



# NOS Storm Surge Partnership Project: Improving Gulf Coast Storm Surge Modeling, Tools, and Methodologies

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## Introduction

NOAA's National Ocean Service (NOS) Storm Surge Partnership Project (SSPP) is a demonstration project aimed at improving Gulf Coast resiliency to inundation through use of emerging technologies. The partnership project team consists of members from across NOS, NOAA's National Weather Service (NWS), and other federal and state agencies. The project's objectives include determining the needs of the management community, assembling needed observation data, improving inundation mapping, testing a prototype storm surge model, and developing innovative management products.

The Alabama and the Florida panhandle Gulf Coast (including Mobile, AL and Pensacola, FL) was selected as the project study area because of significant, well-documented past hurricane events involving storm surge flooding such as Hurricane Ivan in 2004. In order to address issues central to improving coastal resiliency to inundation, project partners took on multiple ongoing efforts. NOS's Coast Survey Development Laboratory (CSDL) and National Geodetic Survey (NGS) developed an implementation of a vertical datum transformation tool for this region called VDatum. VDatum allows for adjustment between disparate vertical datums at the coast, including tidal, orthometric, and ellipsoidal datums. Application of vertical datum transformations to bathymetric and topographic data allows for the construction of a continuous elevation field across the land/water interface. In the study region the latest available hydrographic surveys are combined with high resolution topographic datasets such as Light Detection and Ranging (LIDAR) surveys to construct a continuous elevation field. This elevation field is used as the basis for a prototype storm surge model that provides high resolution of coastal and inland features for modeling inundation. This state of the art storm surge model is an application of the Advanced Circulation (ADCIRC) finite element hydrodynamic model with approximately 450,000 nodes and resolution reaching less than 100 m. It includes land areas up to the 15 meter topographic contour from west of Mobile Bay, AL, to east of Choctawhatchee Bay, FL. Vertical flow obstructions such as barrier islands are included as weirs within the model domain. This high resolution model will allow for accurate modeling of hurricane-driven inundation throughout the region. Model forcing of atmospheric wind and pressure conditions is applied through application of the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) parametric wind model. The prototype model is validated against observations of High Water Marks and water level time series. The output from the prototype ADCIRC storm surge model will be used by the SSPP team to generate geographic information system (GIS)-based visualization tools and methodologies to illustrate storm surge processes and impacts while verifying existing map products.

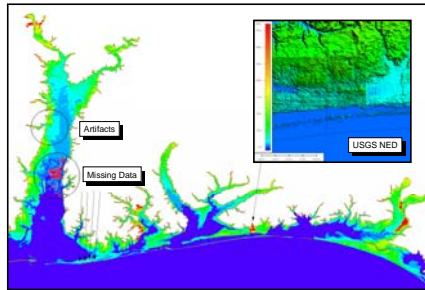


Figure 2. Discrepancies in continuous elevation dataset.

## Continuous Elevation Dataset

By combining best available elevation data for bathymetry and topography along with vertical datum transformations to a common datum through the VDatum tool, a continuous elevation dataset is developed for the storm surge model. It is important to note that the skill of the storm surge model is directly correlated to the quality (i.e., accuracy and resolution) of the elevation dataset. Bathymetric data in this region ranges in age from 1899 to the present, is relative to either Mean Low Water (MLW) or Mean Lower Low Water (MLLW), and according to present accuracy standards has an error of 30 cm in less than 20 m of water. The VDatum tool is used to adjust bathymetry to NAVD 88, and the data is interpolated chronologically from newest to oldest onto grid nodes lacking elevation data. When assembling topography for the region, a wide range in data quality becomes apparent. Whereas hydrographic surveys are primarily collected by NOAA according to strict charting standards (albeit with additional data collection by agencies such as the United States Army Corps of Engineers (USACE) and United States Geological Survey (USGS)), topographic data is collected by a wider range of groups for a wider range of activities. This leads to large variation in data resolution, vertical accuracy, format, documentation, and reference datums. For example, LIDAR data typically exhibits vertical accuracy of 25 cm and horizontal resolution of less than 10 m, while Shuttle Radar Topography Mission (SRTM) data is vertically accurate to within 10 m and horizontal resolution of 1 arc-second. The widely used USGS National Elevation Dataset (NED) is a national seamless dataset based upon the best available data from a range of remote sensors and collection dates; however, its quality has been found to vary noticeably throughout the study region. In fact, the NED includes data that has not been processed to "bare earth", which is necessary for model use. This problem also occurs with USACE coastal bathy/topo LIDAR surveys as well, limiting their usefulness. Therefore, SSPP team members contacted state and local agencies for best available high resolution datasets in order to assemble the best possible coverage. Most counties in the study region have made high resolution topography available but there is a wide range of data sources (e.g., LIDAR, photogrammetry), formats, resolutions, and reference datums. The data was transformed to a uniform datum (horizontal in latitude/longitude NAD 83 and vertical in m NAVD 88) and format (ASCII XYZ) for interpolation to the model grid. However, significant variations in data quality are still apparent in the resulting elevation dataset (Figure 2). The project has coordinated the collection of additional LIDAR datasets for some counties in the area to improve data quality available for modeling and mapping, and this data will soon be incorporated into the model. However, part of the storm surge model skill is dependent upon the modeler's skill in assembling, processing, and augmenting bathy/topo datasets.

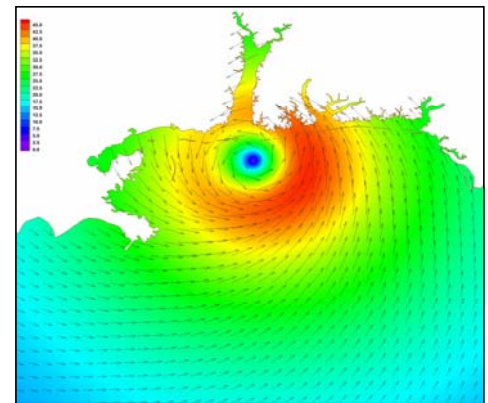


Figure 4. Hurricane Ivan wind speed near landfall as produced by the SLOSH parametric hurricane model (m/s).

## Storm Surge Model

The ADCIRC computational model (Luettich et al. 1992, Luettich and Westerink 2004) is being implemented in this demonstration project because of its unstructured grid capability, computational efficiency, ability to model inundation, and validation as a storm surge model by the community. The unstructured grid technology allows for wide variation in resolution, balancing cost against local accuracy requirements and enabling representation of complex coastal and estuarine features. In order to apply high resolution grids which require a small time step, the model is parallelized to run on high performance computing platforms. ADCIRC also has an effective wetting and drying methodology that allows flood propagation and retreat over land. Finally, ADCIRC is under wide use and development by federal, academic, and private members of the storm surge modeling community.

The model domain developed for the SSPP is centered around four main bays/estuaries: Mobile Bay, Perdido Bay, Pensacola Bay, and Choctawhatchee Bay. The upland boundary is placed at the 15 m topographic contour around these estuarine systems. In order to easily and accurately apply open ocean boundary conditions, the boundary is set in the Western North Atlantic at 60° W, allowing the model to seamlessly track in the Hurricane's effects. Figure 3 shows the model domain, the SSPP study region where most of the grids approximately 450,000 nodes are located, and high model resolution at the entrance to Pensacola Bay. In addition to providing nodal resolution of approximately 100 m along the Gulf Coast, narrow obstructions to flow such as jetties and barrier islands are incorporated into the model; these and other model boundaries are shown in red in Figure 3.

In order to validate the storm surge model, hindcasts of 2004's Hurricane Ivan are performed. Ivan caused extensive flooding throughout the SSPP region and observations of water levels were collected by NOAA, USACE and the Federal Emergency Management Agency (FEMA). Following the storm, NWS's National Hurricane Center (NHC) performed an assessment of the storm surge prediction generated by its operational SLOSH model (Jeleniński and Taylor 1973). In order to produce similar results, the SLOSH parametric meteorological model has been adapted to provide surface wind and pressure fields to the ADCIRC model domain. Ivan meteorological conditions were constructed for the ADCIRC domain by using the NWS best-track data on the storm's size, forward speed, and minimum pressure.

## Ongoing Efforts

The SSPP integrates efforts from across NOS and other agencies to address Gulf Coast community needs for addressing coastal inundation. One part of this effort is the production of the VDatum tool which will be publicly available on the web. Another is the assembly of a continuous elevation dataset, which has illustrated the need for continued collection of high resolution coastal observations done to community quality standards. The SSPP is also focused on the development of a prototype storm surge model for the Gulf Coast. The ADCIRC implementation is being validated for Hurricane Ivan and is producing high resolution water levels. Finally, SSPP team members are developing GIS-based mapping and visualization tools that can be used to communicate coastal inundation to the management community. These products are being constructed in response to input from the user community and will illustrate storm surge inundation and impacts.

## References

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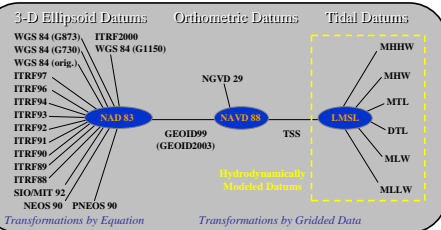


Figure 1. VDatum vertical datum transformation tool.

## VDatum

In order for a storm surge model to accurately simulate inundation it requires a high quality, continuous, combined bathymetric and topographic (bathy/topo) elevation field. However, bathy/topo data is referenced to a variety of vertical reference datums. Furthermore, the difference between tidal datums and the North American Vertical Datum of 1988 (NAVD 88) changes spatially according to variations in the shallow water hydrodynamic response and the gravitational field. Therefore, the VDatum vertical datum transformation tool has been developed by NOS for combining data from nearly 30 different tidal, orthometric, and ellipsoidal vertical datums (Milbert 2002, Parker 2002, Parker et al. 2003). VDatum is being implemented on a regional basis for the U.S. coastline. The tool uses observational and modeled data to transform between datums as shown in Figure 1. A version covering the Gulf Coast SSPP region is being developed as part of the project (Dingra et al. in preparation) and will soon be available at the VDatum web site: <http://naionalcharts.noaa.gov/csd1/vdatum.htm>

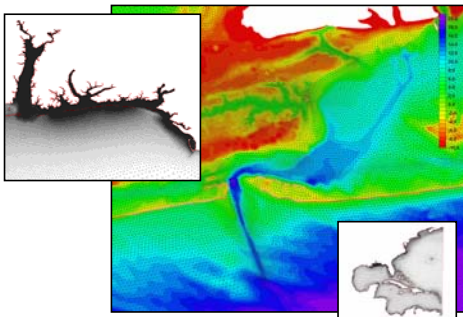


Figure 3. Prototype storm surge grid and bathymetry (m NAVD 88).