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Coastal initiative of the Global Terrestrial Observing System

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Abstract

The three global observing systems (the Global Climate Observing System (GCOS); the Global Oceanographic Observing System (GOOS); and the Global Terrestrial Observing System (GTOS)) are designed to detect and assess global change. A land-based coastal observing system initiative under GTOS is at the beginnings and will lead toward the integration of terrestrial and freshwater observations with marine observations under the auspices of coastal GOOS. The GTOS infrastructure already builds on national, regional and global programs for terrestrial observations, but more emphasis is needed on the unique circumstances of coastal ecosystems. Coastal GTOS will use the observing system philosophy and infrastructure to identify and improve access to data and information about coastal change; assist users to make that access systematically; ensure that appropriate measures are being or can be made; and integrate terrestrial observations with marine observations. Key variables have been defined for GTOS. But major challenges include evaluating these and others for coastal ecosystems and identifying the indicators of coastal condition that operate at appropriate scales.

1. Introduction

Observing systems are designed to detect, assess and predict global change and provide information to recognized users. Climate change and sea-level rise are phenomena most readily identified with global change. But observing systems also address phenomena that occur so commonly across the biosphere that they are in fact considered global. Eutrophication and erosion, which occur locally but commonly, are two of these. Observations are made on the various phenomena

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and used in models to provide information to interested parties. Both the observation variables and models may be considered "indicators" of the observing system. The users of this information of observing systems include organizations and individuals involved at understanding and/or managing national, regional or global scale ecology.

The coastal zone presents a particular challenge to assessing global change. The discontinuity between the land and ocean provides complexities that affect the capabilities of the three observing systems (the Global Climate Observing System (GCOS); the Global Oceanographic Observing System (GOOS); and the Global Terrestrial Observing System (GTOS)). The environmental diversity is great; the ecosystems span a wide range of productivities and susceptibilities to disturbance; human populations are dense in many coastal areas; and human activities significantly use and modify habitat [1–3].

There is a clear and recognized need to address the coastal zone in an integrated fashion within the observing system framework [4]. Much of the planning efforts to do so, thus far, have been through the Coastal-GOOS (C-GOOS), Living Marine Resources (LMR) and Health of the Oceans (HOTO) programs. These are under the auspices of Intergovernmental Oceanographic Commission (IOC), and the current activity is to merge them into a common program using the Coastal Ocean Observations Panel (COOP) [5]. The mission of each and the common program focus on assessing aspects of global change within the ocean, particularly coastal waters. The land, wetlands and fresh waters are considered important for the inputs and boundary conditions. Information about land-based conditions is critical, but the acquisition of that information is outside the perceived realm of responsibilities of these oceanographic programs. Therefore, it is critical to initiate a program that is responsible for the information concerning the terrestrial, wetland and coastal freshwater ecosystems appropriate to observing system needs. A land-based coastal observing program under GTOS will lead toward the integration of terrestrial observations with marine observations to understand better the dynamics of change and the magnitude of its impacts.

Numerous national, regional and global programs address aspects of coastal issues (e.g., [6,7]), but none integrates them into the context needed for observing systems. For example, conventions; such as the UN Framework Convention on Climate Change, the Ramsar Convention on Wetlands, and the Convention on Biological Diversity; include international commitments to specific coastal issues. Other international programs, such as the International Geosphere-Biosphere Programme (IGBP) and the International Long-term Ecological Research Program (ILTER), include coastal research activities. The Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) explicitly focuses on coastal issues with a concentration on sediment and nutrient flows from land into off-shore areas. The GTOS infrastructure already builds on these programs for terrestrial observations, but more emphasis is needed on the unique circumstances of coastal ecosystems.

This initiative serves as a support service to a number of the programs mentioned above. It will use the observing system philosophy to:

- identify and improve access to data and information about coastal change,
- assist users to make that access systematically,
- ensure that appropriate measures are being or can be made, and
- integrate terrestrial observations with marine observations to understand better the dynamics of change.

The coastal GTOS program is at its conception, and this workshop on indicators provides excellent opportunity for the program. Coastal GTOS needs to develop an array of indicators to achieve its goals across a potentially large number of phenomena of interest. A challenge is to find indicators that are appropriate to the scales of interest of an observing system. In this paper I address Coastal GTOS, its structure and goals. This provides a context for the use of indicators.

2. Users

Observing system protocols require that products of the observations be compatible with the needs of and freely accessible to potential users. Thus, indicators must serve specific and recognized clientele. Users may be at local, national, regional and global levels. But local users should generally not need the coordination of observing systems. Emphasis is on regional and global users, although national-scale users are foreseen. Users include the following:

- GTOS and other observing system programs themselves and in particular those associated with coastal waters (e.g., CGOOS, Baltic Operational Oceanographic System [BOOS], Global Sea Level Observing System [GLOSS]).
- The research community, including individual scientists and programs such as the European Land-Ocean Interaction Studies (ELOISE), Land-Ocean Interactions in the Coastal Zone (LOICZ), and ILTER.
- Programs associated with global change or global issues (e.g., IGBP, GPA, Coastal Zone Management Centre).
- Conventions, including the UN Framework Convention on Climate Change, the Ramsar Convention on Wetlands, and the Convention on Biological Diversity.
- Policy makers and environmental managers responsible for large scale systems (e.g., European Environment Agency, National Oceanic and Atmospheric Administration of the USA).
- Modelers working the range in scale from particular species populations of economic or social value to global climate change and biosphere response (e.g., Tool to Assess Regional and Global Environmental and health Targets for Sustainability (TARGETS) [6]).
- Non-governmental organizations for industry, transportation, tourism, agriculture, fisheries and environmentalism (e.g. European Chemical Industry Council, Wetlands international, Birdlife international).

3. Phenomena of interest

The overarching reason for this initiative is to ensure that land-based conditions of the complex and important coastal region are adequately represented within the global observation system. As such, the context for key issues of interest within observation systems can be divided into five categories:

(1) those whose effects contribute to global change,
(2) those whose effects contribute to large-scale regional change,
(3) those for which global change has significant local response,
(4) those for which large-scale regional change has significant local response, and
(5) those that occur so ubiquitously that the result is of global importance.

The coastal initiative of GTOS focuses on environmental issues related to terrestrial, freshwater aquatic and wetland ecosystems. These ecosystems may be highly populated and impacted by humans or relatively unaltered. Human society's interactions with these are included within the context of the modified pressure, state, response described by Bowen in this workshop. Some specific key issues have been identified and listed below:

- *Soil, sand and sediment movement.* The dynamics of soil and of sand and sediment, both above and below the water's surface, are critical features of the coastal zone that affect land use, shipping channels, and nutrient transfers.
- *Chemical contamination.* Chemicals from agriculture and industry include both growth-promoting nutrients and toxic pollutants. Potential access of them to waterways and to the human populations is high within coastal zones.
- *Carbon budget and primary productivity.* The fate of carbon in terrestrial ecosystems and estimation of global primary production involve two major GTOS programs. Although it is recognized that the coastal zone has ecosystems that are highly productive and can be peat forming, these systems are underrepresented in global networks.
- *Water quantity and quality.* The high densities of people at the ocean's edge potentiate the possibilities for a variety of problems. Potable water may be limiting, cultural eutrophication may be accentuated, and flooding frequency and intensity may be high.
- *Wetland conservation.* Sea-level controlled wetlands provide numerous goods and services, including flood water storage, migratory waterfowl habitat, and critical nursery areas for living marine resources.
- *Biodiversity and biocomplexity.* Coastal communities are subject to exploitation by over fishing, intrusions on the landscape by humans, and invasions of exotic species from shipping activities.
- *Sea-level rise from global climate change.* Perhaps one of the most important and uniquely coastal issues is effect of sea-level rise on the landscape. Development along the coast rarely has considered how future changes in sea level will affect hydrogeomorphology and land use.

Table 1
Relationships of coastal issues to the scale of their effects and forcings

Coastal issue	Effects are global	Effects are regional	Response to global change	Response to regional change	Ubiquitous
Sand and sediment movement		X	X	X	
Chemical contamination	X	X			X
Carbon budget and primary productivity	X	X	X	X	X
Water quantity and quality		X	X	X	X
Wetland conservation	X	X	X	X	X
Biodiversity and biocomplexity	X	X	X	X	X
Sea-level rise from global climate change			X	X	X

These issues are placed into the observation system context in Table 1. As can be seen, all of the recognized issues of specific concern within coastal ecosystems relate to more than one category of context of observation systems. Some are involved in feedback loops in which global or regional changes effect change within the coastal zone, and the resultant changes affect global or regional conditions. Interactions may be complex and involve multiple issues as well as scales. For example, global phenomena (e.g., sea-level rise and atmospheric carbon dioxide concentration changes) and local but ubiquitously occurring phenomena (e.g., eutrophication and wetland destruction) may affect coastal wetlands and lakes, their biodiversity and their ability to produce organic matter and sequester carbon [2,8]. These in turn may affect the availability and quality of habitat for waterfowl whose migrations are trans- or intercontinental [9,10] and local wetland sustainability [11].

4. Key observation requirements and relation to indicators

The observing system jargon generally does not include "indicators." Users are envisioned as defining the phenomena of interest to the observing systems. Observations are translated into the GTOS database as variables. These variables may be the indicators of the observing system or preludes to the indicators. The variables are used to create products. These products are often models, with different degrees of complexity. The outputs of these models may in themselves be indicators. Some users are capable of effecting change in the environment in response to the information they receive. It is envisioned that large-scale feedback systems, involving governmental and intergovernmental entities and the observing systems, will help ameliorate global change.

The observations proposed for this initiative are of terrestrial and fresh water variables and complement those described for the coastal oceans by CGOOS, LMR and HOTO and for other GTOS programs. For example, many of the observation variables and the protocols for their sampling (including sites, frequencies and methods) have already been designated under the Global Hierarchical Observing Strategy (GHOST), the GTOS sampling strategy. GHOST spans a large range of sampling intensities and sophistication from elaborate, intensive and large-scale experimental studies to simple periodic sampling on the ground to satellite-based measures. These have been systematically organized within the Terrestrial Ecosystem Monitoring Sites (TEMS), the GTOS metadatabase of terrestrial observing sites and networks. It allows querying by country, site, and eco-region. Sites can be identified by their distance from the coast. TEMS also lists over 100 variables that have been identified by GTOS (www.fao.org/gtos/tems/variable). Descriptions of each variable include definition, rationale, potential users, measurement method, units of measurement, frequency of measurement, spatial resolution, accuracy/precision required, associated measurements, present status, research and development needs, global/regional data holders, and data policy. Variables that have particular importance to the coastal zone (see previous section for list of key issues) have not yet been incorporated in GHOST and TEMS.

As of now, Coastal GTOS has not advanced to the point that a list of specific variables, models or indicators has been identified. Some variables have been suggested for Coastal GTOS by COOP [12]. These include "surface and groundwater transports of water, nutrients, sediments and contaminants". These are important input variables for CGOOS models. However, scale may be a complicating factor to the coordination of the two coastal programs. In other GTOS programs more emphasis has been on users with broader scales of interest. Important users of other GTOS products have included international agencies and conventions. Thus, the scales of user may also have to be coordinated between the two programs as well as the scales of measurement.

5. Scale

Hierarchy theory provides a mechanism to organize our perceptions of the world around us [13,14]. It recognizes that our world view involves both the nature of the observed and that of the observer. The observer views a part of nature of a certain scale or size. This scale has both dimensions of space and time. A person's ability to describe and predict is limited by the scale of observation. Scale has two boundary conditions: "grain" that defines the smallest level of observation and "extent" that defines the largest level of observation.

Recognizing grain and extent is important to developing the appropriate indicators for observing systems. Fine grain measurements can be readily made at the local level. For a simple example, a thermister can provide a continuous record of temperature for a site showing second to second changes. But this information is far more than what is necessary to address global or regional warming. The data may need significant filtering for the site, plus these data are only of use for observing systems if coupled to many other measures of temperature. Thus, the data needs at the scale of the observing system are less than what is collected at one site (i.e., the grain of measurement is too small) but more than can be supplied from the one site (i.e., the extent needed by the observing system is larger). Furthermore, grain and extent are issues for information management. If continuous records require considerable storage capacity, filtering requires proper decision making; and inclusion of multiple measurement sites requires considerable coordination. These issues need consideration, especially if one approaches the development of indicators from a cost/benefit perspective.

Hierarchy involves organization of systems within systems with resultant predictions as to how different levels can affect each other. Generally, lower levels or smaller components of systems provide the potential of the system. The higher levels provide the constraint or context for these lower levels. This concept provides a basis for appropriate scaling of indicators for observing systems. One should be able to infer predictions about regional or global phenomena from indicators chosen at the appropriate scale. Finding the appropriate scale, however, can be a challenge.

6. Status

As indicated, we are only beginning development of a coastal GTOS program. We will be having workshops to set priorities for and establish procedures to put the program into action through an implementation plan. The workshops will be composed of a panel of both terrestrial and ocean scientists and representatives of appropriate organizations. The panel will include members of both the GTOS and COOP communities.

GTOS has been successful in instituting its programs around a limited number of themes. One such theme is the Terrestrial Carbon Observations (TCO) (http://www.fao.org/gtos/TCO.html). This is one of the most developed and appears to be a likely candidate for an initial theme for coastal GTOS. The goals of TCO are the following:

- Demonstration of the capability of estimating annual net land–atmosphere fluxes of carbon at sub-continental scales ($\pm 30\%$) globally and regionally with better accuracy for some areas by 2005.
- Improvement of spatial resolution and accuracy ($\pm 20\%$) of estimates by 2008.
- Incorporation of satellite-based and in situ information for maps of flux emission estimates.

Coastal ecosystems are potentially important areas of flux associated with the global carbon budget. Fluxes may come from anthropogenic and natural sources, and their interaction may provide a positive feedback promoting even more flux. For example, the dense human populations contribute anthropogenic releases of carbon dioxide from fossil fuel use. Also, many sea-level controlled wetlands are peat forming and sequester carbon. However, as humans encroach upon the wetlands and if sea-level rise increases from global temperature increases, coastal wetlands will not provide as great a sink for carbon as they have in the past.

TCO has identified a group of digitally georeferenced products over a range of spatial and temporal scales. These may be considered indicators and include such items as land cover types and changes, leaf area index, growing season duration, CO_2 flux, net primary production and net ecosystem production. The scales differ among the measures. For example, land cover and types is to be addressed by satellite at the global and continental scales with a temporal frequency of seasonal, annual or 5 year. CO_2 fluxes are made at individual sites within the network at sub-daily frequency. It remains to be determined as to the coastal contributions to this process.

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