

SURA Coastal Ocean Observing and Prediction (SCOOP) Program: Integrating Marine Science and Information Technology

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LONG-TERM GOALS

The overarching goal of the Southeastern Universities Research Association's (SURA) Coastal Ocean Observing and Prediction (SCOOP) Program is to advance environmental prediction and hazard planning for our nation's coasts. This multi-institution collaboration between ocean scientists and IT experts is creating a distributed network of shared resources that will broaden access to the requisite data, models, computational resources, and other key components of a real-time environmental prediction system. The SCOOP "partners" are creating a service-oriented architecture (SOA) that will enhance coastal ocean observing and modeling and enable a virtual community to share tools, resources, and ideas. In addition to serving as an integrating component of the Integrated Ocean Observing System (IOOS), the architecture will provide the Navy with a portable suite of methodologies to manage and visualize observed and modeled data on coastal phenomena.

OBJECTIVES

SURA is creating a SCOOP "Grid" that extends the interoperability enabled by the World Wide Web. The coastal community faces special challenges with respect to achieving a level of interoperability that can leverage emerging Grid technologies. With that in mind, the SCOOP Program is loosely broken into the following parallel initiatives and objectives:

- Community building – Participate in outreach activities to engage the research community in identifying and addressing the technical obstacles to creating a Grid. These include the OOSTech Workshop and follow-on, the SCOOP web-site (<http://scoop.sura.org/>), and the OpenIOOS testbed site (www.openioos.org) (Figure 1).
- Data standards – Enable interoperability between existing standards and foster standards use through participation in the Marine Metadata Interoperability (MMI) project. In addition, develop an ontology, metadata catalog, and project documentation.
- SCOOP Data grid – Rely on "Web Services" to advance distributed data sharing, discovery, aggregation and visualization, interactive mapping, and OGC publisher capabilities.
- Model grid – Consolidate Grid technology pilot demonstrations into one Grid of SCOOP coastal modeling efforts. Current models include the ADCIRC (ADvanced CIRCulation) model, the WaveWatch3 (WW3) model, and two high-resolution, storm surge models: the Curvilinear-grid Hydrodynamics 3D (CH3D) and the Eulerian-Lagrangian CIRCulation (ELCIRC).

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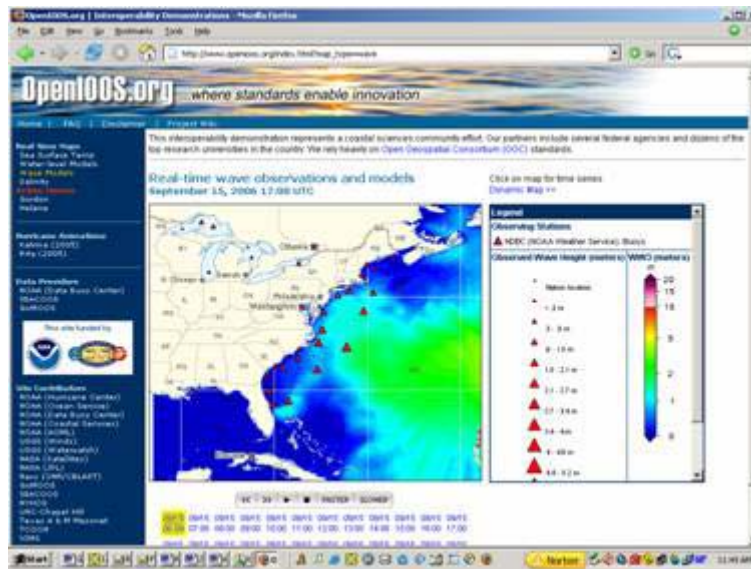


Figure 1: Screen shot of the OpenIOOS.org home page showing observed and modeled wave heights associated with hurricane Gordon on September 15, 2006.

APPROACH

SCOOP brings together the management team of Program Director, Dr. Philip Bogden; Program Manager, Dr. Joanne Bintz, and a SURF Coastal Fellow, Dr. L. Don Wright. The SCOOP partners include the following Principal Investigators:

- Dr. Sara Graves and Helen Conover at the University of Alabama, Huntsville (UAH) are improving interoperability with OpenIOOS by enhancing the catalog archive inventory services, creating data access from the SCOOP catalog search page, and maintaining catalog schema documentation.
- Dr. Gabrielle Allen at Louisiana State University (LSU) focuses on developing software and tools for: archiving, downloads, uploads, and acquisition. She assists in designing and implementing a modular interoperable cyberinfrastructure within SCOOP.
- Gerry Creager and Larry Flournoy at Texas A&M University are responsible for representing SCOOP in the Open GIS Consortium (OGC) as well as developing the SCOOP Archive Data Center, OGC compliant data visualization, SCOOP Grid security, web services development, and SCOOP data standards, transport, and translation.
- Dr. Philip Bogden at The Gulf of Maine Ocean Observing System (GoMOOS) is responsible for maintenance and development of the OpenIOOS site. Through a subcontract with GoMOOS, Dr. Will Perrie at the Bedford Institute of Oceanography (BIO) provides real-time, operational wave forecasts.
- Peter Sheng and Renato Figueiredo at the University of Florida (UF) generate ensemble analytic wind products, forecast high-resolution inundation in Charlotte Harbor, FL, and provide virtual resources to the pool of computers for forecasting and retrospective analysis.
- Rick Luettich, Sc.D at the University of North Carolina, Chapel Hill and Dr. Daniel Reed at the Renaissance Computing Institute (RENCI) focus on advancing and enhancing the ADCIRC model implementation in the SCOOP model grid framework and on research and development of grid technologies for the SCOOP model grid.

- Dr. Harry Wang at the Virginia Institute of Marine Science integrates river and rainfall effects into the ELCIRC model to enhance the coastal inundation simulation capability during storms.

Community Building: The OOS Tech 2006 workshop is currently in the planning stages for fall/winter 2006. The OpenIOOS.org site, developed and maintained by GoMOOS, serves as a front-end, user interface for information products produced in the SCOOP program. OpenIOOS.org receives information products and data from SCOOP partners via standard services including the OGC web mapping service (WMS) and SOAP-based web services. The SCOOP web-site (<http://scoop.sura.org>), developed and maintained by UAH, provides a public presence for SCOOP, presenting information about research and the project in general.

Data Standards: UAH and TAMU are actively participating in the MMI project and development of OOS Tethys (Bermudez et al., 2006). The UAH team continues to document metadata for all of the data products currently being generated or utilized within the SCOOP project. The SCOOP Data Catalog and inventory web services are being refined and expanded to support SCOOP users, applications, and archives that use the catalog information. UAH is refining the usability of the public web interfaces for the catalog and other data management tools by incorporating user feedback on existing interfaces. UAH is developing web services for updating and querying the SCOOP data catalog for both collection level and inventory level metadata.

Data Grid: The underpinning of the SCOOP data transport system is Unidata's Local Data Manager (LDM), providing event-driven data distribution across the SCOOP modeling partners, archives, and data consumers. Where appropriate, functionality is developed independent of LDM providing the flexibility of utilizing other transport systems that might provide improved capabilities. The UAH team is providing an infrastructure of translation services that will facilitate interoperability between models and data, i.e. getting the data to the model in the right format. All SCOOP-generated model data are rendered in OGC-compliant form using web services, visualization products such as Web Map Service (WMS), Web Feature Service (WFS), and Web Coverage Service (WCS). LSU is prototyping basic Grid scenarios and operations, using the existing Grid infrastructure at LSU and expanding this to other sites.

Model Grid: The model grid focuses on: 1) continuous automated forecasts; 2) event-driven ensemble prediction for storm events; 3) retrospective analysis; and 4) model to observation comparisons to monitor prediction accuracy. UF and UNC developed a standard wind-file format based on Climate and Forecast and the Cooperative Ocean/Atmosphere Research Data Services (CF/COARDS) to improve analytic wind model interoperability. UF coordinated the deployment of self-configuring Virtual Machines (VMs) with aid from MCNC and VIMS. VIMS modified the ELCIRC storm surge model to include river discharge and precipitation. The SCOOP Archive Data Center is a production entity that uses a set of dedicated and distributed servers to process incoming data and provide user interface operations, database management, visualization, and web services.

WORK COMPLETED

Community Building - The SCOOP website is the home for the SCOOP model listing (<http://scoop.sura.org/models/getlist.pl>), detailed information on web-based services and utilities (<http://scoop.sura.org/services.html>) including an acronym look-up application, and an interactive utility that translates a filename to SCOOP data catalog collection identifiers. Upgrades to

OpenIOOS.org include: the implementation of automated, event-driven updates; visualization of storm driven ensemble models; model vs observation comparison for real-time and ensemble model runs; and five-day forecast animations during storms. As a follow on to the OOS Tech 2005 workshop, participants implemented a Simple Object Access Protocol (SOAP)/SWE salinity demonstration at OpenIOOS.org (Figure 2) and a SOAP “cookbook” to help others participate.



Figure 2: The OpenIOOS.org salinity demonstration map showing salinity data from partners participating in the OOSTech follow on activity.

Data Standards - UAH implemented, tested and deployed catalog and inventory services (<http://scoop.sura.org/Catalog>). They contain up-to-date information and have been improved based on input from users. UAH implemented a storm database, which is updated in real-time as the National Hurricane Center (NHC) issues advisories and updates (Figure 3). This database is being used to drive an alternate storm-based interface for data search and ordering. Requirements for OOSTethys are under development.

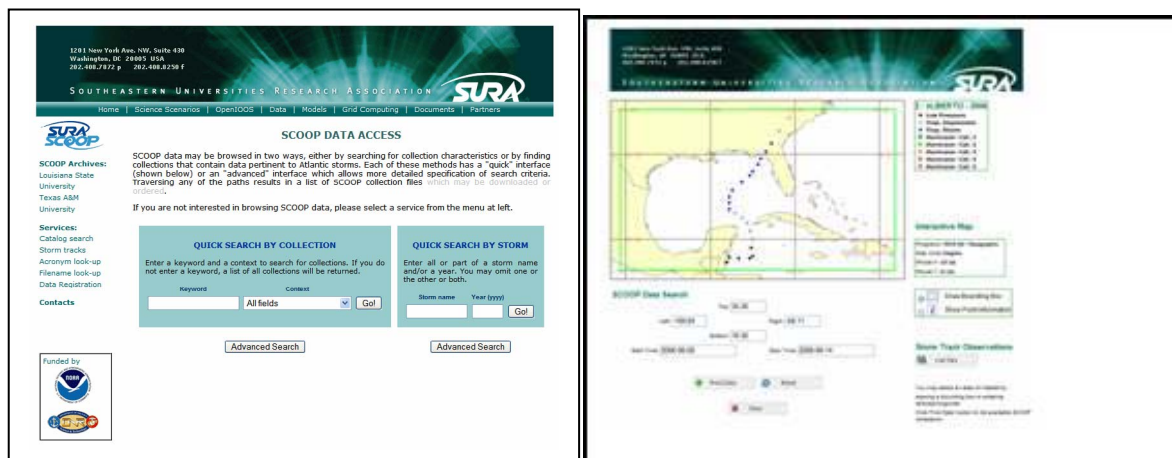


Figure 3: Data Access and Storm-based Search page available on the SCOOP website.

Data Grid - UAH currently serves as the WW3 transport proxy by periodically pulling the model output from BIO and inserting it into LDM. Model point extraction/translation services are deployed for real-time ADCIRC and WW3 model output. This functionality extracts model output values at prescribed geographic locations corresponding to observational instruments. The points are pushed to a GoMOOS database through SCOOP SOAP services. In addition, UAH provides point extraction software to TAMU for eventual incorporation with archived data. UAH is translating WW3 output to netCDF, making it more compatible with other SCOOP systems, and supporting more generalized visualization services. LSU developed specialized grid portlets that allow modelers to use data from the archives as model input, run models on available SCOOP/SURAgriid resources, and specify locations to store model runs.

Model Grid - UF generates eleven forecast ensembles within minutes of a National Hurricane Center (NHC) advisory release. The UNC SCOOP ADCIRC system can now use several of the wind products and uses additional SURAgriid resources for forecast runs. The production version of the UNC SCOOP system chooses from several compute resources, which increases the reliability of the system. If a machine goes offline during a model run, the system is able to recover and complete the run allowing timely and reliable completion of the model runs. BIO implemented post processing of WW3 forecasts and transfers outputs to the SCOOP archive and www.openioos.org where the model-buoy comparisons can be accessed using a web-based data-point extraction tool (Figure 4). UF deployed a 20 node virtual cluster at UF, VIMS, and LSU that is used to run ADCIRC and CH3D. The ELCIRC model has been enhanced to include both river discharge and precipitation flow input on an hourly or daily interval. The SCOOP Data Archive Center has been operational since June 2005 with enhancements to hardware cost-shared by TAMU. It supports routine visualization of SCOOP model data and observations.

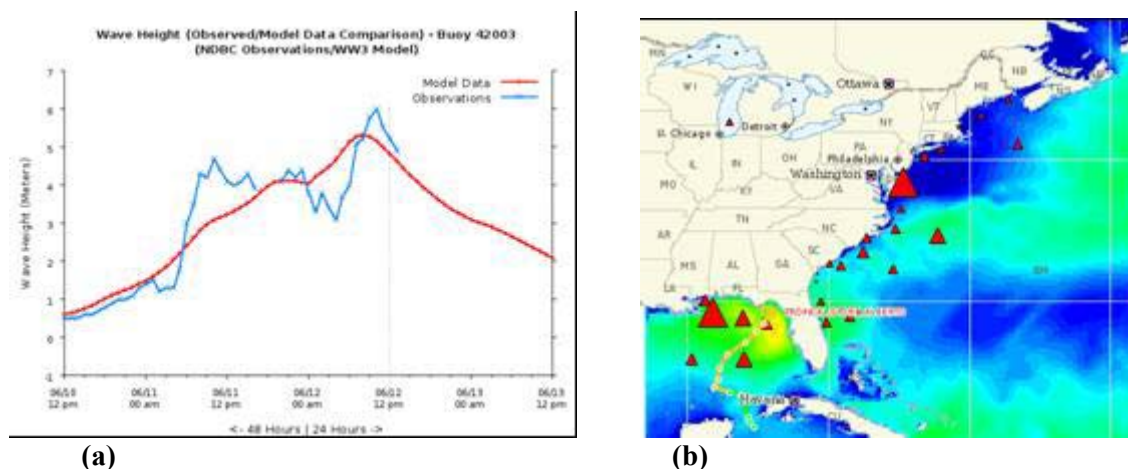


Figure 4. (a) Time series comparison for hurricane Alberto; wave model height (red line) to buoy data (blue line) at NDBC buoy 42003. (b) Model visualization of wave heights and buoy location (▲) on Openioos.org website; icon size is proportional to wave height.

RESULTS

Community Building - The www.OpenIOOS.org site is a public interface that presents information at a level that is useful not only to the SCOOP community, but also to public users in general. GoMOOS helped develop a WMS on the SCOOP archive and a series of animation scripts to exercise the full

range of WMS parameters. In addition, GoMOOS implemented the capacity for new storms to automatically trigger updates on OpenIOOS.org. The catalog storm search interface on the SCOOP site (<http://scoop.sura.org/Storms/dosearch.html>) can be used to search for SCOOP data, based on the time and location of named storms from the storm database.

Data Standards- The SCOOP data catalog is close to being fully populated with collection-level metadata. It contains complete inventory metadata for the LSU archive and inventory metadata for recently acquired files at the TAMU archive. Web services for updating and querying the catalog are functional and available for external users. The catalog is now a functional component of SCOOP and is providing useful information and capabilities. SCOOP data resources are widely conforming to existing and evolving standards.

Data Grid - In general, the SCOOP transport functionality has been handling the SCOOP requirements for timely data delivery of model outputs to other modelers and the archives. Web services have been instrumental in integrating the SCOOP distributed data archive with the central SCOOP data catalog, thereby providing the functionality to easily search and discover data resources across the distributed repositories. Visualizations of ADCIRC and WW3 runs and their associated statistics are available to the general public and to users who require data integration into GIS.

Model Grid - The primary technical achievements for ADCIRC are the integration of a “hotstart” generation method into the SCOOP system and enhanced resource selection that accounts for data movement costs. The former allows the system to keep pace with the NCEP forecast cycle frequency (4 x daily), and will also allow easier coordination with other model simulations in the SCOOP system (e.g., WW3 at LSU). We have developed the capability to support continuous 24/7 and event driven wave forecasts as well as ensemble forecasts. We can compare model outputs with real-time buoy observations and serve results in standardized ways that enable access, interpretation, and incorporation into decision support tools. The comparisons of model to observed values are available through the OpenIOOS application (www.openioos.org) by clicking on a buoy. The WW3 model can use several wind products (e.g., continuous 24/7, hurricane specific, or analytical ensemble). The time to generate analytic wind products has been reduced from 12-18 hours to minutes after the NHC issues an advisory. UF is generating two new high-resolution domains (Tampa Bay, FL and the FL East Coast) for visualization on OpenIOOS.org (Figure 5). The successful deployment of self configuring VMs demonstrates the ability to join a new computing node to an existing pool of Grid resources within seconds without the need for a system administrator (Figure 6). The ELCIRC model calculates flooding and receding robustly with a 3-minute time-step and a 30-m grid (Figure 7). The saving in computing time is 100 fold compared to traditional numerical methods. SCOOP users have access to the data in the Data Archive Center using a local TAMU portal or via the SCOOP catalog interface. It is able to provide backup to the LSU archive, which is engaged in Grid-related storage and archive research.

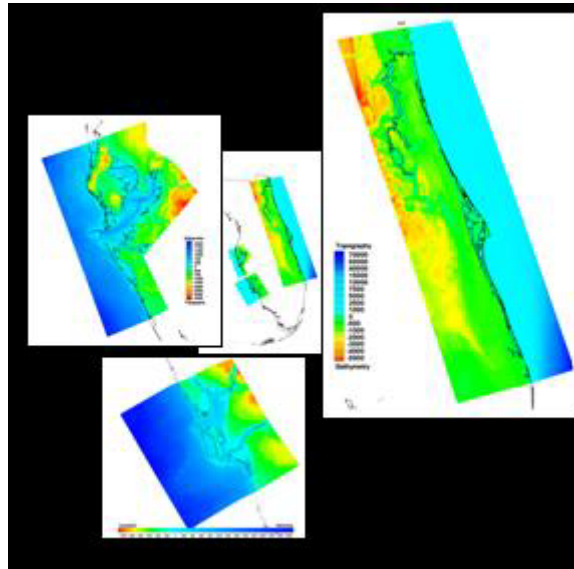


Figure 5: In addition to Charlotte Harbor, FL (lower left), CH3D output from two additional high-resolution model domains, Tampa Bay, FL (upper left) and the East Coast of Florida (right) is now being made available to SCOOP partners and are capable of being shown on OpenIOOS.org.

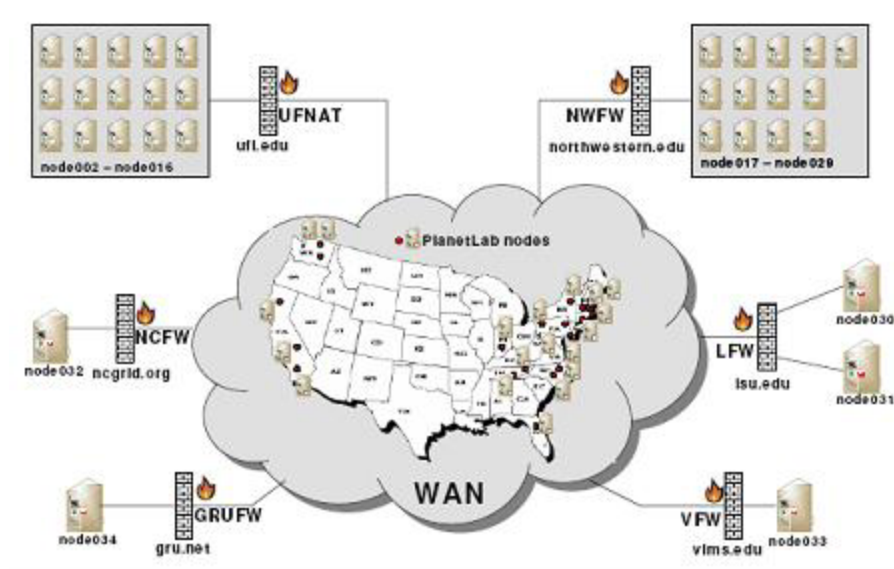


Figure 6: Deployment of a virtual cluster used in performance experiments with machines distributed across six distinct, firewalled domains: UFL, LSU, VIMS, UNC, Northwestern University, and GRU.Net (a broadband ISP provider).

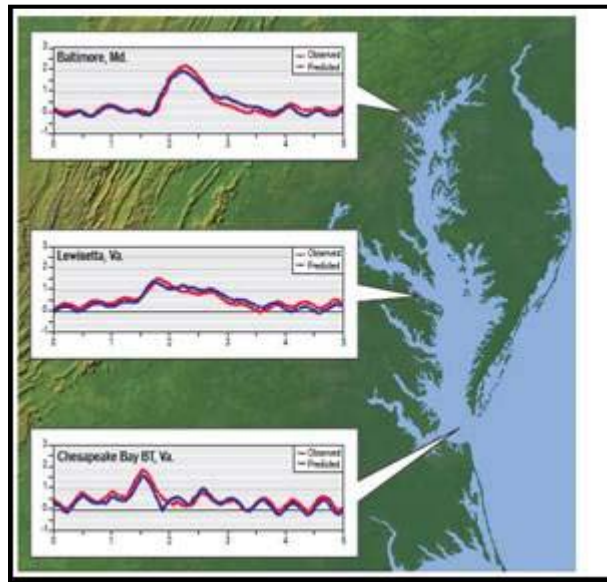


Figure 7: Sample results from a simulation of Hurricane Isabel's impact on the Chesapeake Bay area in 2003 using the ELCIRC model. Model results agree well with observation in the open Chesapeake Bay. Red lines indicate the observed water level from installed gauges; blue lines denote predictions. All graphs are elevation in meters (y axis) and number days (x axis).

IMPACT/APPLICATIONS

Community Building - The SCOOP data catalog on the SCOOP website is becoming more useful to the SCOOP user community. The WMS on the SCOOP archive enables users to access visualizations and view them on OpenIOOS.org. The new storm trigger, eliminates a delay between storm warnings and web site updates and reduces costs by eliminating manual updates.

Data Standards- The on-line, programmatic accessibility of the catalog provides SCOOP modelers with the ability to begin utilizing data from the distributed SCOOP archives for ongoing studies, daily model runs, and for verification and validation efforts. Standards compliance will serve to improve the interoperability of SCOOP data resources with other science research projects and data repositories.

Data Grid - The event-driven nature of SCOOP data transport is providing timely data delivery to/from SCOOP modeling sites providing for better interoperability between these locations. The initial success with the data translation services should support the idea of deploying a more sophisticated subscription-based service infrastructure. Initial success of web service deployment in SCOOP has provided platform/language independent access to catalog functionality and the use of standards interfaces (e.g. SOAP), will promote re-use of these service components beyond SCOOP. Providing data in OGC-compliant form facilitates its use by civic leaders and emergency managers.

Model Grid - The developments and implementations to the SCOOP SOA will provide a more robust and flexible computational system for the execution of models in a Grid environment. For example, several components of the existing UNC SCOOP computational environment are currently being used by a RENCI group to prepare, schedule, and execute ADCIRC storm surge simulations on a high-resolution NC ADCIRC domain. The SCOOP system provides a structure in which to implement and test new forecast models and statistically analyze the results. The virtualization effort allows users to

easily and voluntarily contribute resources to the system and simultaneously access other nodes to run compute-intensive jobs. The enhancement of the ELCIRC model demonstrates that including river discharge and rainfall have a positive effect on the inundation simulation (Figure 8). Upgrades to the SCOOP Archive Data Center assure the ability to acquire, store, inventory, and catalog data, as well as provide for its retrieval in a timely manner.

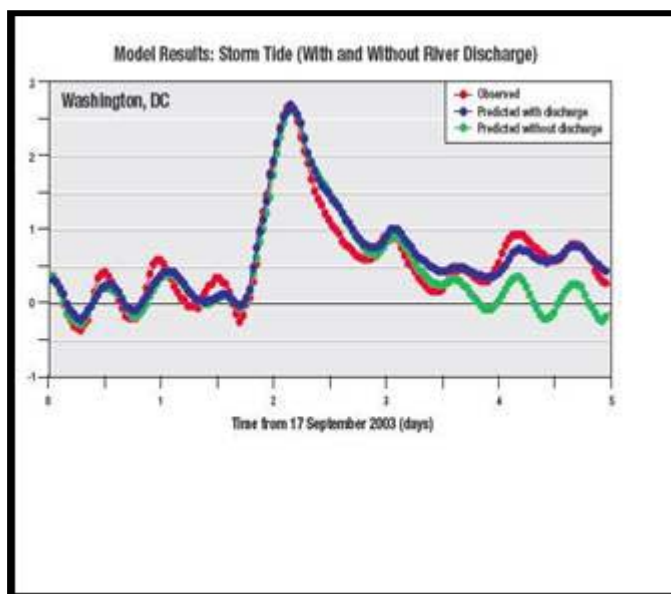


Figure 8: Correlation results of the model in the Upper Potomac River with and without river discharge. The model with just the storm surge (green lines) does not correlate well with observation (red lines), particularly in the later part of the storm. However, significant agreement was obtained when the river discharge was included (blue lines). The model run with river discharge includes the increased river flow from on-land rainfall that drains into the upriver tributaries and typically arrive in Washington D.C., a day or more after the original storm's passage.

RELATED PROJECTS

- Alliance for Earth Observations (<http://alliance.strategies.org/>) - SURA joined the Alliance for Earth Observations in August 2006. The Alliance for Earth Observations™ is a publicly and privately funded initiative of the Institute for Global Environmental Strategies to promote the understanding and use of land, air, and sea observations for societal and economic benefit.
- Data Management and Communications (DMAC) (<http://dmac.ocean.us/index.jsp>) - Helen Conover (UAH) was recently appointed to serve on the Data Management and Communications (DMAC) metadata expert team.
- Federation of Earth Science Information Partners (ESIP) (<http://www.esipfed.org/>) - The Federation of Earth Science Information Partners brings together government agencies, universities, non-profit organizations, and businesses in an effort to make Earth Science information available to a broader community. SURA was elected to ESIP membership in June 2006.

- GridLab <http://www.gridlab.org> - is a Pan-European distributed infrastructure that consists of heterogeneous machines from various academic and research institutions. It has been established as a result of collaboration of all GridLab participants and partners in order to provide a robust grid environment.
- Grid research group at Center for Computation and Technology (CCT) <http://cs.cct.lsu.edu/wiki>
- Linked Environments for Atmospheric Discovery (LEAD) <http://lead.ou.edu/summary.htm>
LEAD will create an integrated, scalable framework for identifying, accessing, preparing, assimilating, predicting, managing, analyzing, mining, and visualizing a broad array of meteorological data and model output, independent of format and physical location. We currently have no formal relationship with the LEAD project, but there are obvious synergies between SCOOP and LEAD, which we will endeavor to explore.
- Marine Metadata Interoperability (MMI) Project (<http://www.marinemetadata.org>) - UAH is participating in the MMI Steering Team and related activities, which include workshops, demonstrations, and outreach efforts.
- OOS Tethys (<http://www.oostethys.org/>) With funding from NSF and NOAA, the MMI project has been enabling the exchange, integration and use of marine data by emphasizing ontologies that employ the Web Ontology Language (OWL), in anticipation of the Semantic Web. With funding from the Office of Naval Research and NOAA, OpenIOOS participants have been demonstrating that "standards enable innovation" by leveraging web-service and data-model specifications developed by the Open Geospatial Consortium (www.opengeospatial.org). Through the support of the MMI project, the OpenIOOS and the SURA Coastal Ocean Observing and Prediction program (SCOOP), we present the lessons learned from this coordinated and combined effort called OOS Tethys.
- Open Geospatial Consortium (OGC) (<http://www.opengeospatial.org/>) - SURA recently joined the OGC with the intention of initiating an Ocean Science Interoperability Experiment (IE). The IE will consolidate a portion of the Ocean-observing community on its understanding of various OGC specifications, solidify demonstrations for ocean science applications, harden software implementations, and produce a candidate OGC Best Practices document that can be used to inform the broader ocean-observing community.
- SURAgrid Initiatives (<http://www1.sura.org/3000/SURAgrid.html>)- SURAgrid is a consortium of organizations collaborating and combining resources to help bring grid technology to the level of seamless, shared infrastructure.

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