

## **SCOOP: ENABLING A NETWORK OF OCEAN OBSERVATIONS FOR MITIGATING COASTAL HAZARDS**

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### **Introduction**

The death toll and costly damage caused by Hurricanes Katrina and Rita emphasize the need to improve our nation's ability to rapidly assess, predict, and mitigate the impacts of large storms. As part of a relatively broad goal of rapid environmental assessment and prediction, we must improve our ability to quickly and accurately measure and forecast phenomena such as storm surge and waves. In addition, we must assure that these capabilities readily support the practical requirements for hazard planning and response.

The Southeastern University Research Association (SURA) Coastal Ocean Observing and Prediction (SCOOP) program is a multi-institution collaboration, bringing together a diverse group of researchers with expertise in oceanography and information technology (IT). The SCOOP program goal is a modular and distributed system for predicting and visualizing the coastal response to extreme atmospheric events, including storm surge, inundation, and wind waves. The service-oriented architecture being developed by SCOOP will provide the capability to achieve these goals. Toward this end, the SCOOP infrastructure will support short-term forecasts, integrate models with real-time observations, and serve results based on standards that enable access,

interpretation, and incorporation into decision-support tools. Moreover, the architecture will support design requirements for a national infrastructure of distributed sensors and predictive models that integrate regional and national observing systems along the coasts.

### **Practical Requirements for Environmental Prediction**

Emergency-response managers need information in advance of potentially catastrophic events. Accurate predictions can either mitigate the costs of disaster recovery or obviate the cost of unnecessary preparation. Estimating the probability distribution of future environmental impacts is much more difficult than creating the single best forecast. Estimating the associated probability distributions requires ensemble-modeling techniques. These techniques require computer simulations to be run many hundreds or thousands of times – once for each plausible outcome.

Another challenge of real-time prediction involves the integration of observational data from the myriad federal, regional, and local ocean observing systems. Aggregation and coordination of these data must be timely and reliable. The SCOOP program is addressing these challenges by creating an open-access infrastructure that will allow communities of scientists to work together to predict coastal hazards of all kinds. The initial focus on inundation from storms and hurricanes is intended to be extensible to a range of environmental events.

### **Innovating Operational Systems**

The SCOOP service-oriented architecture involves a collection of modular components, each providing well-defined functionality and communicating with the other components across standardized interfaces. As with most modern distributed systems, the SCOOP architecture relies heavily on web-service interfaces to manage secure resources and data flows across the relatively insecure Internet.

The approach of modularizing components and standardizing interfaces allows innovation by allowing system components to be updated or replaced incrementally and in a “plug-and-play” fashion, without impacting other components or overall system operation. With this approach, operational systems can become the focus for ongoing research and development by teams of coastal and computer scientists working together on a common architecture.

### **Design Requirements**

Design requirements are developed by considering a range of possible use cases. Extreme events will trigger ensemble calculations that bring all available resources to bear on the immediate needs of hazard response and mitigation. The same system will support ongoing forecasts for use in day-to-day maritime

operations. A retrospective mode with requisite data archives will support coastal research on past events and a development and testing mode will support research, simulation, and innovation of operational capabilities. These multi-mode requirements affect all aspects of the architecture, from computational resource scheduling to data archive, access, and transport.

### ***Real-time Ensemble Prediction***

Real-time, ensemble prediction is a central focus because it introduces some of the biggest technical challenges for the architecture, as well as some of the biggest potential benefits. The techniques being utilized are increasingly common in weather forecasting, but they remain relatively uncommon for most other disciplines of environmental prediction. Real-time, ensemble-modeling techniques are fundamental to advancing our nation's capacity for environmental prediction. The enormous technical challenges can be overcome with a community infrastructure.

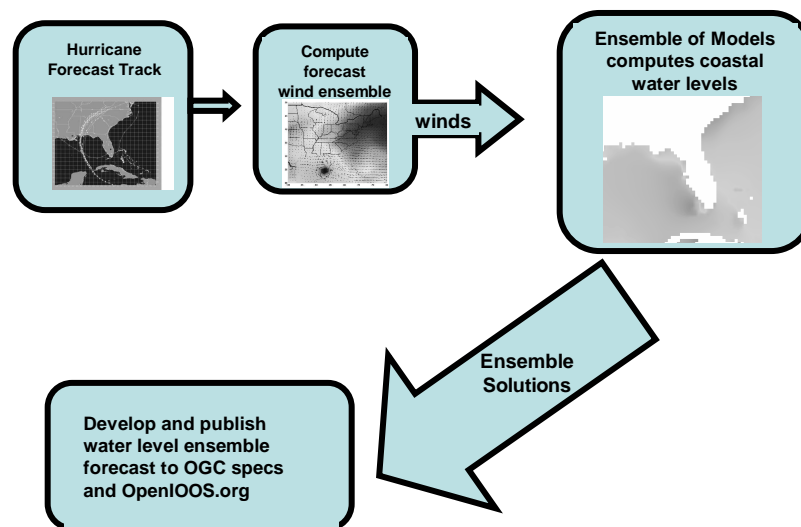
The specific synthetic wind-ensemble use case considered here builds on information made available by the NOAA National Hurricane Center (NHC). NHC warnings are typically produced at 6-hour intervals over the lifespan of a hurricane. These warnings are commonly displayed as "probability cones" showing the likely zone of impact for several days into the future. Every time the NHC issues a warning, it will trigger an automated sequence of events within the SCOOP architecture, supported by SCOOP university partners (Figure 1).

1. The NHC-warning parameters are used to create an ensemble of forecast wind fields. Each of these wind fields represents a plausible set of forecast winds over the entire region of interest for several days into the future. A realistic scenario might involve an ensemble of tens to hundreds of such forecasts. The entire ensemble represents a probability distribution for winds that is consistent with the basic parameters from the NHC.
2. Each forecast wind field is used as input for numerical predictions of storm surge and wave fields. Each individual element in this ensemble of surge and wave predictions involves a numerical calculation that could take many hours on a large supercomputer cluster, especially if the surge model predicts inundation with street-level resolution over large regions. Consequently, each of these predictions is farmed out to the available computational resources within the distributed network.
3. Results from each of the predictions in the ensemble are then aggregated for analysis. Results include maps that show the probability of inundation with street level detail.

4. For verification, all relevant and available observations are aggregated and compared with predictions, which provides a real-time measure of accuracy and quality for the predictions.
5. The results of the analysis are visualized and disseminated in a form that can be readily incorporated into decision-support tools used by emergency-response personnel (currently: <http://www.openioos.org>).

The value of the end product depends critically on the speed with which the complete chain of events can be completed. Although a disaster- or storm-related break in any link could block the flow and leave the users without information they require, SCOOP's distributed structure makes that unlikely to occur.

### SCOOP Storm Surge Ensemble Prediction System



### *Retrospective Analyses*

Research, development, and testing require analysis of historical events. The SCOOP architecture will support these needs as well. As a typical use case, consider comparison of two different models for storm surge. The associated workflow might involve the following sequence of events:

1. A researcher previews and selects a collection of storm events for study.
2. Inputs into the analysis include the best-available historical wind fields, forecasts that were available during the storm, and the range of observations available from that time period for verification.

3. Each of the two different surge and/or wave models are run with the available forcing inputs.
4. The model predictions are aggregated and compared with one another and with the observations using preview tools available in the system.
5. The results are made available to the researcher for subsequent custom analyses, and stored in the archives for future use.

Information relating to historical events exists in a wide variety of places and is increasingly available with dynamic mechanisms. The challenge is making these data discoverable and accessible. Innumerable research scenarios could lead to this type of use case. Various types of model inter-comparison could involve different algorithms, spatial resolution, or forcing inputs. The architecture should be capable of keeping track of such detail and document provenance of the various inputs and observations.

### ***Continuous Forecasts***

Not all predictive scenarios are event driven as with the wind-ensemble use case described above, nor do they require ensemble modeling techniques. For example, moderate winds can effect water level variations in ports and harbors. Predictions of this effect can be critically important for large ships that transit with less than a meter of clearance over the bottom. Similarly, the U.S. Coast Guard is in the process of rolling out a new computer-based search and rescue software suite that relies on predictions of coastal water velocities on a 24/7/365 basis. The model, data translation and transport infrastructure, as well as model results running within SCOOP, provide exactly the type of data streams needed by this application. The SCOOP infrastructure supports continuous forecasts that meet these operational requirements.

### ***Multi-disciplinary Inundation Modeling***

In addition to storm surge and waves that have damaging effects on the coastal zone, the inundation problem can be dominated by precipitation and terrestrial hydrology. Thus, a comprehensive inundation prediction capability includes use cases with models developed in the hydrologic and/or meteorology disciplines. Although the individual components for such disciplines will differ in detail, the service-oriented architecture will readily accommodate them by allowing addition of new system components relevant to other kinds of models, model output, and analysis, as well as new services that facilitate coordination of the components for various specific workflows. This type of extensibility is a basic feature of the architecture.

### **End Note:**

For more information about SCOOP:

[http://www1.sura.org/3000/3300\\_Coastal.html](http://www1.sura.org/3000/3300_Coastal.html).

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