Sensitivity of Storm Surge Predictions to Atmospheric Forcing during Hurricane Isaac (2012)

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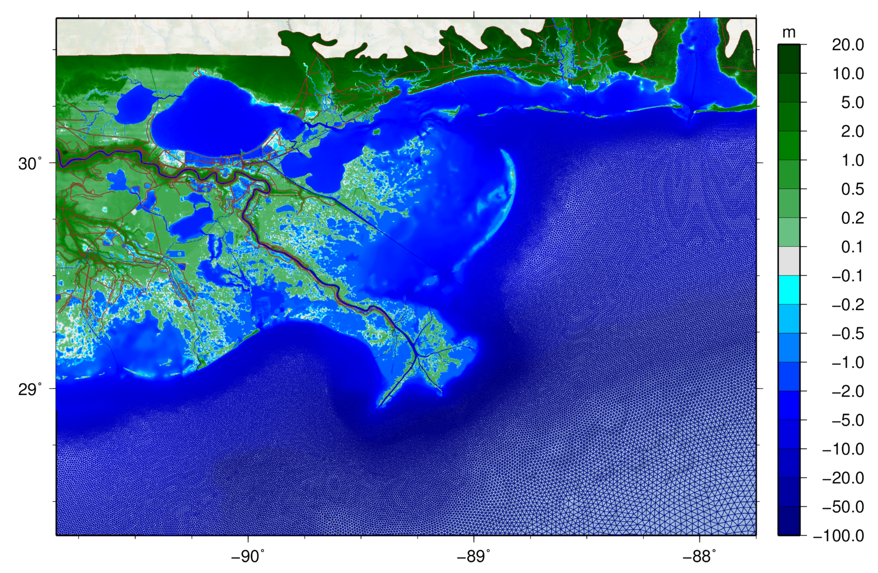
Introduction and Motivation

Landfalling storms can cause surge, flooding, and the transport of contaminants into coastal regions. To improve computational efficiency in forecasting applications, surge models use atmospheric forcing from vortex models based on a few storm parameters, but the future of storm surge prediction could involve real-time coupling of surge and full-physics atmospheric models. **We compare predictions from a parametric vortex model and a full-physics atmospheric model during Hurricane Isaac (2012).** The predictions are then applied within a tightly-coupled, wave and surge modeling system on a high-resolution, unstructured, finite-element mesh describing the northern Gulf of Mexico and the floodplains of southwest Louisiana.

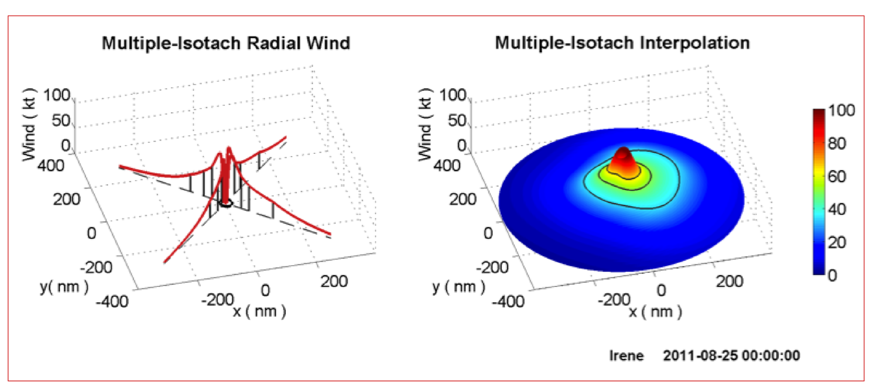
Wave and Storm Surge Models

Storm-induced waves and surge are modeled with the Simulating WAves Nearshore (SWAN) and **ADvanced CIRCulation (ADCIRC)** models, which are are highly efficient in parallel computing environments. These models have been applied successfully to detailed hindcasts of several recent storms in the Gulf of Mexico, including Katrina and Rita [Dietrich *et al.*, 2011a], Gustav [Dietrich *et al.*, 2011b] and Ike [Hope *et al.*, 2013]. ADCIRC uses meshes with triangular elements, and thus it allows localized refinement to represent the coastal ocean.



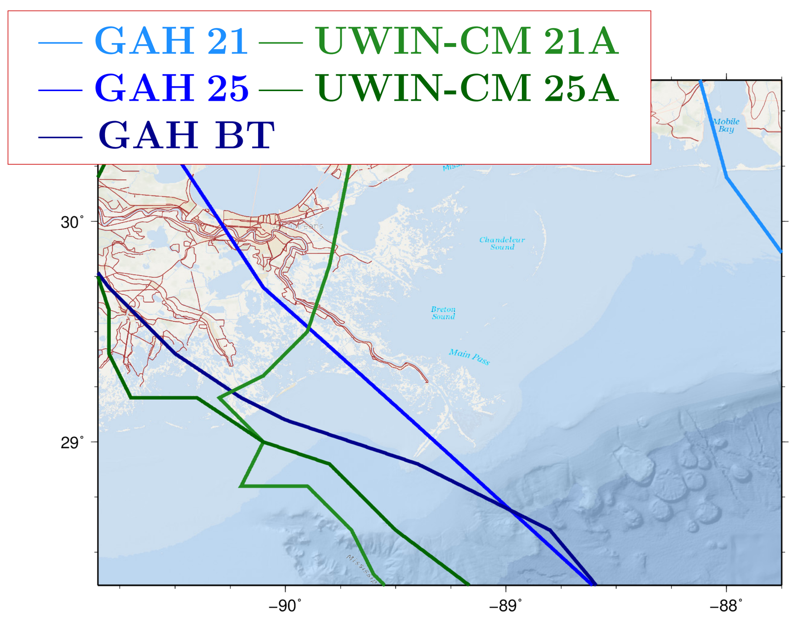
Atmospheric Models

During tropical cyclones, the pressure and wind fields can be represented with a parametric vortex model based on Holland [1980] and updated to account for storm asymmetry [Mattocks *et al.*, 2006; Mattocks and Forbes, 2008]. It has also been updated recently as the **Generalized Asymmetric Holland Model (GAHM)**, which removes the assumption of cyclostrophic balance, and uses all storm isotachs to construct the wind field. GAHM uses the storm parameters from the National Hurricane Center (NHC) forecast advisories.



An alternative is to consider the Weather Research and Forecasting (WRF) model within the **Unified Wave INterface Coupled Model (UWIN-CM)**. These wind fields include the effects of storm-induced ocean cooling, and the wind-wave stress is computed directly from the wave model. For each forecast, UWIN-CM relies on the National Center for Environmental Protection (NCEP) Global Forecasting System (GFS) for its inputs.

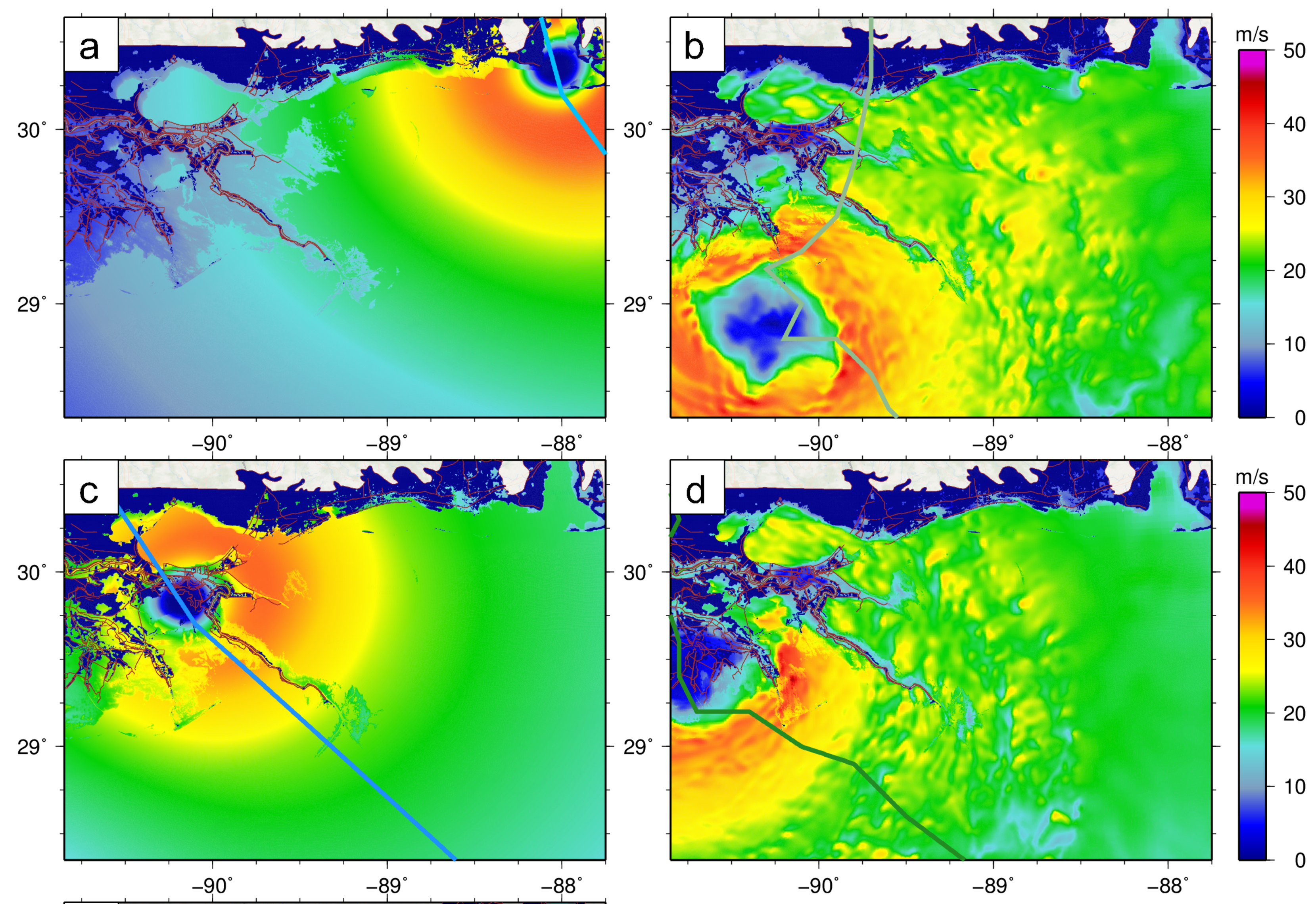
Summary of Forecasts and Hindcast of Isaac

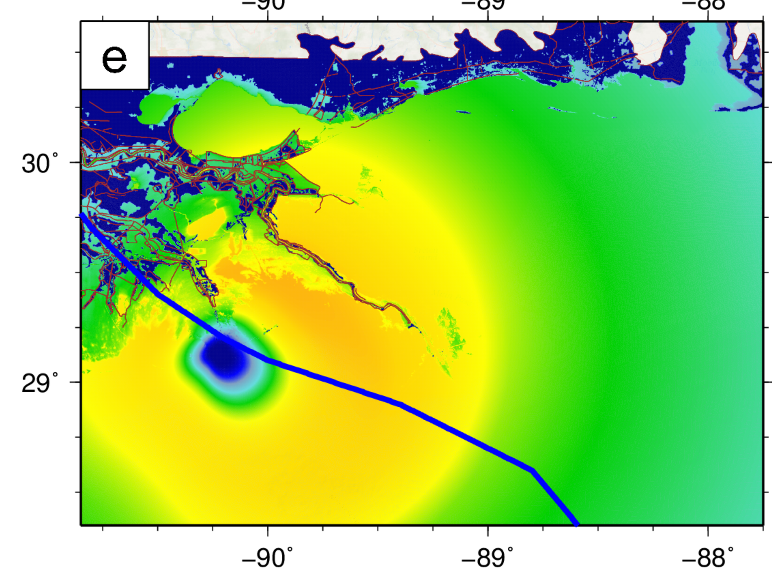


Forecasts were initialized with the best-available information as the storm progressed. Performance is quantified with root-mean-square (RMS) errors to observations throughout the Gulf.

	Model	Start (UTC)	Landfall	RMS Errors Pressures (mbar)	RMS Errors Wind Speeds (m/s)	RMS Errors Water Levels (m)
(a)	GAHM 21	2012/08/26/0900	63 hr	20.0	5.19	1.32
(c)	GAHM 25	2012/08/27/0900	39 hr	18.8	4.25	0.49
(b)	UWIN-CM 21A	2012/08/26/1200	60 hr	9.7	4.59	0.55
(d)	UWIN-CM 25A	2012/08/27/1200	36 hr	7.8	3.96	0.42
(e)	GAHM BT	Best-Track Hindcast	–	12.1	3.82	0.35

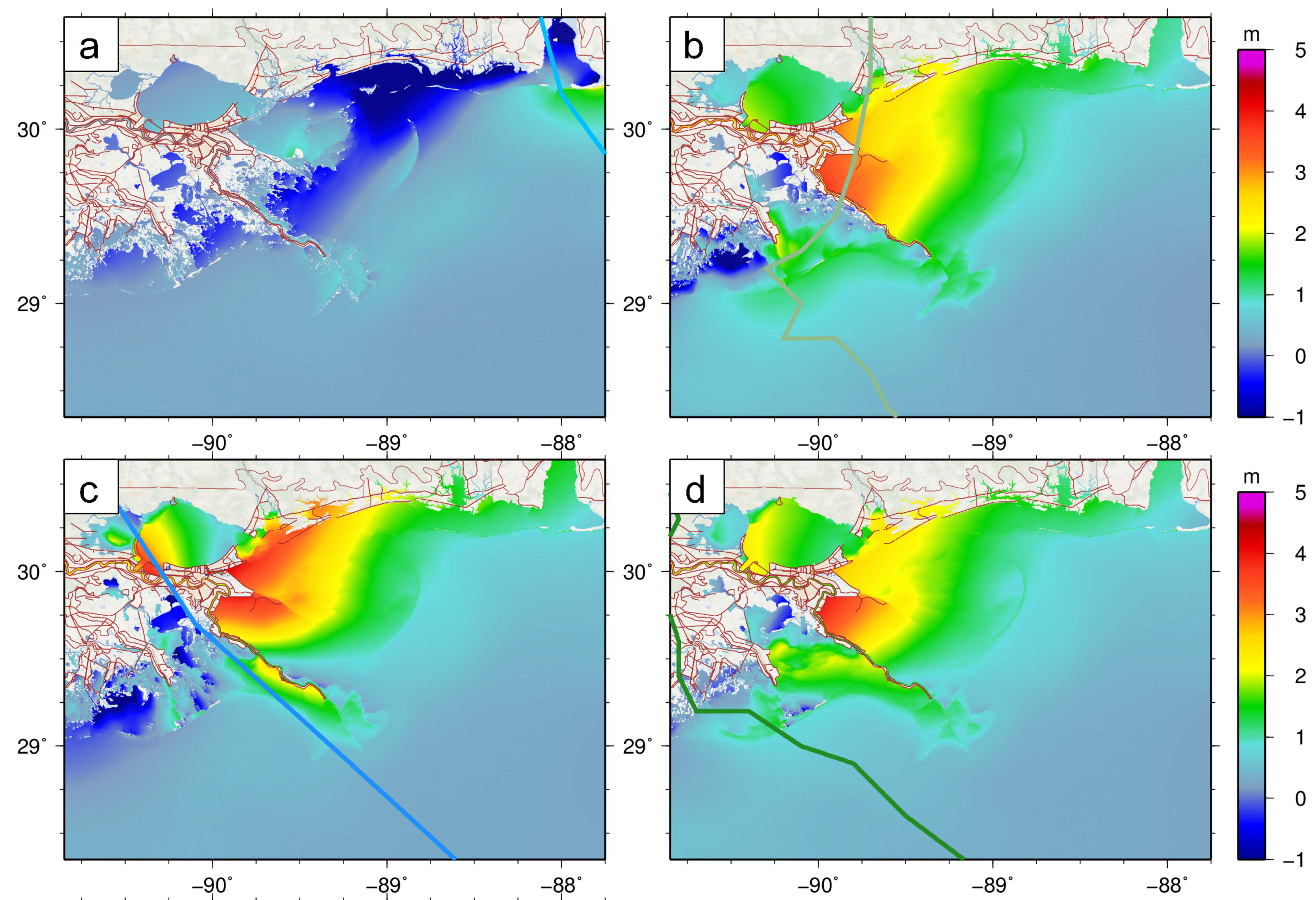
Wind Speeds at Second Landfall in Louisiana

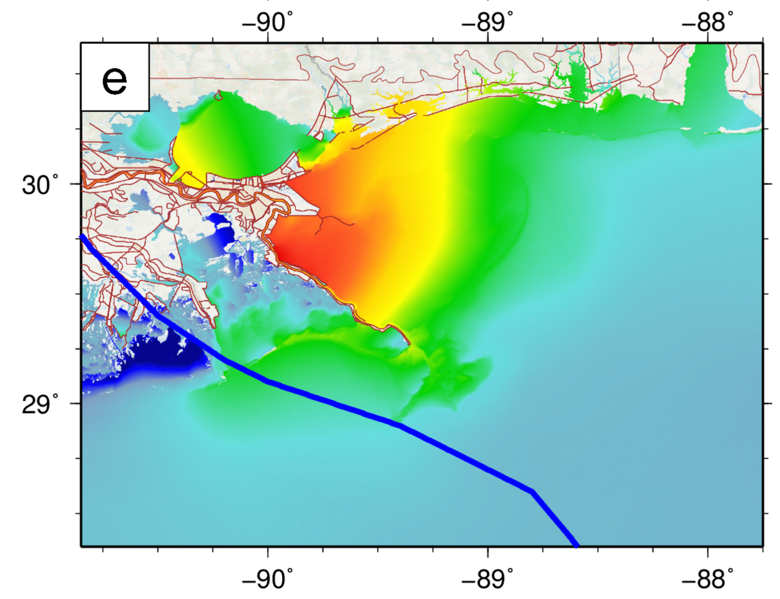




Wind speeds (m/s) at 08/29/0800 UTC:
- (a) **GAHM 21** has wrong track
- (c) **GAHM 25** has storm moving too fast, winds too strong (35-40 m/s)
- (b) **UWIN-CM 21A** has the storm moving east of New Orleans after landfall
- (d) **UWIN-CM 25A** has correct track and landfall, storm is moving too fast
- (e) **GAHM BT** is the best-track hindcast

Water Levels at Second Landfall in Louisiana





Water levels (m) at 08/29/0800 UTC:
- (a) **GAHM 21** has drawdown in Louisiana
- (c) **GAHM 25** has the correct peak surge, but flooding is too small along river
- (b) **UWIN-CM 21A** is correct in Caernarvon Marsh, but too small to north
- (d) **UWIN-CM 25A** has too much flooding south and west of the river
- (e) **GAHM BT** is the best-track hindcast

Results and Discussion

The SWAN+ADCIRC modeling system was applied to high-resolution simulations of storm surge and flooding during Hurricane Isaac (2012). The surge model was forced with forecasts of surface pressure and wind fields from two atmospheric models: GAHM and UWIN-CM. The effects of the atmospheric forcing were evaluated for forecasts issued 2.5 days and 1.5 days before the storm made landfall in Louisiana.

GAHM represents the storm as described in each NHC forecast advisory. For the earlier forecast in which the storm was projected to make landfall along the Florida panhandle, the northerly winds were blowing offshore and causing a drawdown in the coastal water levels. The surge predictions improved for the later forecast, with only a few errors caused by the storm moving too fast and thus not pushing enough surge over the marshes to the southeast of New Orleans. **These analyses demonstrate the considerable sensitivity of the surge model predictions to the hurricane forecast.**

Full-physics atmospheric models also have errors associated with their forecasts. The UWIN-CM predicted the storm to move through southern Louisiana, even in its earlier forecasts. The peak surge values were within 0.5-1 m of their observed values near the storm track. Even with these timing errors due to the storm forward speed, the surge model predictions were generally good when forced with results from UWIN-CM. These findings demonstrate the forecast skill of a full-physics atmospheric model coupled to a high-resolution storm surge model.

These findings have implications for storm surge predictions using any combination of atmospheric and ocean models. While parametric vortex models are efficient, they are limited by errors in storm parameters from the forecast advisories. When the projected track is too far eastward or the forward speed is too fast, the surge predictions can be too small by 2 m or too early by 12 hr. Although full-physics atmospheric models also contain errors, they incorporate additional information about the far-field meteorology, temperature and momentum transfer with the sea surface, etc. Future work will include a tighter coupling between the UWIN-CM atmospheric forcing and SWAN+ADCIRC.

Acknowledgments

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JC Dietrich, A Muhammad, M Curcic, A Fathi, CN Dawson, SS Chen, RA Luettich Jr (2016). "Sensitivity of Storm Surge Predictions to Atmospheric Forcing during Hurricane Isaac (2012)." *Journal of Geophysical Research – Oceans*, in review.