AN INTEGRATED OCEAN OBSERVING SYSTEM (IOOS®): A US BASED OPERATIONAL WAVE OBSERVATION PLAN

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1. ABSTRACT

The deployment of an *Ocean Observing System* is one of three central science and technology elements of the Ocean Research Priority Plan issued by the Joint Subcommittee on Ocean and Science and Technology in January 2007. In support of this goal, this document presents an operational plan for observing waves along the US coastlines [1], one of the most important ocean variables, as part of the national Integrated Ocean Observing System (IOOS®).

2. INTRODUCTION

On any given day, the ocean surface is occupied by surface wave patterns that are derived by different mechanisms. A good way to characterize one wave form from another is based on the wave period (defined as the time between successive wave crests). Reference [2] identified waves, from short capillary waves, to long tidal motion in terms of their relative wave period and their disturbing and restoring forces. The waves entering and crossing the nation's waters, whether generated by a distant Pacific storm, local sea breeze, or a hurricane in the Gulf of Mexico, have a profound impact on navigation, offshore operations, recreation, safety, and the economic vitality of the nation's maritime and coastal communities.

User requirements for short-term wave information differ: commercial fisherman want the wave conditions at their fishing grounds, as well as a forecast for the length of their trip; ship captains on the Columbia River want to know if they will be able to safely clear the waves breaking on the dangerous outer bar before they leave port; surfers look for large swell while recreational fisherman and divers seek calm waters; lifeguards want to know if the high surf warnings of yesterday will be needed today; marine engineers require continuous wave measurements in order to identify extreme waves; and Navy and commercial ship captains require wave information for safe and efficient ship routing to reduce fuel usage. Long-term wave records are also important for studies of climate change and the development of climate information for the design of coastal and offshore structures and facilities.

This National Operational Wave Observation Plan [1] focuses on wind-generated gravity waves as other national programs already focus on the measurement of tides (NOAA's National Water Level Observation Network), and tsunamis (NOAA's Deep-ocean Assessment and Reporting of Tsunamis, DART® program).

Moreover, existing locations were placed based on local requirements, resulting in a useful, but ad hoc wave network with limited integration of the observations into user products, (Fig 1). The proposed system will increase the wave observation spatial coverage along and across the US coasts; and will serve as a stimulus for wave modelling activities in verification/validation, improvements, data fusion and assimilation. The design will complement existing and future remote sensing programs (land and satellite based systems). This effort will also coordinate with and leverage related international efforts, such as the Global Earth Observing System of Systems (GEOSS).

3. THE WAVES PLAN

The plan is comprehensive in that it defines a level of measurement accuracy that will serve the requirements of the broadest range of wave information users. This plan recognizes that in order to serve the broadest range of IOOS users, that a national wave observation network should accurately resolve the details of the directional wave field. To achieve this requires that the observations satisfy a First-5 standard. Setting the standard to a First-5 level will directly lead to improved estimates in height, period, direction, and provide better information to all users of wave information. First-5 refers to 5 fourier coefficients defining variables at a particular wave frequency. The first variable is the wave energy, related to the wave height, and the other four are the first four coefficients of the Fourier series that defines the directional distribution of that energy. The second, third and fourth moment descriptors can better rectify multiple wave systems in direction space, compared to sensors not providing this information.

The plan identifies existing wave observation assets, presents a comprehensive system design and then makes

Figure 1. Location of existing wave measurement sites along the US coastline.

specific recommendations to (1) upgrade existing sensors; (2) add additional observations in critical "gap" locations; (3) implement a continuous technology testing and evaluation program; (4) support the Quality Assurance / Quality Control and data integration of wave observations from a large number of IOOS operators; (5) support the operation and maintenance requirements of the system; (6) include the training and education of IOOS wave operators; and (7) promote the development of new sensors and measurement techniques.

4. THE DESIGN

The design of the network is based on establishing four along-coast observational subnets (Fig 2). These include:

- Offshore Subnet: deep ocean outpost stations that observe approaching waves, prior to their passage into coastal boundary currents;
- Outer-Shelf Subnet: an array of stations along the deepwater edge of the continental shelf-break where waves begin to transition from deep to shallow water behaviour;
- Inner-Shelf Subnet: on wide continental shelves (notably the Atlantic and Gulf of Mexico coasts), an array of shallow water stations to monitor cross-shelf bottom dissipation and wind generation of waves;
- Coastal Subnet: shallow coastal wave observations, which provide local, site-specific information.

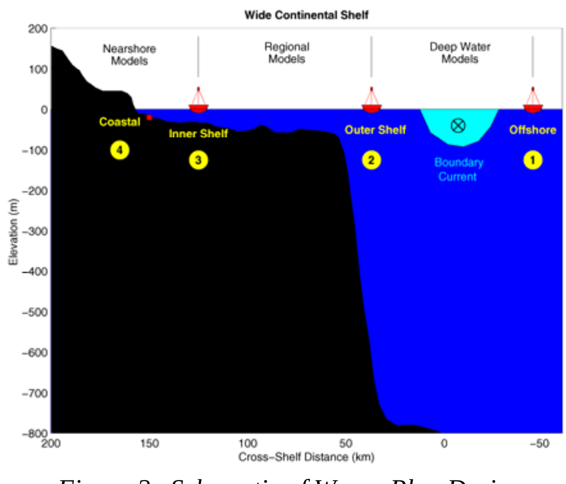

Figure 2. Schematic of Waves Plan Design

5. SUMMARY

For the first time, experts in the wave community have designed a wave network that meets the nation's needs. The development and implementation of this National Operational Wave Observation Plan will provide a consistent network of accurate First-5 directional wave measurements along the US coast from deep to shallow water. The design is based on four subnets which acknowledge the natural scaling of the generation, propagation and transformation of directional waves. The underlying motivation of this schema is to align the observation system with wave modelling activities with the goal of significantly improving wave forecasts [3], [4], [5]. First-5 quality directional measurements will not only provide verification of modelling efforts, they will also lead to improvements in technological advancements, useful in data fusion and assimilation techniques, improve and extend a wide range of wave observation-based products and serve as ground truth for the next generation of wave models and satellite based remote sensing systems.

The plan divides the US coastline into seven primary regions: Atlantic, Gulf of Mexico, Pacific, Alaska, Hawaii and South Pacific Islands, Great Lakes, and the Caribbean Sea. The subnets for each region were first defined by incorporating existing assets and then expanded based on physical principles of wave mechanisms, and requests from the Regional Associations. When completed, the observation network will include a total of 296 sensors: 56 in the Offshore, 60 Outer-Shelf, 47 Inner-Shelf, and 133 Coastal. Of these, 115 will be new locations. Directional upgrades are anticipated at 128 locations. This design has for years been used successfully along the California coast to incorporate wave measurements with modelling in order to fulfil the needs of a large user community for both real-time observations and forecast wave conditions.

Multiple tasks will be undertaken during the implementation process including testing existing directional platforms to determine First-5 capability; rigorous field evaluation of pre-emerging technologies that could substantially reduce procurement costs; and deployment of new assets. The plan will support IOOS® DMAC data requirements and flow wave data through the IOOS Data Assembly Centers and to permanent data archives. An integral part of this plan is to continuously review the deployment progress to add or modify the placement of new directional wave assets.

The benefits to the large and diverse community of IOOS users will be significant. The plan, when implemented will equally serve requirements for general wave information in the form of height, period, and direction. It will also serve users requiring detailed, highly accurate directional wave information. The nationwide availability of real-time directional wave data will provide timely information to commercial, Naval, and recreational boating; minimize loss-of-life and property through improved forecasts, aid the US Coast Guard in their search and rescue mission, and serve the heavily populated US coastlines during storms, hurricanes, and tourist seasons.

6. REFERENCES

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