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ASSIMILATING IFSAR DEM DATA INTO AN ADCIRC SIMULATION OF HURRICANE CAMILLE

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1. INTRODUCTION

A crucial component in storm surge simulations is Digital Elevation Model (DEM) data. However, conventional DEM data is often coarse (30-m resolution), suffers from poor sampling due to manual surveying techniques, and may be inaccurate since some digitized data is derived from hand-drawn contour maps. Advances in remote sensing, such as InterFerometric Synthetic Aperture Radar (IFSAR), yield potentially more accurate (2.5-m horizontal, 2-m vertical) DEM data. This will be discussed in Section 2.

This new DEM dataset, which naturally incorporates recent coastal development, will be used in a storm surge simulation of Hurricane Camille (1969). The Advanced CIRCulation (ADCIRC) model based on finite element methods, will be used for this simulation. The grid resolution used will reflect the IFSAR data resolution. A description of ADCIRC and the grid generation program is provided in Section 3.

However, IFSAR does contain some noise, and also elevated objects need to be removed to represent a true "bald earth" DEM. The development of a new DEM dataset for the Mississippi Gulf Coast, blending USGS and IFSAR data using variational analysis along with a quality control scheme for elevated objects will be discussed in section 4.

2. OVERVIEW OF INTERFEROMETRIC SYNTHETIC APERTURE RADAR (IFSAR) APPLICATIONS TO DIGITAL ELEVATION MAPS

Conventional global DEM information is determined from many sources (see U.S. Geological Survey [USGS] (1993) for details). The primary DEM sources for the U.S. are the USGS datasets, stratified by different resolutions. The highest resolution dataset is stored in 3-arc second bins, approximately 30-m wide. However, the USGS DEM data contains several problems. First, manual surveying methods are often used, which suffers from poor sampling. Second, this dataset, primarily derived from cartographic and photographic sources (U.S. Geological Survey, 1993), is sometimes computed by digitizing from analog contour lines; often these contour lines are in 5- and 10-foot intervals, resulting in imprecise DEM values. Finally, the general depiction of coastlines and estuaries is crude.

Advances in remote sensing the past decade have the potential for defining much higher precision DEM maps. One of these techniques uses Synthetic Aperture Radar interferometry. Originally developed by the Environmental Research Institute of Michigan (ERIM) and the Jet Propulsion Laboratory (JPL) under a Defense Advanced Research Projects Agency (DARPA) project, Intermap Technologies obtained rights to market and operate the system, and named it STAR-3I (formerly called IFSARE). The technique uses two airborne antennas in the X-band which alternate pulses, and receive backscatter from the same target with a difference in phase between the two signals; based on accurate GPS positioning and geometry relationships relating the phase difference to the antenna separation, the relative height of all the targets may be obtained (Mercer and Gill 1998; Mercer et al. 1998).

Intermap flew a mission in response to NASA's Commercial Remote Sensing Program's (CRSP) Databuy along the Mississippi Gulf Coast Biloxi Bay area. A comparison of the DEM maps from the USGS and IFSAR shows the obvious advantages of the IFSAR data (Figs. 1 and 2).

3. STORM SURGE SIMULATION USING ADCIRC

ADCIRC was initially developed under the Dredging Research Program, a 6-year program funded by the

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Office of the Chief of Engineers. The model was developed as a family of 2- and 3-dimensional codes (Westerink et al. 1992) with the capability of simulating ocean circulations and storm surge propagation over very large computational domains while simultaneously providing high resolution in areas of complex shoreline and bathymetry. ADCIRC also includes a "wetting/drying" mechanism for the simulation of flooding and drying of tidal flats. More information can be obtained at http://www.marine.unc.edu/C_CATS/adcirc/document/ADCIRC_main_frame.html.

The high-resolution is achieved by using a finite element grid that can depict complex domains with high precision, and makes grid generation very flexible. The finite element method allows increased nodal density in the shallow regions and over land while maintaining a coarser resolution in deeper waters, which leads to savings in computational time. Another advantage is that the geometric complexity of the coastline can be accurately represented without changing the coordinate system. Thus, rivers and coastal estuaries are readily incorporated into the domain.

The mesh-generation software is based on restrictions given by shallow-water gravity wave speed. On land, a minimum resolution is specified which will allow for wetting/drying calculations to be performed with the required accuracy. The algorithm for mesh generation is as follows: a coarse grid is generated in a rectangular region encompassing the entire domain. The water depth at each node of the coarse grid is interpolated from the bathymetry data. This coarse grid is then successively refined using the water depths specified either by the restrictions on the gravity wave speed or by the user until the minimum resolution is reached. The algorithm is implemented using MATLAB.

In this project, two grids, one comparable to the old USGS DEM data, and one comparable to the blended IFSAR/USGS dataset, are being developed for two storm surge simulations in Biloxi Bay for Hurricane Camille (1969). Differences in the simulations will be noted, and a validation study against the storm surge observations in Camille will be conducted.

4. GENERATION OF DEM MAP USING VARIATIONAL ANALYSIS

The resulting mathematical relationship results in a phase difference which can only be measured between 0 and 2π, creating an ambiguity which is usually resolved through a technique known as "phase unwrapping," but ambiguity errors can still remain. In addition, there are resolution errors in the IFSAR data, and elevated objects need to be accounted for. The USGS and ISFAR datasets will be merged into a new dataset that statistically accounts for the errors of both. To merge these datasets, a variational data interpolation technique based on the standard Bayesian statistical approach will be used (McIntosh 1990). Given the two datasets, and error statistics for both, the Bayesian Maximum Likelihood approach allows building an optimal field ("a new data set") which maximizes the conditional probability density of the observed field. The maximization of the conditional probability density can be extended to the minimization of a cost function which accounts for these errors. To that end, the error variance of USGS and ISFAR data and the prior estimates of the correlation of these errors will be approximated.

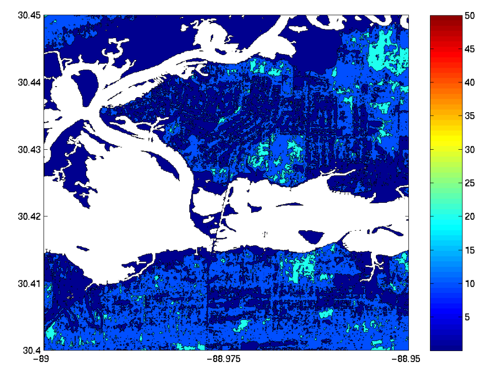

Figure 1. DEM values (m) based on IFSAR data for western Biloxi Bay, with land masses to the north and south, and the Biloxi River in the northwest. The white area is water.

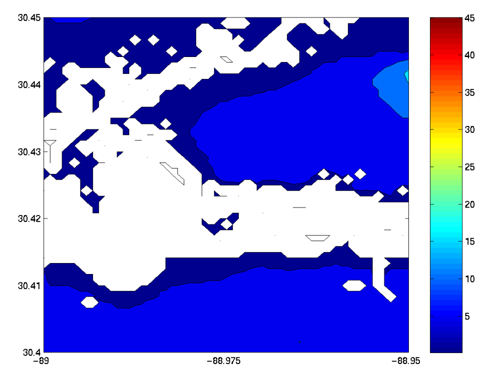

Figure 2. As in Fig. 1, but for USGS data.

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References

References available upon request.