Ocean and Coastal Observations: Challenges and Opportunities

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ABSTRACT

Ocean and coastal observations benefit the society and economy in a variety of ways. However, there are obstacles and other challenges that prevent us from achieving its full benefits. Meanwhile, new opportunities to advance these enterprises have been opened up by technological advances, demands to resolve critical issues such as climate change, decreasing supply of energy and fishery, degradation of ocean environment, competing and conflicting uses of ocean resources, and trends of increasing globalization and international collaboration. A timely assessment of the challenges and opportunities, followed by strategic actions, will allow us to advance observation capability and provide high quality ocean and coastal data and information products and services.

The advancement in observation technology through innovative research, efficient transition of research results to practical applications, and strategic international partnership can also elevate the ocean industrial capacity in Taiwan.

This paper discusses the challenges and opportunities in ocean and coastal observations with emphasis on their applications to Taiwan. An example of international collaboration is suggested.

Key word: Taiwan, ocean and coastal observations, innovation, collaboration, research to application, ocean industry

1. Introduction

Ocean and coastal observations (For brief, the term ocean observation will be used in the following text) provide data and information products and services that benefit the society and economy in a variety of ways. These include improving the performance of model forecasting and prediction of weather, climate and ecosystem; making sound assessments of long-term environmental changes; conducting efficient emergency response to environmental disasters; and aiding decision making and management on ocean and coast related matters such as adaptation to climate change, resource utilization, and protection of human health and maritime security [1, 2]. However, there are obstacles, inadequacies, inefficiencies, global pressures, limited funding and support, and other challenges that restrain us from reaching its full benefits.

Meanwhile, new opportunities are being opened up by technological advances, demands and pressures to respond to critical domestic and international issues such as climate change, decreasing natural resources, degradation of ocean environment, competing and conflicting uses of ocean resources, and emerging trends of increasing globalization and international collaboration.

A timely assessment of these challenges and opportunities, followed by strategic actions, will allow us to advance observation capability to develop high quality data and information products and services. The advancement in observation technology through innovative research and efficient transition of research results to applications, and strategic international partnership could also elevate and widen industrial capacity in Taiwan.

This paper discusses the challenges and opportunities with emphasis on advancing both the ocean observation capability and industrial capacity in Taiwan. Examples of international collaborations are also briefly discussed.

2. Challenges

Challenges to ocean observation include obstacles, inadequacies, inefficiencies, global pressures, limited funding and support and other critical needs. These are briefly discussed in the following.

2.1 General state of the ocean [3]. About 99% of the world ocean floor and 95% of ocean water, especially the water columns, have not been observed. Knowledge of biological and geological activities, chemical and physical processes in these media is needed for better understanding of the earth evolution and for discovery and management of new resources.

2.2 Climate change [4]. In spite of the observed and predicted climate changes and associated impacts (e.g., sea level rise and associated salt water infiltration, warming of ocean water, alternation of ocean currents and extreme weather, increasing coastline erosion, melting of Arctic ice sheet, etc.), there are uncertainties and information gaps that need to be resolved. Examples include regional variability, global transfer of water, heat and carbon, and ocean acidification.

2.3 Utilization of ocean and coastal resources [5, 6].

There are increasing human activities in the ocean and coastal waters (e.g., marine transportation and commerce, recreation and tourism) and uses of other ocean and coastal resources. Over exploitation combined with the lack of adequate observation and forecasting/warning have resulted in degradation of ocean water quality and threaten marine ecosystem, human health, and sustainable marine resource utilization. Examples include overfishing, massive fish kills, harmful algal blooms, marine accidents, large scale oil spill, and increasing number of conflicting and competing uses.

2.4 Observation technologies and methods [4-7].

Remote sensing - Existing systems are mostly research-driven and fixed duration missions focused on operational weather prediction. They are not adequate to support climate change research which requires long-term and integrated data collection of physical and biological process in both ocean and atmosphere, and adequate ocean ground truth observations

In-situ sensing – There are urgent needs to establish autonomous observation in harsh environment, develop reliable bio-chemical sensors, and improve sea level measurement using advanced sensors, satellite altimetry, and gravimetry. The lack of adequate in-situ ocean observation to track global transfer of water, heat and carbon has also affected the performance of climate and weather prediction models.

Methods – Traditional patch work observation approach to meet special need is not adequate. Integrated, sustained long-term real-time observing network from both space and in-situ sensing is needed to support scientific research, engineering application and aid to ocean and coastal management and policy development.

Data and data management - Existing marine data are mostly fragmented and lack of common agreed standards (e.g., measurement units, nomenclatures, measurement methods, and quality control criteria). The lack of adequate communication between different disciplines and feedback mechanism between users and data providers also impedes the improvement of data quality and applications. Other challenges include integrating data from different sources; efficient management of large volume data with compatible format from various systems; archive and retrieval of real-time data; and mechanism to receive data from private sources.

2.5 Global pressures [4-7].

Global competition – Increasing globalization has heightened worldwide competition for resource development and utilization. The associated issues such as maritime safety and security, ocean environment sustainability, efficient ocean observation become increasingly important.

Shortage of natural resources – The decreasing supply of conventional natural resources (e.g., fossil fuel and major fish stocks) results in increased global efforts in developing new ocean resources (e.g., renewable energy, offshore aquaculture and biochemical materials). However, the lack of long-term physical ocean data such as winds, waves, and currents has slowed down the progress of these efforts.

International law and treaties – The U.N. Law of the Sea and increasing number of national treaties and agreements have significant implications on future uses and claims of resource and territorial (e.g., Economic Exclusive Zone, continental shelf, and polar frontiers). Adequate environmental data (e.g., from observation and hydrographic and geological surveys) will help resolve any potential disputes.

2.6 Sustainable coastal community [4, 5, 8].

Recurring natural hazards (e.g., typhoon/ hurricane, storm surge, flooding, wind), sea level rise (due to global warming and/or land subsidence), extreme events (e.g., tsunami) and other human-induced risks (e.g., marine accidents, oil spill, harmful algal bloom) often cause severe socioeconomic damages to coastal community. Figures 1 and 2 illustrate these challenges. The lack of long-term real-time observation (e.g., winds, waves, currents, and sediment movements) will affect the community's ability to response, mitigate, adapt and rebuild.

2.7 Funding, support and workforce [5, 6].

Limited funding, inadequate support (from government, industry, research institutions, and general public) and workforce (quality and quantity) are common barriers affecting the advancement in ocean observation. Public awareness of the importance of ocean enterprises (e.g., observation network, sensor R&D, exploration) is also critical to long-term success in ocean observation. The education and training of knowledgeable and efficient workforce (e.g., innovation, multi-disciplinary team building, hand-on skills, continuing skill development) are keys to build and operate modern observation systems.

2.8 Coordination, communication, and collaboration [6, 9]**.** The lack of adequate coordination, communication, and collaboration among academia, industry, and international partners often limits the ability to solve complex ocean problems (e.g., development and validation of marine weather forecasting models, acquiring data to support global climate change research).

2.9 Research-to-application. Inefficiency in transitioning research results to application is a major barrier in advancing ocean-related industry or business. Innovative research in ocean observation technology and efficient research-to-application transition shall help overcome this challenge.

3. Opportunities

The challenges described above, if strategically addressed, are also opportunities to generate larger socioeconomic benefits. In addition, the following favorable trends, both domestic and international, have created good opportunities for advancing ocean observation and for promoting related industrial products and services.

3.1 Domestic trends [13, 14]**.** The recent (2008) establishment of Taiwan Ocean Research Institute (TORI) as one of the nine major national research institutes provides excellent opportunities for ocean research and for advancing Taiwan's capability in ocean observation and marine industry. The currently low funding level should not reflect TORI's significance and future potential (Note that the 2008 Korean Ocean Research and Development Laboratory budget was about 130 times larger than TORI, while South Korea has a coastline that is only about 1.5 times longer.)

The expanding trade with Mainland China will significantly increase the marine transportation and commerce activities in the Taiwan Strait. This will require better ocean observation, monitoring, and marine weather forecasting and warning to provide a safe and efficient operating condition and a sustainable ocean environment.

3.2 International trends.

Technological developments [7] - The emerging unmanned mobile underwater vehicles (e.g., ROVs, AUVs, gliders) and unmanned aircraft system (UAS) (Fig. 3) are especially useful for observation and exploration in deep depths, open oceans, dynamic continental shelves and harsh polar oceans. Advances in other areas such as hydrographic survey instruments, digital data technology, high-resolution video, data/information communication networking infrastructure, and biochemical sensors also provide great opportunities to improve the capabilities in ocean observation.

Climate change research [4, 8, 9] - The awareness of the significance of impacts and consequences associated with climate change and the important role of ocean in the climate system promotes opportunities to advance existing observation systems and developing useful data/information products and services These products and services will support a range of applications such as better prediction models, ocean renewable energy development, ocean carbon sequestration, and adaptation engineering.

Sustainable coastal community [4, 5, 8] – The resilience of coastal community against recurring natural disasters, extreme events and climate change impacts depends on quality real-time data to provide reliable forecast, warning and prediction and to aid managers in making sound and timely decisions.

Integrated observation system [7, 9-12] – Integrated, sustainable long-term observation system provides high-resolution data and is capable of supporting a wide range of operational services such as weather forecast, coastal storm warning, algal bloom monitoring, fishery and coastal management. It is becoming a high priority effort in the North America and European nations. Examples include the U.S. Integrated Ocean Observing System (IOOS). More recently, large ocean basin wide observation systems are also being planned or established. Examples include the U.S. Ocean Observatories Initiative (OOI), Canada/U.S. NEPTUNE, and European Union's ESONET. These systems will provide integrated, long-term observations using multi-disciplinary sensors and advanced sensor networking and internet-based data communication. Fig. 4 shows design components of the U.S. OOI system. Many innovative design and operational approaches are employed in these systems. They provide good opportunity to engage in the next generation observation technology development.

Offshore aquaculture [5, 6] – With increasing demand of seafood and a decreasing wild fish stocks, fish farming in the offshore waters is starting to grow (e.g., Norway, U.S. and South Korea). This opens up doors for developing efficient ocean environmental observing and monitoring techniques and methods to ensure sustainable ocean environment.

Globalization and Partnership [6, 9, 14] - The Increasing global business development has created an environment of competitiveness and innovation toward ocean resources exploration and utilization. This will require efficient ocean data collection and information services to support these efforts. The awareness of the need for partnership to resolve complex ocean problems (e.g., ocean climate observation, large scale ocean modeling) calls for better coordination, communication and collaborations among national and regional partners. The Norway's salmon farms in south Chile, the installation of UK's wave energy conversion system in Portugal, and the establishment of ROK's tropical ocean research center in Chuuk, Federated States of Micronesia for exploration of new chemicals, pharmaceuticals and source of food are examples of new approaches to promote ocean enterprises through international partnership.

5. Promoting Ocean Industry in Taiwan

As global business becomes increasingly competitive, it is significant that the advancement in Taiwan's ocean observation could lead to the advancement of its ocean-related industrial capability. The following is a brief analysis of this issue.

5.1 Assets and core capacities [13, 16]**.** Taiwan has many significant and unique advantages and core capacities in advancing its ocean-related industry enterprise. This include its strategic location for global marine transportation and commerce and easy access to the world ocean (Figs. 1, 2); favorable climate for year-round coastal and marine operation; well established technology and manufacturing bases (e.g., semiconductor, communication devices, computer, biotechnology, and small to medium sized manufacturing); sound business environment (as indicated by the Global Competiveness Index ranking of #12, vs. ROK's #19); as well as established education and research systems as indicated by the achievement in research paper publications (e.g., Science Citation Index, and Engineering Index) and results of International Olympiad of Physics and Mathematics.

5.2 Potential development areas [7, 17, 18]**.** These can be identified based on careful analysis of assets, core capacities (strengths), global markets, strategies, etc. The following are examples for reference: data (including in-situ, gridded satellite and model outputs, and images) processing and display tools (e.g., integrated sensor network real-time data processing, data synthesis, integrated sonar data processing; 3D or 4D visualization); instrumentation (e.g., innovative smart sensor using MEMS and nanotechnology; biological and chemical sensors with effective biofouling protection); power supply (e.g., high energy density, small volume power source, renewable ocean energy utilization); sensor networking and data communication (e.g., an ocean IT including two-way, broad-band near real-time digital data communication between sensors and system operator and between unmanned underwater vehicle to shore/or ship via satellite; networking and Internet); data and information dissemination (e.g., efficient near real-time data/information delivery to users utilizing existing and emerging advanced digital display devices).

5.3 Innovation and efficient transition of research results into applications. These are key factors in advancing the industrial enterprises and achieve a sustainable economy. Some successful approaches employed in the U.S. to improve innovation include: hands-on education (e.g., emphasizing integration of theory with hands-on learning, early participation of multi-disciplinary projects and design challenges), non-requirement-based research program (e.g., DARPA), and Small Business Innovation Research (SBIR) program (a mechanism to meet agency's needs through innovative research and product development by small business sector).

In promoting efficient transition, the U.S. NOAA implemented a transition policy and procedures [19] that emphasize identification of promising ideas; transition plan with identified resources; transition team consisting of researchers and users including industry partners; review, checks and balances in investment decisions and implementations at various project phases; and prototype system test and evaluation.

6. Example of International Collaboration

The author suggests a synergic collaboration effort to collect comprehensive high-quality ocean and coastal data set for validating the hydrodynamic forecasting model(s) for the Taiwan Strait (Larger ocean coverage could be considered later). This will significantly improve the accuracy and reliability of the existing forecasting tool. Since the ocean domain of such model is large and often shared by several international parties or regions (Fig. 1). It is cost effective and efficient to collect this data set via international partnership. The benefits of such a reference data set will be shared by all participating partners. Potential partners include Taiwan, mainland China, South Korea, Japan, and the United States (and Vietnam and the Philippines later for larger ocean domain). These partners can be either model developer(s) or users.

7. Conclusion

Among the challenges and opportunities discussed in the text, the following remarks are significant to the advancement of Taiwan's Ocean observation and ocean-related industrial capacity:

a) The establishment of Taiwan Ocean Research Institute (TORI) provides opportunity for advancing ocean R&D. Close communication and collaboration with other national laboratories, agencies, universities, and industry, as well as increasing public awareness of the benefits of ocean enterprise shall help TORI to reach its full potential.

b) An integrated, sustainable long-term, observation system is needed to address issues of competing and conflicting uses of ocean and coastal resources, hazard resilient coastal communities, and impacts of climate change.

c) Strong capability in ocean observation shall help improve competitiveness in the global business environment and resolve any future international disputes in the utilization and claims of marine resources and territories.

d) The busy shipping routes around Taiwan and the increasing marine transportation and commerce activities with Mainland China calls for better observation capability to provide safe and efficient transportation and sustainable ocean environment.

e) Global collaboration is needed to resolve complex ocean issues, explore new ocean resources and expand maritime commence. A collaborative effort to validate the hydrodynamic (for currents, waves, water level, etc.) forecast model is suggested.

f) Taiwan has unique ocean assets and core technologies and industrial strength to expand its ocean-related industry. Innovation and efficient transition of research results to practical products and services should be emphasized. The emerging ocean observation systems (e.g., the U.S. OOI) provide technological directions that future ocean observations are heading. These could be viewed as guide for Taiwan ocean industrial development.

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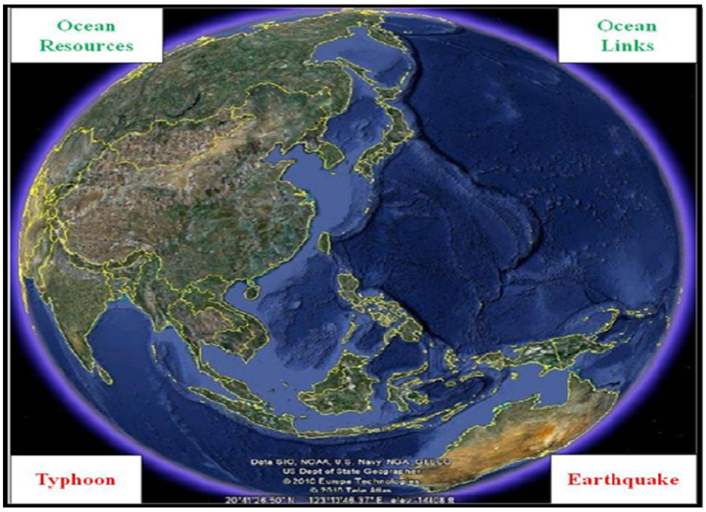

Fig. 1 Taiwan's strategic location and major natural challenges and opportunities (courtesy of Google Earth)

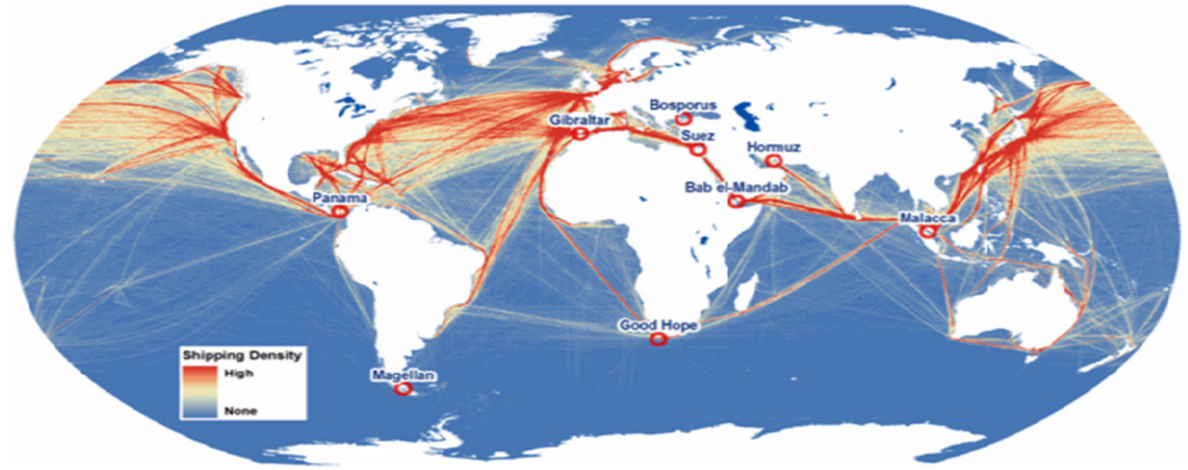

Fig. 2 Global Shipping Lanes (Courtesy University of California at Santa Barbara [16])

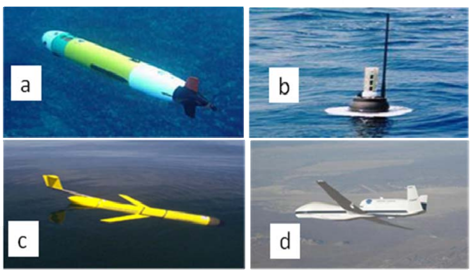

Fig. 3 Mobile observation platforms (a: AUV, b: Argo float, c: glider, d: UAS) (Courtesy of NSF, NOAA, NASA)

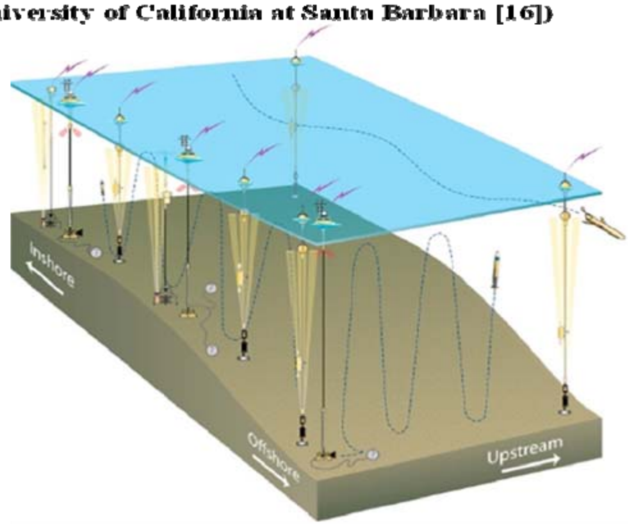

Fig. 4 Example of U.S. Ocean Observatory Initiative design with moored fixed sensors, profilers, AUV and glider [12]