COASTAL FUTURES AND OCEAN OBSERVING INITIATIVES

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ABSTRACT

The Coastal Module has become the bottleneck in completing the Global Ocean Observing System (GOOS). The complexity of the coast as a social-ecological system demands nurturing a bottom-up collaborative process. At the scale of GOOS Regional Alliances (GRAs), member states need to take a few yet decisive steps to initiate this process. They must identify minimum core sets of priority coastal observations, for which competence, assets and commitments for sustained measurements exist. They will need to evolve a data sharing policy that is open, transparent and free or at minimum cost. A sustained capacity building program in modelling and planning by in-country scientists, and in the use of data products by user communities, should be established. Progress may proceed at incremental pace, focusing on one or few variables at a time, and building trust and experience as milestones of scientific collaboration. The long-standing impasse that has rendered developing country GRAs non- or minimally functional may then be broken. Smart coastal planning has to begin soon so resilience, not vulnerability, would underpin the fate of the planet's most productive ecotone.

1. INTRODUCTION

Coastal areas worldwide face many challenges in the 21st century including greater exposure to natural disasters for some, and increased livelihood dependence on degraded ecosystems for many. The need for data and information to address these issues is urgent. Despite the compelling need, many coastal states especially those with developing economies have yet to subscribe to international initiatives aimed at setting up coastal ocean observing systems beyond official paper agreements. This paper aims to examine underlying constraints that prevent meaningful participation, and to explore ways through which coastal states can work for common needs. It discusses data and information products that may engender purposeful engagement by coastal developing states. It highlights a minimum action program to mobilize GRAs (GOOS (Global Ocean Observing System) Regional Alliances). The analysis complements a community white paper by Malone et al. on a strategy to implement the coastal module of the Global Ocean Observing System [1]. It builds on recommendations proposed by community white papers on storm surges [2], on ecosystem monitoring using chlorophyll [3] and coral reef health [4], and on observations of local sea level changes [5].

2. COASTS ARE SOCIAL-ECOLOGICAL SYSTEMS

Acknowledging that the coast is shaped by interactions between humans and nature provides the basic context for examining the role coastal ocean observing systems may play in informing coastal governance. Culture, government and economy determine how society organized at different scales, gains access to and use coastal ecosystems (Fig. 1) [6, 7 and 8]. These interactions make the coast a social-ecological system (SES) and they determine its complex system attributes [9]. The social-ecological coast is vulnerable to factors such as disease outbreaks, market failure, political instability, climate change and natural disasters. At the same time, the linked system has properties that allow it to withstand exogenous shocks and maintain resilience. Prudent governance protects and enhances these properties to ensure that the integrity of human systems and ecosystems, including livelihoods, are sustained.

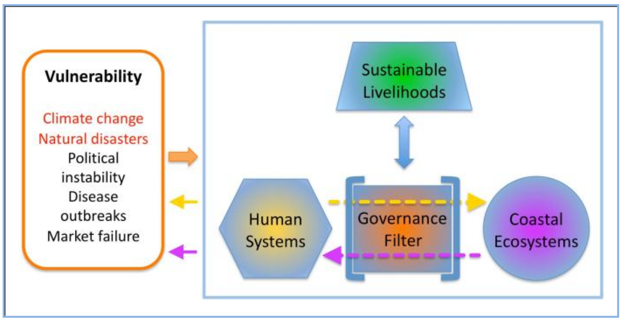

Figure 1. Societal need for livelihood determines the state of the coast as a social-ecological system (modified from [6, 7, and 8].

Data and information on the states of component systems and the changes they undergo are critical inputs to coastal governance. However, scientific information is just one of many factors that affect societal choices regarding ecosystems and the goods and services they provide. Power and leadership, voice and representation, and the market economy are palpable forces that can and do override science on the discussion platform [10]. For science to become policy relevant, it must squarely address the questions of decision-makers, imperfect though these answers may be [11]. It should elaborate on the consequences of societal choices, cognizant that uncertainty in predictions might translate to indecisiveness. At the end of the day, a society decides on these issues based on its collective ethic to protect human life and on its shared vision to conserve coastal ecosystems that provide livelihoods [10].

On the coast, jurisdictions and sovereignty play major roles in governance [12]. These provide the nuanced contexts that are unique from state to state for vetting whether or not to participate in internationally coordinated science initiatives like coastal ocean observing systems (COOS). Observing systems emphasize coordination and broad uniformity and interoperability of protocols for data acquisition, transfer, integration, and product development, among collaborating partners. Coastal governing systems, in contrast, operate as entities independent of other states, quite mindful of their sovereignty in identifying their perceived needs and solutions. Such fundamental difference creates conflicted mindsets among scientists and civil servants. It explains the mutually exclusive attitudes both harbors [13]. Such difference is not immediately obvious to nor is appreciated by both groups. The working environments of collaborative global science and that of coastal state governance may be unfamiliar to one another. Without further dialogue, the apparent conflict can erode the potential for a major mechanism like COOS to contribute to smart national coastal planning. The discussion below helps to elucidate why such difference in focus can become an initial stumbling block. Understanding these mindsets could in fact pave a sufficiently solid foundation so that the COOS can become a politically accepted and viable scientific mechanism for developing and using data products that are necessary to achieve sustainable coastal futures.

3. COASTAL OCEAN OBSERVING SYSTEMS: GOOS COASTAL MODULE

The vision and implementation plan for COOS as a module of the Global Ocean Observing System (GOOS) has been in development since the mid 1990s along with the evolution of various bodies to implement it. The strategic design and its implementation were articulated in 2003 and 2005, resp. [14 and 15]. A community white paper in this conference provides an update of the status of the GOOS Coastal module and provides a strategic action plan to further promote its implementation [1]. All the documents to date have envisioned a Global Coastal Network (GCN), the collaboration for which would consist of: (a) a global network of coastal laboratories to document local ecosystem states; (b) the global network of tide gauges (Global Sea Level Observing System or GLOSS); (c) sensors on at-sea stationary and moving platforms for measuring common variables; (d) ships of opportunity and voluntary observing ships; (e) research vessels and repeat survey programs; (f) land-based platforms with remote sensing capabilities; and (g) satellite and aircraft-based remote sensing assets. However, the set of variables to be monitored by the GCN has yet to be determined by the GOOS.

To organize the needed data collection capacities above, engagement of coastal states are facilitated mainly through the GOOS Regional Alliances (GRAs). They provide platforms where regional priorities are identified so that national and regional information needs critical to coastal planning could be met (Fig. 2). Since 2002, four GRA Fora have been held to facilitate implementation of GCN components and to explore interoperability among observing systems. In addition, the GOOS Regional Council has been established to provide a coordinating body as well as a mechanism for representing the GRAs at the Intergovernmental Committee for GOOS.

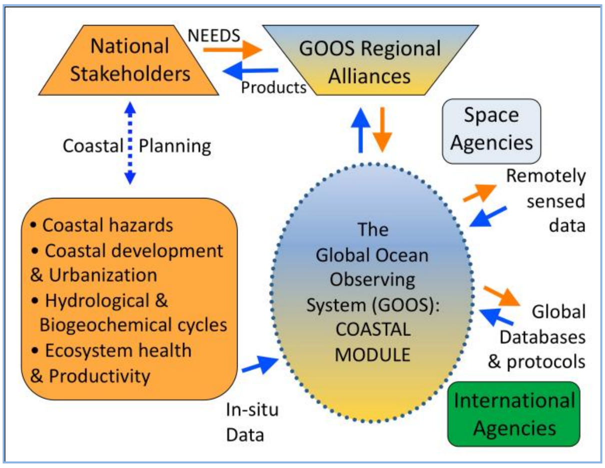

Figure 2. Institutions involved in the GOOS Coastal Module with national stakeholders defining their data needs. These prioritize the observation data collection and analyses as well as development of data products.

Despite having a community vetted and scientifically robust infrastructure and institutional blueprint to make the GOOS Coastal Module functional, progress has been slow and geographically uneven [1 and 13]. Among the GCN components, only the GLOSS is operational globally [13]. The Chlorophyll Global Integrated Network (ChloroGIN), which started as a GOOS/GEO (Global Ocean Observing System/Group on Earth Observations) demonstration project in 2006, is expanding successfully, and has the potential to become operational with global coverage [3]. GLOSS and ChloroGIN each tracks a single variable that is of immense value to local economies as well as to global science. Taking cue from these two success stories, might it be prudent to reconceptualize the GCN as one to be established as an incremental series of single-variable initiatives, building trust and experience on scientific collaboration along the way?

Across the GRAs with developing country members, cooperation with member countries and engagement in implementing regional and national component systems of the GCN has met with mixed success [16]. Some have been successful in developing operational data products like chlorophyll for use in fisheries management (such as ANTARES (Sustained Coastal Observing System for Latin America) in South America and the Indian Ocean GOOS) [3]. Others have yet to develop an implementation plan and to identify resources to carry one out (as in IOCARIBE (IOC (International Oceanographic Commission) Sub-commission for the Caribbean and Adjacent Regions)) [17 and 18]. Constraints in member state-sourced financial support, inadequate expertise and organizational capacities, and lack of national interest, are recurrent themes for some GRAs. A collective desire among member states to identify and implement an ocean observing system that is mutually beneficial underpins the existence of a functional GRA. Thus, a GRA reflects the collective strengths and weaknesses of its member states. When its leadership is able to build on shared commitments in resources and capacities and meet prioritized needs for ocean observations, the experience could become mutually reinforcing at national and regional scales. It is critical that coastal ocean observation systems be perceived as highly beneficial, and that national investments in scientific manpower and financial resources are justifiable commitments.

4. COOS AND NATIONAL PRIORITIES

What planning needs of a developing coastal state may be best met by a coastal ocean observing system? A framework that has been extremely useful in planning is the Sustainable Livelihoods Approach (SLA) (Fig. 3) [7 and 8]. It was originally intended to measure the effects of development projects on recipient countries. The framework examines factors relating livelihoods and livelihood assets that include the natural ecosystem-based services, and how these are vulnerable to climate change, natural disasters, and market failure, among others. Because the SLA framework explicitly uses key indicators of human wellbeing, ecosystem health and vulnerability, it has become a favoured tool in designing integrated human-environment assessments. Climate change and natural disasters that affect livelihood assets including ecosystem services (natural capital) and societal wellbeing can be made explicitly visible using the SL Approach. More importantly, the SLA allows one to assess inputs across multiple scales. This is necessary in order to capture interests and value systems across scales of human organization [19]. For biological systems, emergent properties are nested across the hierarchy of scale. In contrast, human values and interests cannot be totally subsumed by higher aggregations because representation is imperfect even among the most democratic institutions [9]. Thus, it is critical that public consultations at multiple levels become embedded mechanisms in decision-making processes.

The priority data needs for coastal ocean observations may be defined from local to national levels following the SLA framework. These may be implemented one or two variable at a time, accumulating experience in collecting and analyzing data as well as developing data products to support coastal planning. While coastal observing systems serve subnational jurisdictions, the support of state leaders is needed. State recognition of the utility of coastal observing systems in providing societal benefits enables critical international partnerships.

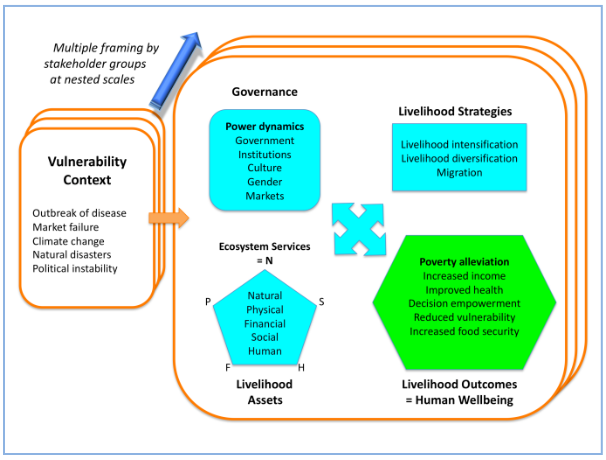

Figure 3. The sustainable livelihood approach takes into account vulnerabilities of natural resource-based livelihoods and uses indicators of ecosystem services and of human well being in integrated assessments (modified from 8 and 19).

5. A NEAR-FUTURE VISION OF COOS IN DEVELOPING COASTAL STATES

To envision how developing states may participate in adopting functional coastal ocean observing systems, this paper briefly describes data products and modelling studies that are essential components of coastal planning. These include mapping and modelling for disaster mitigation, and understanding both anthropogenic and natural processes that cause adverse coastal ecosystem changes, among others. This exercise by no means pre-empts coastal states from identifying their priorities for observation data and products. The discussion is provided to allow coastal scientists and managers to examine a sample of products along a gradient of increasing data demand and modelling complexity. They may then determine which ones are achievable given their current resources and capacities. In addition, managers and planners may identify data products that may be developed with investments in national capacity building as well as by active participation in a COOS regional network where common needs for data and data products may be met through mobilization and use of pooled resources.

5.1. Vulnerability Maps of Low-Lying Coastal Populations

A distribution map of coastal inhabitants by elevation and distance from the coast is necessary to determine vulnerability of populated areas to coastal flooding. The latter may be caused by storm surges, precipitation-induced river flows and by gradual sea level rise, among others. A global coastal population distribution map has been produced by Columbia University's Centre for International Earth Science Information Network [20] by overlaying three spatially explicit datasets: (a) high-resolution elevation data from the Shuttle Radar Topography Mission (SRTM); (b) national census-based population data; and (c) delineated urban footprint map based on the NOAA (National Oceanic and Atmospheric Administration) night-time light satellite data. All three geographic layers are at 1 km resolution. The maps and spreadsheets are available for download [21]. The distribution of coastal human populations around Manila Bay, Philippines is shown in Fig. 4.

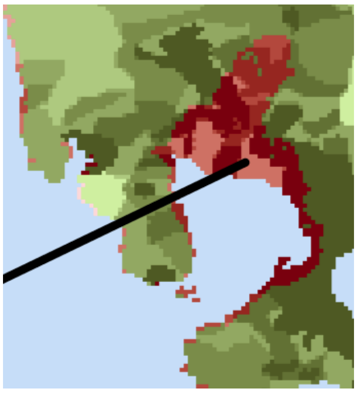

Figure 4. Population distribution around Manila Bay, Philippines indicating densities inside the 10 m low elevation coastal zone (shades of red), and outside the low lying areas (shades of green) (21).

National and local coastal planners can update the population data and provide additional data layers that will help in multipurpose planning including that for the delivery of emergency services in the event of natural disasters. Spatially explicit population data is also critical in implementing medium to long-term projections such as the allocation of coastal space for conservation and development. With additional biophysical and climate data, modelling various scenarios of vulnerability of coastal inhabitants in rural and urban communities to climate, environmental change and coastal development may be determined at finer resolution. Mitigation of these vulnerabilities may proceed more realistically and efficiently than without vulnerability maps.

5.2. Seamless Topographic-Bathymetric Mapping

In order to have more accurate projections of the extent of water movement from the coastal ocean to the coastal zone and its impacts under various climate change scenarios, it is critical to define the width of the shoreline. To discriminate the shoreline, it is necessary that bathymetric data for the coastal basin and topographic data for the adjacent land be seamlessly merged. Bathymetric and topographic data would need to use a common vertical reference datum. For countries with the technology, mapping using Light Detection And Ranging (LIDAR) techniques allows for highly resolved topographic-bathymetric mapping of the coastal zone (Fig. 5) [22].

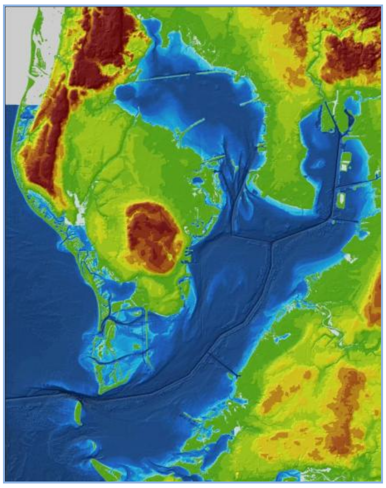

Figure 5. Seamless topographic-bathymetric map of Tampa Bay, Florida (22).

It is worth noting here that although shoreline detection has been done globally through products such as the World Vector Shoreline, the current resolution at 250 m is too coarse for coastal planning use. Presently, the US National Geospatial-Intelligence Agency is engaged in refining a Prototype Global Shoreline Data that is based on satellite derived High Water Line data (orthorectified NASA, 2000 era, LANDSAT (Land Remote Sensing Satellite) GeoCover) [23]. At its current state of development, the Global Shoreline Data set has not been tide- coordinated, even with an improved resolution of 50 m.

In areas where limited resources prohibit the use of the airborne LIDAR technology, a coastal mapping strategy may be implemented to resolve the coastline and to merge basin bathymetry and adjacent land topography. The strategy components include: (a) establishing real-time tidal measuring stations, (b) developing hydrodynamic models with tidal components, and (c) designing protocols to merge offshore bathymetric and onshore topographic datasets. Expertise in coastal physical oceanography is needed to develop tidal models and to integrate elevation and bathymetric data. Member countries may use Global elevation datasets such as that produced by the SRTM and which are currently available at 20 m horizontal and 16 m vertical accuracy. These may be further validated with finer resolution data where available. Digitizing historical nautical chart soundings in comparison with contemporaneous *in situ* depth measurements yields bathymetric data where LIDAR mapping is not possible. COOS GRAs may encourage national representatives to assess data and availability of expertise for coastal mapping, and examine realistic mechanisms to support and enhance this.

5.3. Modelling Coastal Physical Processes to address risks to natural disasters

With maps indicating the location by elevation of coastal inhabitants, the dynamic location of the shoreline, and the geomorphology of coastal basins and adjacent land areas, scenario models of natural and man-made disasters may be implemented. These can include models of coastal flooding resulting from storm surges and from extreme disasters such as tsunamis for tectonically active areas. Such models are essential to increasing preparedness and planning efficient mitigation and emergency protocols.

As an example, this paper examined current modelling initiatives on storm surges and tsunami run-ups in the Philippines. The latter is highly vulnerable to natural disasters including cyclones, earthquakes and volcanic eruptions. Drews created a 2009 coastal storm surge model for Manila Bay using a Regional Ocean Modeling System (ROMS), a modern Ocean General Circulation Model that can be configured at local to basin scale [24]. However, the model did not include tidal forcing which is the major driving force in the circulation of Manila Bay [25]. In addition, the model was not parameterized using real wind field data and instead assimilated an idealized hurricane wind field based on Hurricane Katrina 2005 parameters, which was not necessarily appropriate for mean tropical cyclone wind fields for the bay.

In the meantime, physical and geological oceanographers in the Philippines have empirical and modelled data on wind, bathymetry and tidal and wind-induced circulation of Manila Bay. They have not however assimilated these data into a coastal storm surge model because of lack of access to or resources in programming and computing capability to implement ocean general circulation models. ROMS is fairly new and has been in development only since 2002. Storm surge models have been developed for Manila Bay as early as 1984 using shallow water hydrodynamic equations. Since then, these have progressed from one (wind-driven barotropic component) to two dimensions (wind and tides), and with the inclusion of non-linear advection. Villanoy et al. have developed a circulation model for Manila Bay using the three-dimensional Princeton Ocean Model in order to explain *Pyrodinium* bloom dynamics as below [26].

In the case of tsunami, modelling, local bathymetry is crucial in determining the extent to which earthquake-induced wave front amplitude is reduced by bay mouth restriction and by wave breakage. The tsunami simulation models usually subsume four sequential processes: (a) seabed displacement to simulate an earthquake in a subduction zone; (b) initial wave generated by seabed displacement; (c) wave propagation using a dispersive oceanic wave model; and (d) wave amplification at shoreline. The last component requires detailed local basin scale studies on coastal processes including tidal circulation. For modelled tsunamis generated at the Manila Trench and entering Manila Bay, Løvholt et al. could not provide meaningful estimates of run-up times and amplitude using public domain bathymetric data from GEBCO1 (General Bathymetric Chart of the Oceans) [27].

The scenario above describing the constraints that face developing country scientists and their developed country counterparts is fairly typical. Such constraints may be strategically addressed by COOS GRAs by facilitating workshops through which scientists can come together to assimilate existing data such as those shown in Fig. 6. This would enable developing country expertise to build scenario models for coastal storm and tsunami surges, for example. The high potential to develop such data products in collaborative fashion is sufficiently appealing to engage the support of coastal states in implementing regionally coordinated efforts.

5.4. Modelling Coastal Ecosystem Change

The occurrence of harmful algal blooms in eutrophied coastal waters has spurred modelling in developing coastal states where fisheries-based food consumption is high. To continue with the example of Manila Bay, Villanoy et al. modelled the bloom dynamics of *Pyrodinium bahamense* var. *compressum,* a toxin-bearing dinoflagellate [26]. The distributions of *Pyrodinium* cells in the water column and of cysts in the sediments in relation to wind forcing, water circulation, and sediment dispersal, were examined. The authors employed a number of models to simulate wind-forced and tidally driven water circulation, wave influenced sediment resuspension and transport of *Pyrodinium* cysts. Modelled simulations indicate that maximum bottom currents achievable during spring tides and under constant wind forcing are sufficient to stimulate bloom formations when cell survival is allowed over a 15-day period and with a doubling time of 3 days. The simulations appeared to explain the timing of observed blooms in 1998 (Fig. 7).

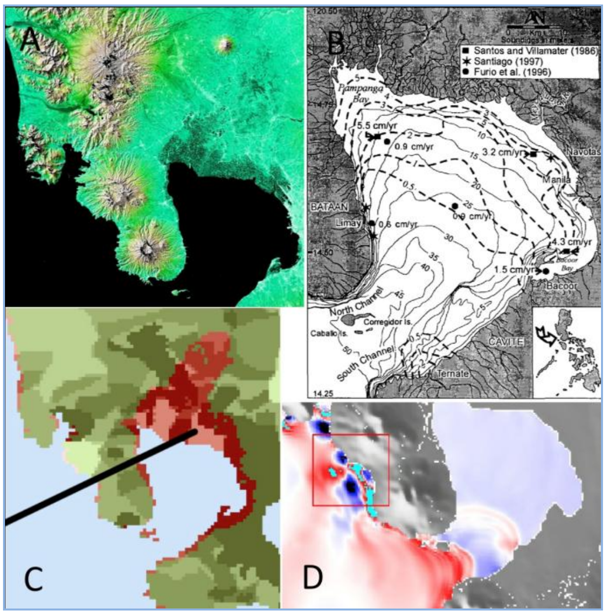

Figure 6. Merging data from multiple sources to develop vulnerability maps such as tsunami impact models for Manila Bay, Philippines: A. SRTM elevation map of areas around the bay (28); B. Bathymetry (29); C. Low elevation coastal population (21); D. Tsunami run up model constrained by lack of local bathymetric data (27).

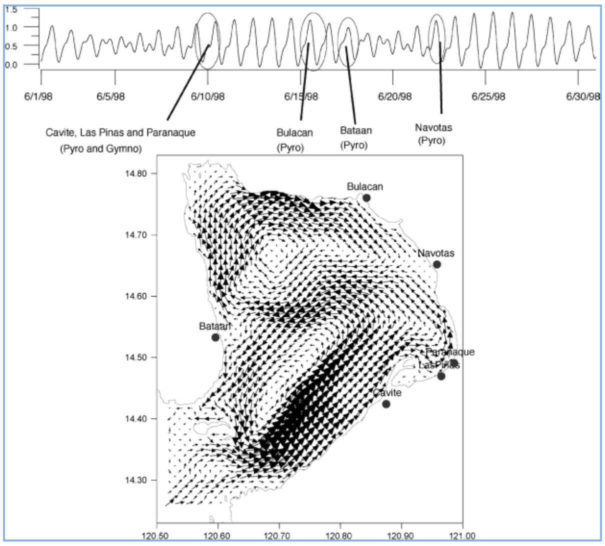

Figure 7. Modelling harmful algal blooms in Manila Bay (26).

When in-country competence to develop coupled biophysical models is advance, the need to obtain data on input parameters in real time is much more obvious. In developed countries, the concept of coastal observatories within a broad framework of ocean observing systems, with both in situ automated instrumentation and access to operational satellite-based data products, has increasingly become the normative approach [30]. In the US, the infrastructure to develop ocean- observing systems including coastal ocean observatories has been in development in the last two decades [30 and 31]. The initial investment in physical outlay and organizational structure is high, but is more cost-effective than traditional field campaigns that have limited spatial and temporal coverage.

For developing countries, the cost of setting up similar coastal observatories will remain prohibitive. This despite an increasing clamor for the knowledge they can generate in assisting countries to deal with natural disasters and climate and human-induced changes in coastal ecosystems. The model of a coastal observatory for developing countries may be modified to mean sustained field observations using existing resources. The key element is that funding for thematic ocean observations may have to transition from project funding with finite longevity to core institutional support with sustained government assistance. As knowledge products meet societal demands to enhance preparedness and mitigate losses from natural disasters and ecosystem changes, acquiring automated sensors with low-cost, low power acoustic transmitters, is no longer a remote possibility.

Developed countries such as Japan in Asia-Pacific, the US and Canada in the Americas and Caribbean, and the EU in Africa may have to expand their distributed cyber-infrastructure to regional scales to support increased capabilities among their developing country neighbors in operational oceanography. The US and Canada are pioneering this initiative for regional scale ocean observations [30]. In particular, NEPTUNE (NorthEast Pacific Time-Series Undersea Networked Experiments) Canada has launched the world's first regional-scale underwater ocean observatory with an 800 km cabled ocean observing system on the Juan de Fuca tectonic plate. The system is accessible through the worldwide web, engaging multiple audiences including the public and policy makers while scientists in their laboratories conduct their field campaigns remotely while in their home laboratories [32].

6. THE ROLE OF GOOS REGIONAL ALLIANCES

The growing awareness among developing coastal nations to increase knowledge about the ocean domain, and a realization to foster international collaboration is central to how GRAs may envision their role (Fig. 8). An appreciation that ocean observing systems can enhance a coastal nation’s capacity to minimize and mitigate what may otherwise be catastrophic consequences of natural and human-induced ecological disasters is necessary to establish a functional GRA. Furthermore, investments to enhance this process is money well spent compared to disaster aid, which is expensive, highly inefficient and insufficient to meet rebuilding needs in the aftermath of a catastrophe.

The contributions of Member States and the GRAs as well as the assessments provided by experts contained in the IOC Reports were reviewed for this section. The recent reports that examined the status of the GRAs [33, 34 and 35] were most helpful.

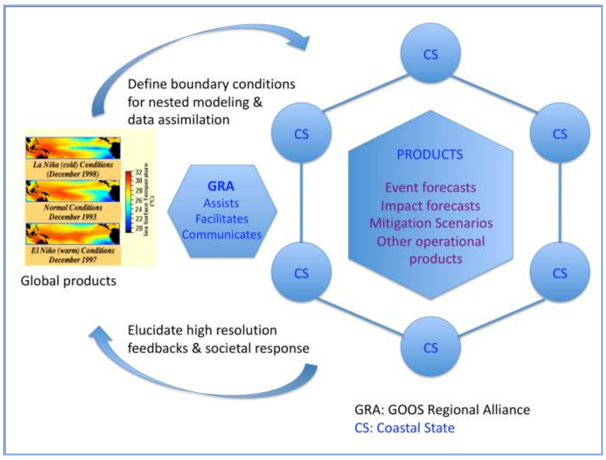

Figure 8. The functional relationships of Coastal States and the GOOS Regional Alliances (GRAs) in developing observation-based data products for the use of the former in coastal planning.

6.1. GRAs as platforms for multilateral strategic needs assessment

For coastal nations that have identified their needs for coastal ocean observations, GRAs can serve as platforms for identifying strategic and common needs. This can proceed at an incremental pace of one parameter/sensor at a time, as discussed in Sect. 3. Such needs from member countries must be coupled with formal statements of their willingness to invest in capacity and institutional building. These should accompany the acquisition of hardware and satellite data. The active participation of scientists from member countries in such assessments is fundamental. In addition, a transparent mechanism that fosters ownership of the assessment process and its outcomes, can lead to a sustained engagement of participants.

In 2006, the Coastal Theme of the Integrated Global Observing Strategy identified key coastal parameters for which sustained observations using remote and in-situ sensors are highly desirable [36]. Using this comprehensive list, this paper recommends that a draft core set of parameters be identified by each GRA. These can include: surface wave height and direction, wind speed and direction as well as salinity for geophysical observations; phytoplankton pigments, colored dissolved organic matter, and nutrients for biological/ biogeochemical observations; and land cover/ use and coastal ecosystem cover for ecosystem-level observations. Using this draft list, GRAs may conduct systematic assessments of modelling needs and observation capabilities at regional scales. These core set of parameters except those on areal extents of land and coastal ecosystems, are currently remotely measured for oceanic systems at coarser resolution and lower frequencies than what may be required for coastal studies. North-South partnerships in each region may develop strategies to build capacities in setting up in-situ measuring platforms and generating coastal models that are nested within larger basin scales, which maybe characterized using coarse scale forcing based on available satellite observations in the immediate term.

6.2. GRAs and data sharing principles

As research, groups develop local and national coastal plans using data and data products that have been developed out of international collaboration, one hopes that governments learn to respect and appreciate basic data sharing principles. Even more crucial is that this awareness spreads and triggers a more collaborative generation of knowledge and tools to understand the coast, where territorial lines are easier to draw than in the offshore. The motive and incipient infrastructure to do so exist.

At the global level for example, the Global Earth Observation System of Systems (GEOSS) 10-Year Implementation Plan adheres to the following data sharing principles [37 and 38]:

- Full and open exchange of data, metadata and products shared within GEOSS, recognizing relevant international instruments and national policies and legislation.
- Availability of all shared data, metadata and products with minimum time delay and at minimum cost.
- Sharing of data, metadata and products free of charge or at no more than cost of reproduction will be encouraged for research and education.

About 60 governments and the European Commission endorsed the Implementation Plan during the Third Earth Observation Summit in 2005. All new GEO (Group on Earth Observations) are required to endorse the Plan and the data sharing principles.

Another example at the global level is Google Earth that has been providing free high-resolution maps online since 2006. While not without controversy because of security issues surrounding military installations, Google has dealt with these on a case-to-case basis, collaborating with concerned countries on public data access of national-defense sensitive locations [39]. The impact of Google Earth as a data product in raising environmental awareness on planetary scale is unprecedented.

At the regional scale, data sharing principles may be more nuanced. In 2008, the European Union proposed its Earth Observation initiative called the Global Monitoring for Environment and Security (GMES). The program shall focus on land monitoring, emergency management, security (along jurisdictional borders), monitoring of the marine environment, atmosphere monitoring, and climate change adaptation and mitigation. It hopes to integrate space-based an in-situ observations (airborne, seaborne and ground-based installations) [40]. In 2009, a proposal for regulation of the GMES and its initial operations articulated the GMES Data and Information Policy. The latter shall aim for a "full and open access to information produced by GMES services and data collected through GMES infrastructure, *subject to relevant security restrictions…* [italics in this paper]*"* [40]. The GMES Program shall build on research made by participating states and groups, defined to include European Free Trade Association (EFTA) countries, candidate and potential counties based on Framework Agreements, the Swiss Confederation, other third countries and international organization in accordance with agreements concluded by the European Community with the latter [40]. By implication, participating states and organizations with contractual agreements with the European Community will have full and open access, and countries outside of this domain will have regulated access. Very recently, it was announced that an open access data policy would be adopted once the program's sentinel satellites become operational beginning in 2012.

At national and bilateral levels, there are excellent examples of operational free access policy for data and data products. In 2007, China and Brazil announced that imagery from their joint CBERS (China-Brazil Earth Resources Satellite*s)* satellite missions would be freely accessible through the worldwide web. In 2008, the US Geological Survey opened the Landsat archive for free access.

While issues about intellectual property rights and environmental, economic and national security remain, it is important to weigh these against the need to promote data sharing policies that provide the greatest societal benefits from local to global scales. Open and free (minimum-cost) data policy nurtures public and private support, making the process from data generation to data and data products delivery feasible, efficient and cost-effective.

6.3. GRAs as facilitators to leverage multilateral support

Identified strategic needs provide excellent bases for building interactive countrywide action and regional (multilateral) programs. Such cooperation warrants support from international donors including the Global Environment Facility (GEF) of the World Bank. The GRAs can facilitate a process that will translate the identified needs into fundable action programs, underscoring in-country investments to match requests for international support. The GEF portfolio includes the assessments of international (transboundary) waters from lakes, groundwater, and rivers, and large marine and open ocean ecosystems. It is logical to include coastal ocean observing systems as a necessary component in these regional water system assessments, especially those of the large marine ecosystems. The GRAs can facilitate a bottom-up assessment and which is an excellent opportunity for GEF to support.

6.4. GRAs as hubs of regional operational oceanography

With definite targets identified and financial support leveraged to meet these goals, one can envision GRAs to become hubs of scientific activity in operational physical and ecological oceanography. They may then generate data products and knowledge at scales appropriate for coastal ocean planning by member states. As the latter gains, incremental experience in multilateral scientific cooperation and in using the products for integrated planning, one can envision that the GRAs can become sustainable institutions. The process would need to start soon, but not without the momentum that should be seeded at national scale.

7. CONCLUSION

Coastal ocean observing systems are scientific tools that can revolutionize oceanography and coastal planning in the 21st century in a profound way. To build them, coastal states need to share a vision to monitor their oceans in real time so they can better respond to planetary changes that often entail loss of lives and livelihoods. Collaboration to realize this vision has had a rough journey, but the potential that it will flourish with purpose remains high. A strategic identification of coastal observation priorities for common measurements using satellite, airborne, sea and land installations; an open and free access data sharing policy, and a sustained capacity building program to engage developing coastal country scientists and user communities are key areas that GRAs need to address. The current challenges to implement these are daunting but perpetuating the default situation is simply unacceptable.

8. REFERENCES

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