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Efficient Simulations of Operational Risk in Coastal Environments (eSORCE)

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Abstract

During extreme storms, fluvial processes resultant from localized flooding can seriously impact human lives. Also the sustainability of coastal infrastructure can be impaired by the frequency of future hurricanes and evolution of storm surge. The current technology to estimate overland flooding is to use an integrated, coupled system for wind and waves. Real time data including wind, surface waves, and inundation area, all have tremendous impacts on decision making in any coastal regions. Also, the applications of process based and coupled simulations are often constrained by the fact that execution of such numerical exercises are often time consuming and in most cases, information related to these processes is nonexistent for most coastal areas in developing countries like Bangladesh, India or Myanmar. To overcome this problem, an efficient technique has been developed to estimate operational risks in coastal environments.

1. Introduction

In natural disaster, there is an immediate need to determine possible risks and prepare or produce robust plans for short- and long-term goals. For example, in case of flood hazard due to storms, it is a very important to identify flood inundation areas and provide information related to storm surge to emergency mangers in order to support evacuation planning and resource deployment during storm events. However, under dynamic emergency situations, it is very difficult for decision makers or planners to make quickly an appropriate decision because of limited time and information resources (Kebair & Serin, 2008 [1]). Thus, in the decision making processes, it is a very critical to collect and analyze the most current and reliable data as soon as possible and provide a baseline for decision making by providing a common operational picture (COP) through collected information analysis.

The state-of-the-art practice of estimating local storm surge elevation for an approaching hurricane or tropical storm is to use an integrated, coupled system for winds and waves. The simulation and prediction of storm surge are intrinsically complex due to the non-linear interaction of wind, waves and fluid motions. Real time data including wind, surface waves, and inundation area, all have tremendous impacts on decision making in any coastal regions. However, the applications of process based and coupled simulations are often constrained by the fact that execution of such numerical exercises are often time consuming and in most cases, information related to these processes is essentially nonexistent for most coastal areas, especially for developing courtiers like Bangladesh, India and Myanmar.

To address these limitations, an alternative, efficient and robust data mining technique has been developed to estimate high resolution local storm surge in coastal areas (Das et al., 2011 [2]). Recently this technique is fully integrated in GIS. With the help of this integrated tool, decision makers and emergency managers can quickly assess the impact of an approaching hurricane and make objective decisions by evaluating what-if-scenarios starting two to three days ahead of landfall.

2. Data

Unlike conventional storm forecasting methods using integrated and coupled numerical models, **E**fficient **S**imulations of **O**perational **R**isk in **C**oastal **E**nvironments (eSORCE) tool uses intelligent data processing technique to identify the best matching synthetic storms from synthetic storm database with pre-computed storm surge results. These pre-computed results are by-products of the study conducted separately by Federal Emergency Management Agency (FEMA) and U.S. Army Corps of Engineers to characterize hurricanes in Gulf of Mexico after Hurricane Katrina (Resio et al. 2007 [3]; Niedoroda et al. 2010 [4]). From these studies, 275 synthetic storms are available with unique hurricane characteristics. Each of these storms was simulated using highly detailed surge (ADCIRC) and wave (STWAVE, SWAN and WAM) models to predict storm surge and waves for the coast of Mississippi. The modelling was more accurate than any other modelling of its type as it incorporated all the key physical processes, including cyclone intensity decrease and filling (expansion in size) as hurricanes/cyclones approach the coast. Examples of archived dataset are shown in Figure 1.

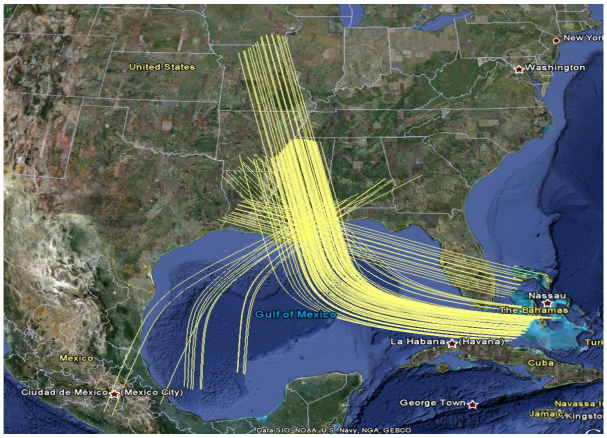

Figure 1: Track distributions of synthetic cyclones used by the eSORCE tool.

3. Methodology

The eSORCE tool has been developed using the archived data where the central pressure, radius, and landing location of an approaching cyclone are used to search for the characteristics of cyclones that best matches with the properties of the synthetic cases within the database. The flowchart of computation in the toolbox is shown in Figure 2.

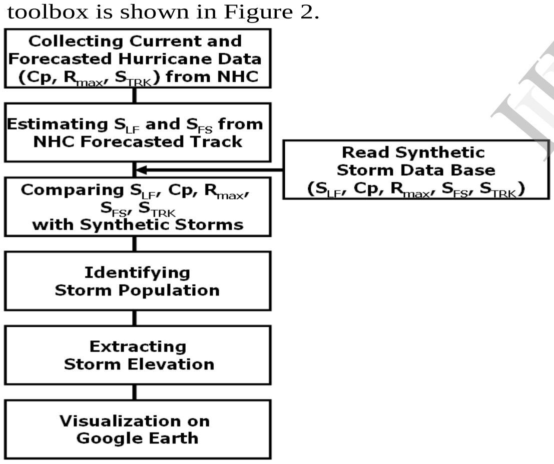

Figure 2: Flow Chart of the eSORCE Toolbox

The computed results are then displayed in a GIS environment with layers of forecast cyclone track, surge and wave information, assessment of potential flooding with hydrographs. The toolbox has the capability to work in real time by automatically extracting approaching cyclone information (e.g., current location, central pressure) from the National Hurricane Center (NHC) or Joint Typhoon Warning Centre (JTWC) website and then extract a group of synthetic cyclone from the database that best matches with the characteristics of the approaching cyclone.

4. Model Validation

For validation, results were compared with observed High Water Marks (HWM) from historical hurricanes such as hurricanes Katrina, Camille, Betsy and Gustav which made landfall in the Gulf coast. It was found that modelled results using the data mining approach were well compared with the observed High Water Marks (Figure 3).

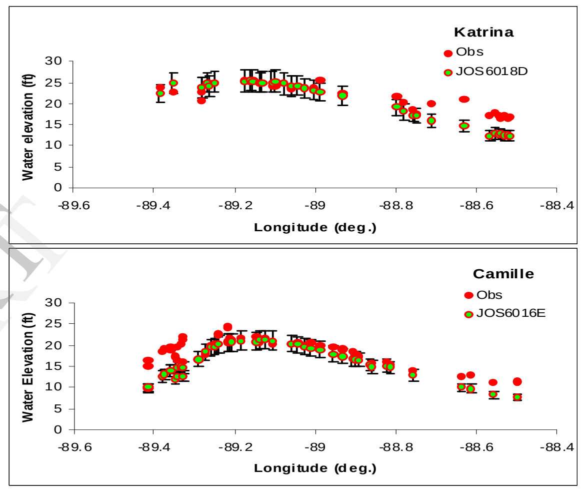

Figure 3: Observed [In red] and simulated [in black with 1.5 ft error bar] High Water Marks along the coast of Mississippi from Hurricanes Camille and Katrina.

5. Model Application

For real time application, the forecast data set provided by the National Hurricane centre (NHC) during hurricane Gustav is used. Two advisory data sets (al072008-5day-020A, and al072008-5day-027A; herein, referred as advisory numbers 20 and 27) are chosen. Each data set has the projected hurricane track along with current storm location, Central Pressure deficit (Cp) and Radius to Maximum Winds (Rmax) values. Figure 4 shows the NHC forecasted Hurricane Gustav track and cone of uncertainty for advisory numbers 20. Figure 4 also shows the best matching synthetic storms in the database identified by the eSORCE tool.

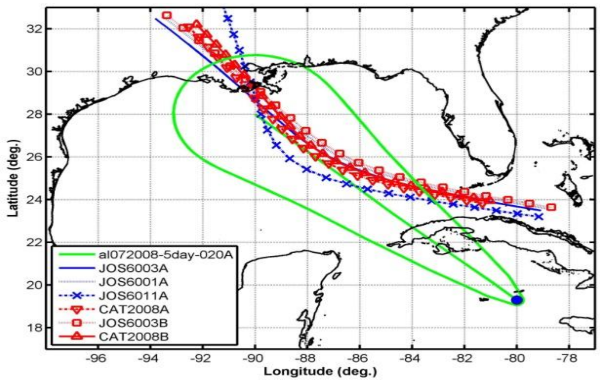

Figure 4. Forecasted Hurricane Gustav tracks (Advisory Number 20) and synthetic storm tracks in the database. The blue dots (o) indicate the current hurricane location and the green line shows the cone of uncertainty.

Figure 7 shows the integration of GIS ArcMap (ESRI) and eSORCE toolbox for visual analytics. For visualization, the pre-computed maximum surge elevation raster data of the matching storm has been displayed on the map. The toolbox then conducts spatial analysis using this surge elevation data with other GIS data including road, population, important facilities and infrastructure, etc. With this information, hazard areas are identified, and then evacuation routes and shelter locations are set up for local resident and tourist in the hazard areas (Figure 5). The evacuation routes and shelter information are updated dynamically on the basis of changes in current traffic condition, population distribution, travel time, etc. The estimated processing time from collecting a new hurricane advisory data to GIS data analysis through eSORCE takes less than 20 minutes. This allows decision makers or emergency management teams to response very quickly under circumstances which may change dynamically.

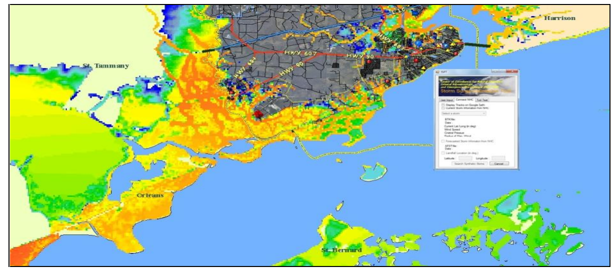

Figure 5. After analyzing the GIS data with maximum storm surge elevation, eSORCE displays flood areas with evacuation routes and shelters.

6. Discussion

A method to predict storm surge heights using an efficient data oriented approach has been developed. With this Efficient Simulations of Operational Risk in Coastal Environments (eSORCE) tool, decision makers and emergency managers can quickly assess the impact of an approaching cyclone and make objective decisions by evaluating what-if-scenarios starting two to three days before the impact. For the application and demonstration of this method, the United States Gulf of Mexico (GOM) coast of Eastern Louisiana and Mississippi has been used. However, this methodology can be adopted easily to study storm surge in Bay of Bengal and expand the toolbox to assess risks in the coastal areas of Bangladesh, India and Myanmar.

7. References

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