The US Coastal Act

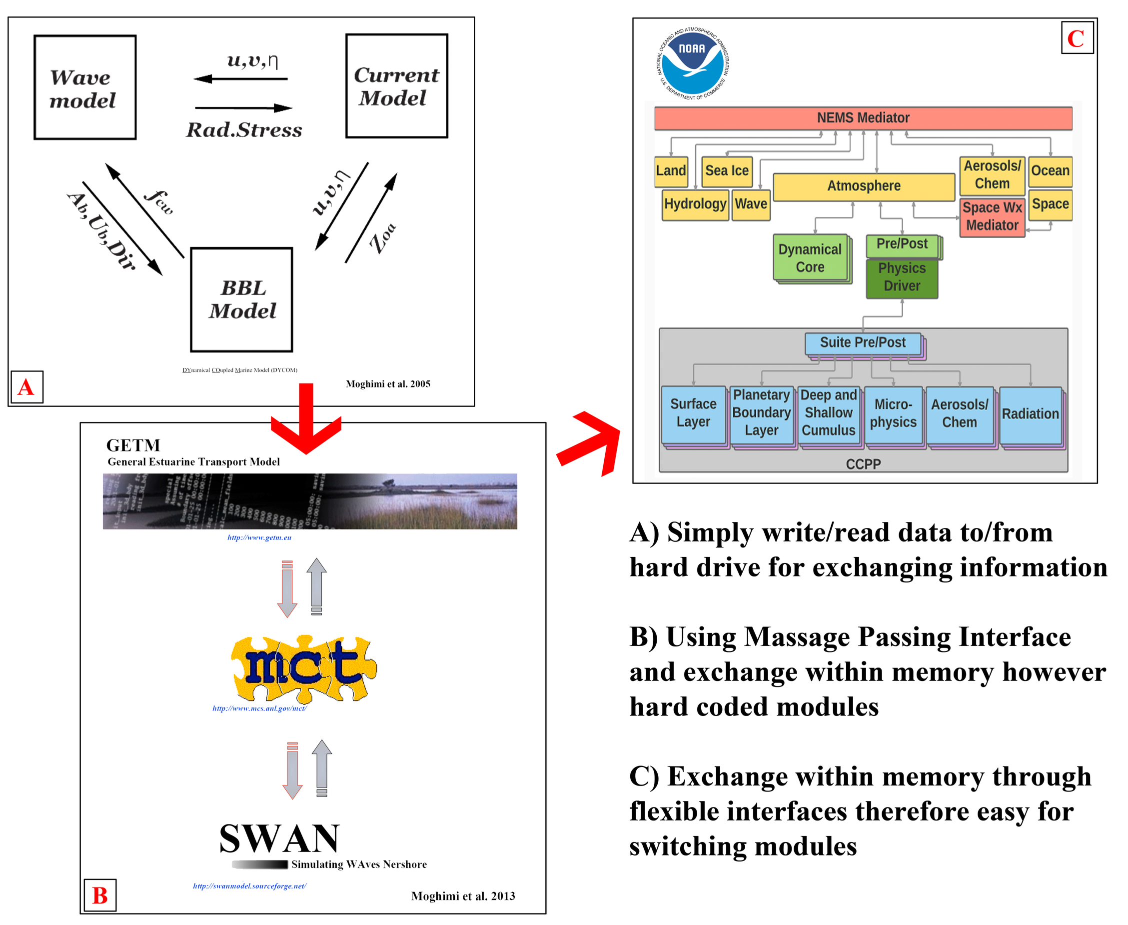
Hendrik Tolman[1], Nicole Kurkowski[1], Andre Van der Westhuysen[1], Saeed Moghimi[1], Ali Abdolali[1], Zaizhong Ma[1], Sergey Vinogradov[1], Jessica Meixner[1], Yuji Funakoshi[1], Ed Myers[1], Arun Chawla[1], Avichal Mehra[1], Fei Liu[2]
1- National Oceanic and Atmospheric Administration
2- NUOPC / ESMF developer team
NOAA / National Weather Service, 1325 East-West Highway, Silver Spring, MD 20910-3280 , USA
E-mail: Nicole.Kurkowski@noaa.gov; tel: +1(301)427-9104 E-mail: Hendrik.Tolman@noaa.gov; tel: +1(410)279-3320

1st International Workshop on Waves, Storm Surges, and Coastal Hazards; Liverpool, UK, September 10 -15, 2017

Background

The US Consumer Option for an Alternative System to Allocate Losses (COASTAL) Act requires an accurate hindcast modeling of flooding and wind caused by hurricanes to assist with recovery efforts. A significant portion of flooding due to hurricanes are caused by the interactions of wind-generated waves and the underlying surge, with radiation stresses from wave processes playing a significant role in the surge and the combined wave-current bottom boundary dynamics being important for both the wave and surge processes. Highly-sophisticated numerical models that separately simulate surge and wave processes have been developed and validated at the National Oceanic and Atmospheric Administration (NOAA) over the last decade (the **ADCIRC**-based ESTOFS system for the surge modeling and **WAVEWATCH III** Global Multi-1 system for wave modeling). The two modeling systems will be dynamically coupled to exchange physical processes so as to obtain accurate estimates of total wave-surge induced inundation. For this purpose, NOAA is furthermore partnering with the U.S. Army Corps of Engineers (USACE) in the development of a more efficient numerical solver for the WAVEWATCH III model that will make it possible to carry out wave simulations in very high resolution domains with extensive computational grids. This coupled modeling system, called the Named Storm Event Model (NSEM), will undergo validation of performance in representing total water level as a combination of storm surge, tides, and wave activity. Skill assessment techniques and criteria will be determined in order to be consistent with the 90% accuracy requirement of the COASTAL Act.

Evolution of Model Coupling



NEMS

NOAA Environmental Modeling System (NEMS)
NEMS coupling infrastructure is based on the Earth System Modeling Framework (ESMF) and National Unified Operational Prediction Capability (NUOPC) Layer code and conventions.
> The model components in NEMS can be assembled into a number of different modeling applications, each associated with:
- a purpose, such as seasonal forecasting
- a set of model components
- a set of parameters that represents a range of supported options, including grids and resolutions
> Different NEMS modeling applications can have different types and numbers of model components
> The same physical domain may be represented by different model components in different modeling applications:
- For example, in some NEMS modeling applications the ocean component may be **HYCOM** and in others it may be MOM5 (DeLuca, 2015).
Information exchange is secure among model components
> The only way data moves in or out of a Component is via instances of the **ESMF State** class.
> A State is a **container** for ESMF data types that wrap native model data.
> Model data can be **referenced**, avoiding duplicates and copies.
> **Metadata** (e.g., name, coordinates, decomposition) travels with data objects.

NSEM Application

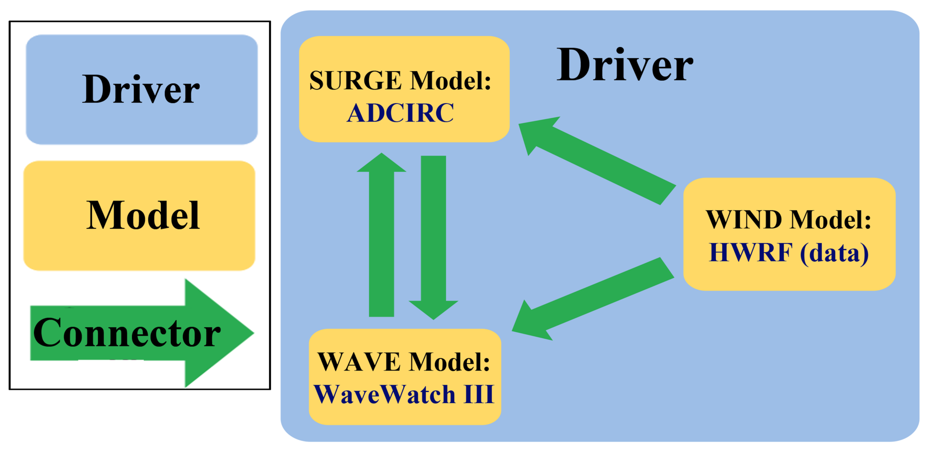


Figure 1: Model components HWRF, ADCIRC and WaveWatch III

National Unified Operational Prediction Capability (NUOPC) Layer

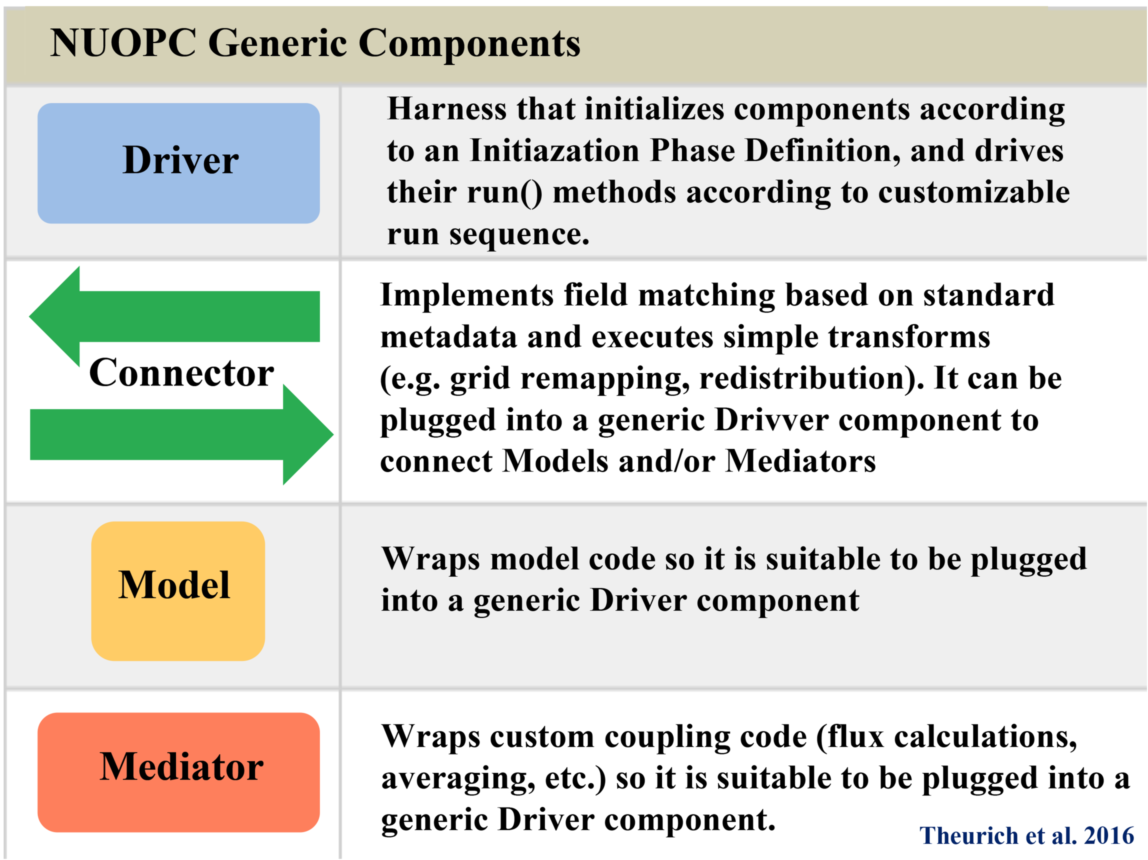


Figure 2: NUOPC Layer interoperability rules are implemented using a set of generic components that represent the major structural pieces needed to build coupled models.

Data Exchange

ADCIRC-WWIII-HWRF Coupling System:
> HWRF:
- Grid: Structured (moving mesh)
- Exports:Atmospheric forcing to ADCIRC and Wave Watch III from stored HWRF model outputs
- Imports: Nothing
> ADCIRC:
- Mesh: Unstructured
- Exports: Water surface elevation and current velocities to Wave Watch III
- Imports: Atmospheric forcing from HWRF
- Imports: Wave forcing from Wave Watch III
> Wave Watch III:
- Mesh: Unstructured
- Exports: Wave forcing to ADCIRC
- Imports: Atmospheric forcing from HWRF
- Imports: Water surface elevation and current velocities from ADCIRC

Wave Component Validation IKE-2008

HWRF forcing scenarios:
GFS25d : HWRF forced by GFS with 2.5° Spatial resolution
GFS1d : GFS 1°
GFS05d : GFS 0.5°
GFS05d-OC : GFS 0.5° also coupled with Ocean model
GFS05d-OC-DA : GFS 0.5° coupled with Ocean model and employed data assimilation package

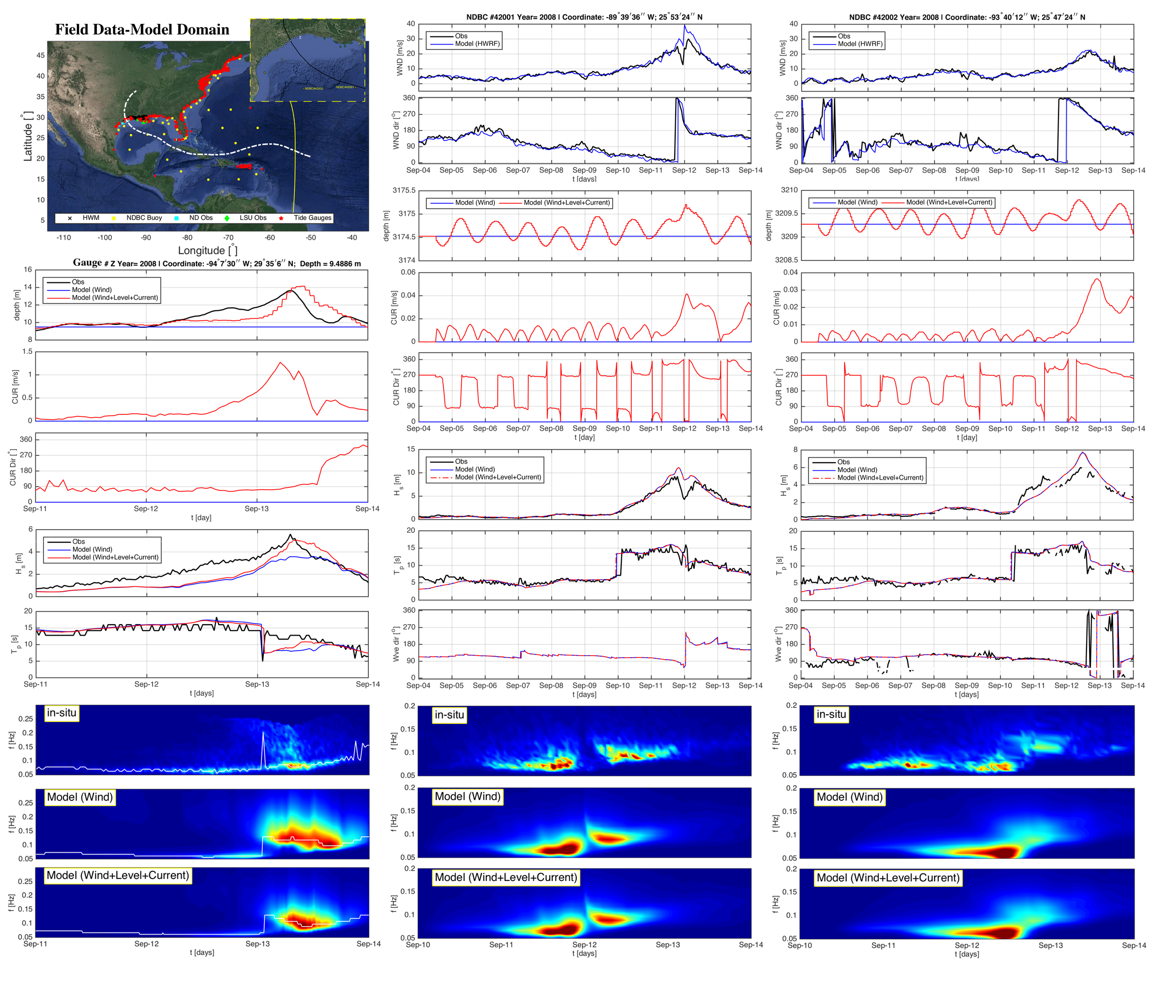


Figure 3: WAVEWATCH III output in shallow water (left panel) and deep water (right panels), forced by wind vs wind, water level, and current, showing the influence of tide/surge water levels and current.

Surge Component Validation IKE-2008

Observations:High Water Marks (HWM); Tidal stations water level time series (CO-OPS data).
High Water Marks (HWM): USGS provides HWM data after each major storm. Properly collected and recorded HWM from preserved evidence is one of the most important resources for our storm-surge model validation. High quality HWM data normally collected by experienced hydrographers, using the best available techniques.

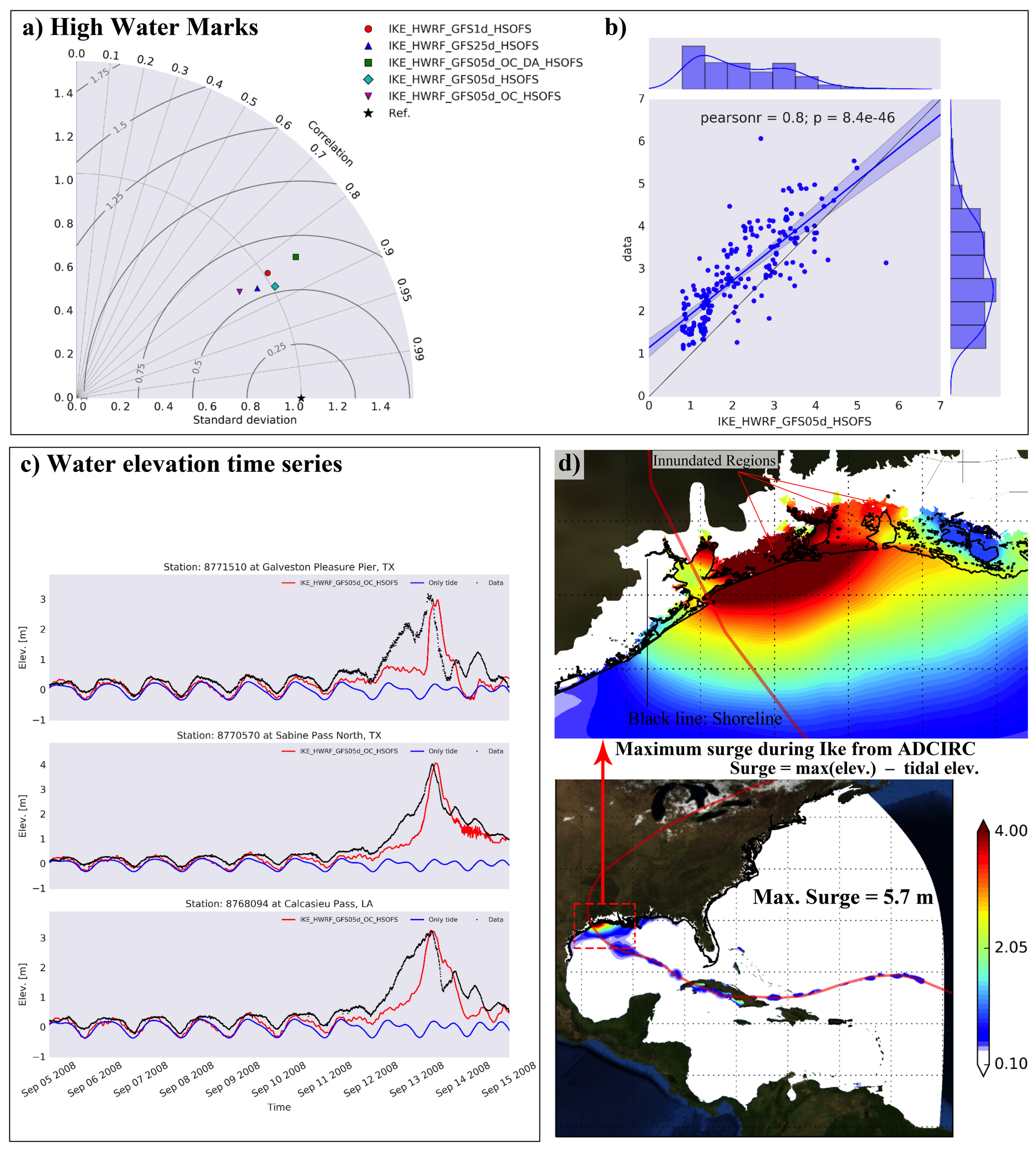
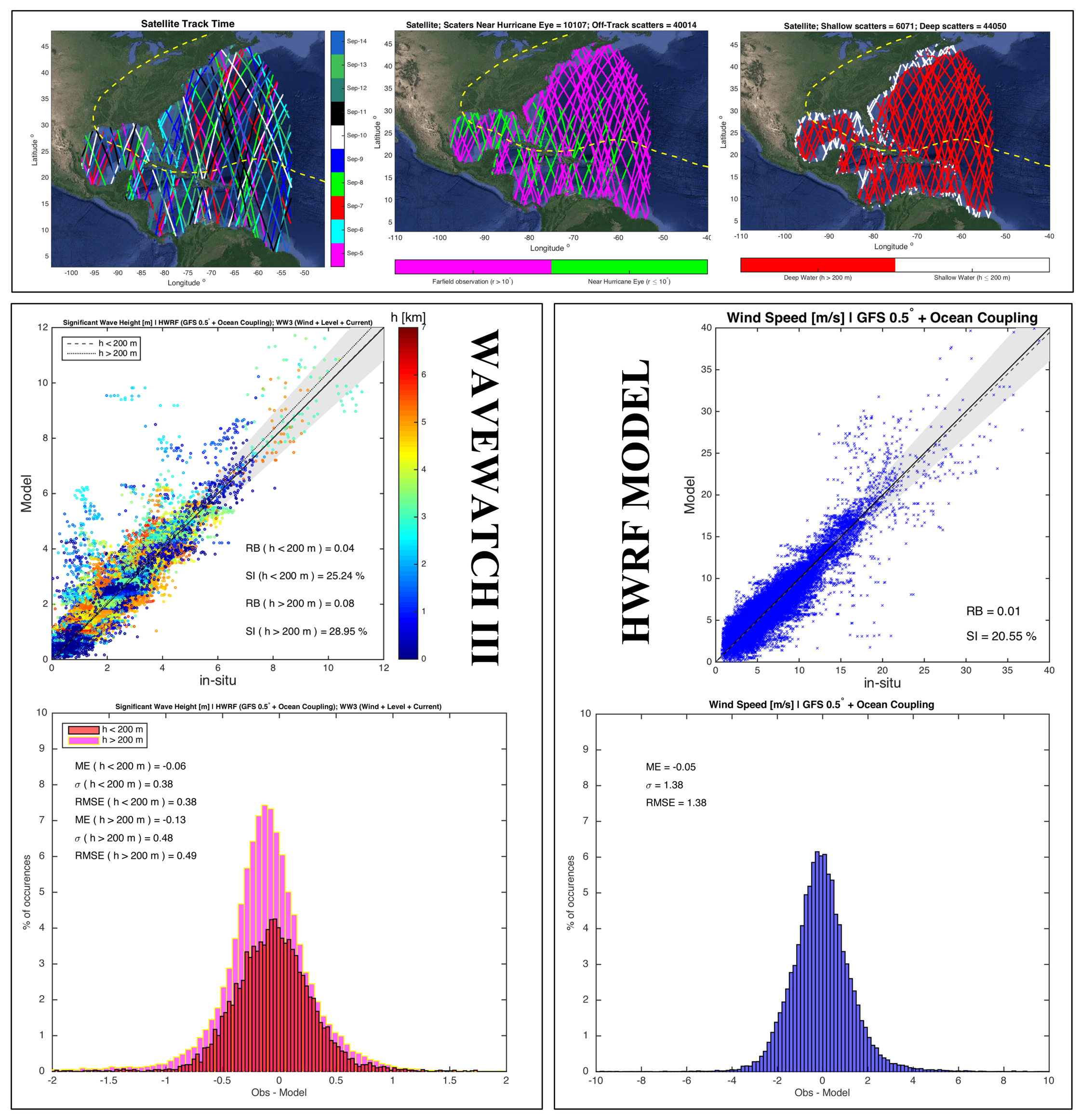


Figure 4: a) Taylor diagram Based on HWM information provided by USGS. b) Pearson's r: The Pearson correlation coefficient measures the linear relationship between two datasets.ăp-value: represents the probability of error that is involved in accepting our result as valid. c) Water elevation time series. d) Stand alone ADCIRC forced by a range of HWRF forcing scenarios with High Water Marks. Black star (Ref) represent HWM data (standard deviation of ∼1 m) HWRF forcing produce similarly correlated results (∼0.85). Standard deviations of HWRF forcing are not in the same range. GFS05d-OC-DA is more similar to data. The rms-error for all forcing's are in the same range (∼ 0.5 m).

Comparing on the HWRF forcing (GFS 0.5 deg) HWM data and model results are highly correlated . More improvement expected after incorporation of the wave model (ADCIRC-WWIII coupling)

Validation (Satellite Obs.) IKE-2008



Summary

Efforts are underway to dynamically couple NOAA's **WAVEWATCH III** and the **ADCIRC**-based ESTOFS system to obtain accurate estimates of total wave-surge induced inundation. The coupled modeling system will continue to undergo validation. The results for wave and surge modeling have been promising thus far. Additional advancements are being made with regards to high-resolution wind forcing, increased resolution of the surge-wave model mesh, improvement in model physics, and river coupling.
The **COASTAL Act** stipulates an accuracy of 90% for each gridded output product. Skill assessment techniques and criteria are being developed to be consistent with this accuracy requirement. Each gridded product (wind, water level, wave height, precipitation, river flooding) will be evaluated for accuracy using multiple methods, including: (i) analyzing the error relative to observations at measurement stations, and (ii) estimating model uncertainty through the generation of ensembles, via perturbations of the atmospheric model and variations in the physics of the surge and wave models.