilities. Both of these are important for sustaining observing systems by establishing a positive feedback between scientific research and observing system needs. We now have the capability not only to make observations on appropriate time-space scales but also provide data and information in forms and at rates needed for both public and private user groups to achieve their goals more effectively. For this capability to be realized, data providers, users from private and public sectors, decision makers and scientists must work together more closely than they have in the past. This cooperation ensures the development of observing systems that meet their needs and evolve as needs change.

One example where coastal observing systems have benefited by a research program involves the Land Ocean Interactions in the Coastal Zone (LOICZ) Project. Data integration underpins the quality of the products of observing systems, and LOICZ is a research project focused on such integration in the coastal domain. The project has blended data from multiple sensors with in-situ data and analyzed these using interdisciplinary frameworks to address human-coastal environment interactions. Now in its second decade, LOICZ addresses five themes: vulnerability of coastal systems and hazards to society, coastal ecosystems and their human appropriation, river basin-coastal zone interactions, biogeochemical cycles of coastal and shelf waters, and governance towards coastal system sustainability (Kremer et al. 2005). Among its products most relevant to coastal observing systems are a mass-based biogeochemical budget modeling protocol (Gordon et al. 1996), a coastal typology framework based on a coastal environment and nutrient budget database with a clustering and visualization software (LOICZVIEW) (Maxwell and Buddemeier 2001), and applications of the Driver-Pressure-State-Impact-Response framework to coastal systems at regional scales (Salomons et al. 2005). The project is the foundation for a pilot program of

C-GTOS within the Mediterranean Sea by providing access to networks of monitoring sites, technical tools and initial analyses (Christian 2005).

In addition to increasing technical capabilities, the recognized need for and value of operational observing systems have also increased. Scientifically sound information and actions are needed to sustain and restore healthy coastal ecosystems and to mitigate the impacts of natural hazards, climate change and human activities. At the same time, organizations and governments have come to realize that large scale events (e.g., El Niño-Southern Oscillation) and global trends (e.g., global warming) can have dramatic environmental and socioeconomic consequences on local scales in the coastal zone. Observing systems are being designed to span the full spectrum of scales from local to global. Thus, the economic value of observing systems capable of addressing coastal issues has been estimated with very positive cost benefit ratios (Kite-Powell et al. 2004).

Challenges

The coastal observing systems have lagged behind other observing systems for a variety of reasons, which are also relevant to the issue of sustainability. The scientific foundations for the design of the ocean-climate observing system and the technologies required for its implementation are in place, and the need is clear. Since the ocean-climate system is primarily concerned with the open ocean, a relatively small number of developed nations are the primary implementers. In contrast, the coastal modules of GOOS and GTOS must address the impacts of climate change, natural hazards and human activities in complex environmental settings that have substantial spatial variation. Requirements differ from place to place and must be tailored to regional and local needs. Perhaps more importantly, the political and socio-economic issues are more complex: human populations are concentrated and growing along the coast with multiple cultures and requirements; more countries need to be involved (all coastal states at a minimum); establishing and maintaining the capabilities of observing systems are limited, especially in developing countries; and socio-political barriers deter timely data exchange among countries. Addressing these issues requires international cooperation and sensitivity.

Challenges to establishing sustainable, coastal observing systems may be broadly characterized as: integration of the many parts, making transitions to multi-user observing systems, capacity building (i.e., providing education and tools to develop and sustain capabilities), and funding on continuous and adequate bases. The many parts include those of general structure (i.e., linking programs for monitoring to data assimilation and management to model development, calibration, validation and analysis to communication with user groups) and those of geography (i.e., linking land and sea, local scale to regional to global scales, and developing and developed countries). A strength of the observing system approach is its dependence on user groups for determining product requirements and hence observational needs. However, different users may have conflicting purposes, and these may jeopardize the free access to information; one country may not wish to share information with another, or the military may not wish to make information public.

The lack of capability or capacity to implement observing systems is one of the most significant deterrents. This limited capacity plays out at many levels. The obvious need for improvement is in the developing world where resources are limited. Strategies must be developed to take advantage of ongoing national and international programs to secure observing system capabilities in these areas. One strategy that is being instituted is the use of sites of conservation and cultural heritage within international networks (e.g., Ramsar Wetlands Convention, UNESCO World Heritage and Man and The Biosphere). People already have demonstrated appreciation of the value of these sites and are likely to support the monitoring of them (Mazzilli and Christian 2006). But other aspects of capacity are limited. Data collection, data management, informatics and predictive modeling all require more research and development to address the vast needs of the global observing systems. The following is an example of the interplay between the various needs.

Satellite observations are viewed as an element of coastal observing systems requiring integration with other components (Integrated Global Observing Strategy 2006). Satellites provide synoptic, frequent observations for a number of important ecosystem parameters, mitigating weaknesses of in situ networks (e.g., coarse sampling) and complementing their strengths (e.g., broad suite of parameters, accurate measures at surface and at depth). In this regard there are two remote sensing challenges to be addressed. In the short-term, satellite data providers and coastal users need to cooperate to identify specific information needs and formulate ways to derive products from existing satellite data streams. Most users do not want low-level information products (e.g., water-leaving radiances from satellite ocean color sensors). Instead, they want distilled, integrated information (e.g., near-real time representations or predictions on fate and transport of pollutant-laden runoff). This challenge is being addressed by most if not all ongoing observing systems, but there is a significant need and opportunity for growth in this area.

Another remote sensing challenge, representing a longer-term research and development effort, is to develop new, improved and sustained satellite remote sensing capabilities for observing coastal regions. These include improved spatial, temporal and spectral resolution and coverage for existing observations (e.g., sea-surface height, vegetation cover and coral assessments, ocean color) and novel measurements (e.g., surface currents, three-dimensional vegetation structure, stream flow/river discharge). Continuity of selected existing space-based capabilities is a crucial need, particularly to assess accurately climate variability and change. These space-based observations support both basic research and sustained operations and should support the transfer of capabilities between them. In this context the IGOS Coastal Theme Report (Integrated Global Observing Strategy 2006) identifies specific observing priorities for space agencies to implement. Improved government funding for earth observations is absolutely required to address these priorities.

None of the promise of the observing systems will be realized unless sustained funding is forthcoming. The GEO process is to provide ministerial support for observing systems, but it may be too early to determine if this support will translate into financial security of a global program. Perhaps one indication of the difficulties for support can be found in the United States. The reports of the Pew Oceans Commission and the U.S. Commission on Ocean Policy were published in 2003 and 2004, respectively, to considerable fanfare. The development of a U.S. Integrated Ocean Observing System was a major component of the ''Blueprint'' for U.S. ocean policy (U.S. Commission on Ocean Policy 2004) and has been organizing around regional efforts and often short-term funding. However, in 2006 the Joint Ocean Commission Initiative, composed of commissioners from both of the original commissions, released a U.S. Ocean Policy Report Card (Joint Ocean Commission Initiative 2006) with an overall grade of D+. The grade for new funding for ocean policy and programs, the section related to IOOS, was F. It remains to be seen if sustained financial support becomes available.

Recommendations

Would the assessment of Duarte et al. (1992) be qualitatively the same today? They called for more comprehensive and larger scale efforts. The evidence is that the conceptual, technical and political foundations for sustained and large-scale observations are much better now than then. However, the task of implementing global, including coastal, observing systems is substantial and has not been achieved yet. Successful component and regional systems are recognized and the long-term strategies are being mapped in part through the GEO process. The implementation of the global program remains. To ensure success we make the following recommendations:

- Sustainable systems need cultivation. Positive feedback mechanisms are required among the various components of the system to foster interactions and improvements.
- Governments are unlikely to provide sustained support without connection to human wellbeing. Observing systems must provide clearly articulated value to society beyond the preservation of nature. The role of science in providing data and information that can enhance societal benefits including health and economic well-being must be exemplified in the application of knowledge derived from observing systems.
- Local monitoring programs in isolation have a significant probability of being non-sustainable. Redundancy among monitoring programs (resilience) should not be discouraged, and explicit linkage to larger scale observing systems should be fostered.
- Information management plays a central role and must target a timely delivery of products to address environmental problems appropriately. It requires a well-coordinated mechanism for interagency collaboration, and particular efforts are needed to promote that cooperation and improved information technology.
- Sustainable observing systems in the developing world are the largest challenge to global coverage. International and intergovernmental efforts are required if this challenge is to be met.

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