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Research papers

Skill assessment of a real-time forecast system utilizing a coupled hydrologic and coastal hydrodynamic model during Hurricane Irene (2011)

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ABSTRACT

Due to the devastating effects of recent hurricanes in the Gulf of Mexico (e.g., Katrina, Rita, Ike and Gustav), the development of a high-resolution, real-time, total water level prototype system has been accelerated. The fully coupled model system that includes hydrology is an extension of the ADCIRC Surge Guidance System (ASGS), and will henceforth be referred to as ASGS-STORM (Scalable, Terrestrial, Ocean, River, Meteorological) to emphasize the major processes that are represented by the system.The ASGS-STORM system incorporates tides, waves, winds, rivers and surge to produce a total water level, which provides a holistic representation of coastal flooding. ASGS-STORM was rigorously tested during Hurricane Irene, which made landfall in late August 2011 in North Carolina. All results from ASGS-STORM for the advisories were produced in real-time, forced by forecast wind and pressure fields computed using a parametric tropical cyclone model, and made available via the web. Herein, a skill assessment, analyzing wind speed and direction, significant wave heights, and total water levels, is used to evaluate ASGS-STORM's performance during Irene for three advisories and the best track from the National Hurricane Center (NHC). ASGS-STORM showed slight over-prediction for two advisories (Advisory 23 and 25) due to the over-estimation of the storm intensity. However, ASGS-STORM shows notable skill in capturing total water levels, wind speed and direction, and significant wave heights in North Carolina when utilizing Advisory 28, which had a slight shift in the track but provided a more accurate estimation of the storm intensity, along with the best track from the NHC. Results from ASGS-STORM have shown that as the forecast of the advisories improves, so does the accuracy of the models used in the study; therefore, accurate input from the weather forecast is a necessary, but not sufficient, condition to ensure the accuracy of the guidance provided by the system. While Irene provided a real-time test of the viability of a total water level system, the relatively insignificant freshwater discharges precludes definitive conclusions about the role of freshwater discharges on total water levels in estuarine zones. Now that the system has been developed, on-going work will examine storms (e.g., Floyd) for which the freshwater discharge played a more meaningful role.

1. Introduction

Since the devastating effects of Hurricanes Katrina, Rita, Ike and Gustav in the Louisiana and the northern Gulf of Mexico region, the development of a high-resolution, real-time, total water level prototype forecast system has been accelerated: the development and assessment of such a system is the subject of this manuscript. It produces a holistic representation of the coastal flooding through development of a total water level product (defined herein to be tides + waves + rivers + surge + precipitation).

Over the last several years, the ADCIRC Coastal Circulation and Surge Model, which forms the backbone of the system described

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herein, has been used in many hurricane studies, in particular, the Interagency Performance Evaluation Task Force to study Hurricane Katrina (Link et al., 2006), and evaluations of the hindcasts of Hurricanes Gustav (Forbes et al., 2010) and Rita (Dietrich et al., 2010). As part of this process, a wave component (Dietrich et al., 2010) was added and there has been continued development of a parametric tropical cyclone model following Holland (1980) and Mattocks et al. (2006). In addition, a real-time system has been developed, the ADCIRC Surge Guidance System (ASGS), to automate the use of ADCIRC in forecast applications (Fleming et al., 2008). The model system described in this paper demonstrates a further extension of ASGS to include a hydrologic model, capturing both coastal and inland total water levels associated with tropical and extratropical storms. This model system is herein referred to as ASGS-STORM (ASGS-Scalable, Terrestrial, Ocean, River, Meteorology). A parallel, collaborative effort with NOAA (National Oceanic and Atmospheric Administration) through their CI-FLOW (Coastal Inland-Flood Observation and Warning) project is reported in Van Cooten et al. (2011), which documents the history of the system's development and its initial testing.

In some coastal storm events, the surge and wave components play the most significant role; while for others, the freshwater component from upstream river flow is the dominant component. An event that illustrated the need to incorporate the upstream freshwater component in the coupled model system was Hurricane Floyd. The North Carolina watersheds saw only a small surge (≈3 m) during Hurricane Floyd, but inland main stem river reaches and their tributaries experienced record precipitation that produced historical flooding (comparable to the 500-year flood levels on the Tar/Pamlico River) (Tromble et al., 2011). Hurricane Dennis preceded Floyd and alleviated the drought conditions in the North Carolina coastal areas; however, it also set up the antecedent conditions that brought about massive flooding during Hurricane Floyd. Thus, in order to accurately represent the coastal flood inundation caused by both the upstream flooding and storm surge, a system is needed that incorporates not only the tides, waves, winds and atmospheric pressure differences due to the storm but also the antecedent conditions, precipitation and riverine flows. Events such as these have spurred the development of a total water level product, which has been the focus of both DHS (Department of Homeland Security) and NOAA projects. Thus, herein, we describe progress towards the development of a modeling system to produce high-resolution, total water level forecasts for coastal, near-shore and inland areas.

Previous studies have looked at real-time systems; however, none of these previous systems have coupled a hydrologic and hydrodynamic model in a real-time framework. Blain et al. (2002) documented a real-time tidal modeling system designed to integrate meteorological information from different scale meteorological models. However, this system did not include waves, hydrological components, or the ability to develop the meteorological forcing from tropical cyclone advisories. Mattocks et al. (2006) developed a system that provided real-time coastal modeling utilizing ADCIRC and a new parametric tropical cyclone model. This system included the tidal effects; however, it did not include the waves and hydrological models. Modern cyberinfrastructure tools were applied to ADCIRC by Ramakrishnan et al. (2006) to develop a real-time modeling capability that could

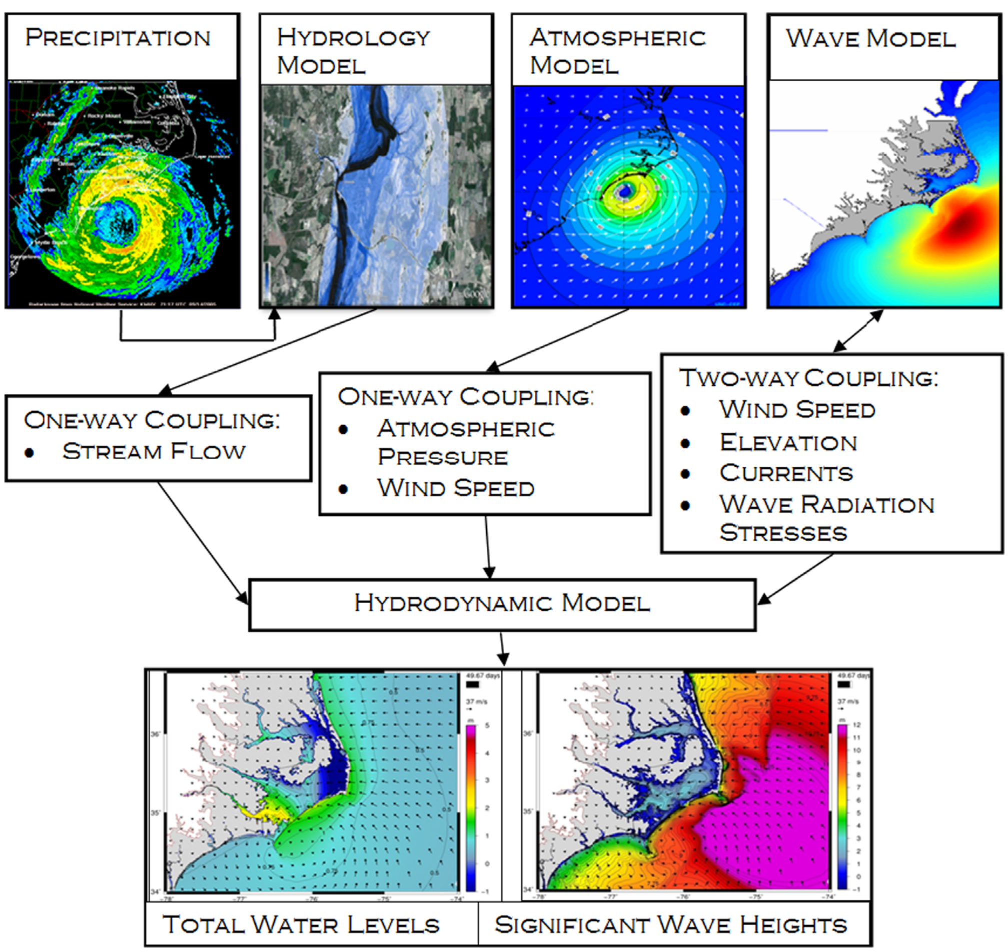

Fig. 1. Schematic of ASGS-STORM for predicting total water inundation in coastal North Carolina; upper boxes illustrate model components in the coupled system, lower boxes illustrate output products, and arrows and text boxes indicate data flow.