High-Fidelity Coastal Coupling of WAVEWATCH III and ADCIRC using an ESMF-based framework

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[3]UCAR at NOAA/NWS/NCEP
[4]NOAA/NOS/CSDL

- Determination of model accuracy and uncertainties during severe events using point observations, satellite data and model ensembles. Ali Abdolali, Andre Van Der Westhuysen, Saeed Moghimi, Aron Roland, Zaizhong Ma, Avichal Mehra, Arun Chawla, Sergey Vinogradov, Edward Myers and Nicole Kurkowski BB3
- *Multi-physics Coastal Storm Surge Modeling in Alaska in Highly Fractured Ice Scenarios, Joannes Westerink and 18 others* E1
- *High-Fidelity Coastal Coupling of WAVEWATCH III and ADCIRC using an ESMF-based framework, Andre van der Westhuysen, Saeed Moghimi, Ali Abdolali, Sergey Vinogradov, Zaizhong Ma and Edward Myers* E2
- *Combining Ocean, Wave, Hydrologic, Riverine Flow Models at a Local and Regional Scale along the East Coast of the United States. Trey Flowers, Hendrik Tolman, Thomas Graziano, Edward Clark, Roham Bakhtyar, Nicole Kurkowski, Kazungu Maitaria, Saeed Moghimi, Beheen Trimble and Panagiotis Velissariou* JJ1
- *Towards coupling coastal ocean models to inland hydrology at NOAA National Ocean Service Saeed Moghimi and 25 others* JJ2
- *Unified Environmental Modeling from research to operations . Hendrik L. Tolman* K4
- *Modeling of Wave Interaction with Natural and Nature-Based Features. Jane McKee Smith and others.* QQ5

National Unified Operational Prediction Capability (NUOPC) Layer

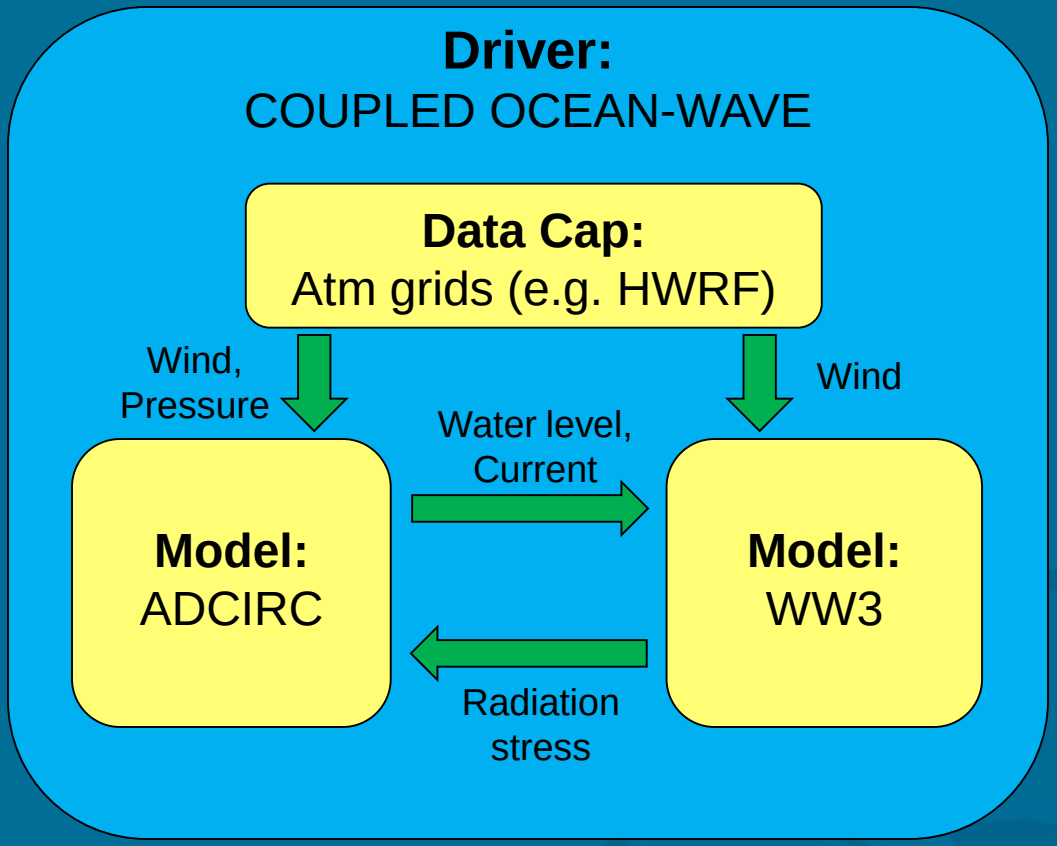
NUOPC Layer interoperability rules are implemented using a set of generic components that represent the major structural pieces needed to build coupled models.

NUOPC Generic Components	
Driver	Harness that initializes components according to an *Initialization Phase Definition*, and drives their Run() methods according to a customizable run sequence.
Connector	Implements field matching based on standard metadata and executes simple transforms (e.g. grid remapping, redistribution). It can be plugged into a generic Driver component to connect Models and/or Mediators.
Model	Wraps model code so it is suitable to be plugged into a generic Driver component.
Mediator	Wraps custom coupling code (flux calculations, averaging, etc.) so it is suitable to be plugged into a generic Driver component.

From Theurich et al. 2015

NEMS Coupled ADCIRC-WW3 Model

- An ADCIRC-WW3 application (“App”) in NEMS/NUOPC
- Based on NEMS interfaces or “Caps”
- One-way atmospheric forcing from gridded data file (e.g. HWRF model)
- Two-way exchange between ADCIRC and WW3 models



NEMS Configuration and Components

```
##########################################
###  NEMS Run-Time Configuration File  ###
##########################################

# EARTH #
EARTH_component_list: ATM OCN WAV
::

# ATM #
ATM_model:                      @[atm_model]
ATM_petlist_bounds:             @[atm_petlist_bounds]
::

# OCN #
OCN_model:                      @[ocn_model]
OCN_petlist_bounds:             @[ocn_petlist_bounds]
::

# WAV #
WAV_model:                      @[wav_model]
WAV_petlist_bounds:             @[wav_petlist_bounds]
::

# Run Sequence #
runSeq::
  @@[coupling_interval_sec]
    ATM -> OCN   :remapMethod=redist
    ATM -> WAV   :remapMethod=redist
    ATM
    OCN
    OCN -> WAV   :remapMethod=redist
    WAV
    WAV -> OCN   :remapMethod=redist
  @
::
```

Configures interface with ADCIRC, via Model Cap

Configures interface with WW3, via Model Cap

Specifies coupling scheme

WW3 Cap: Extended for unstructured mesh support

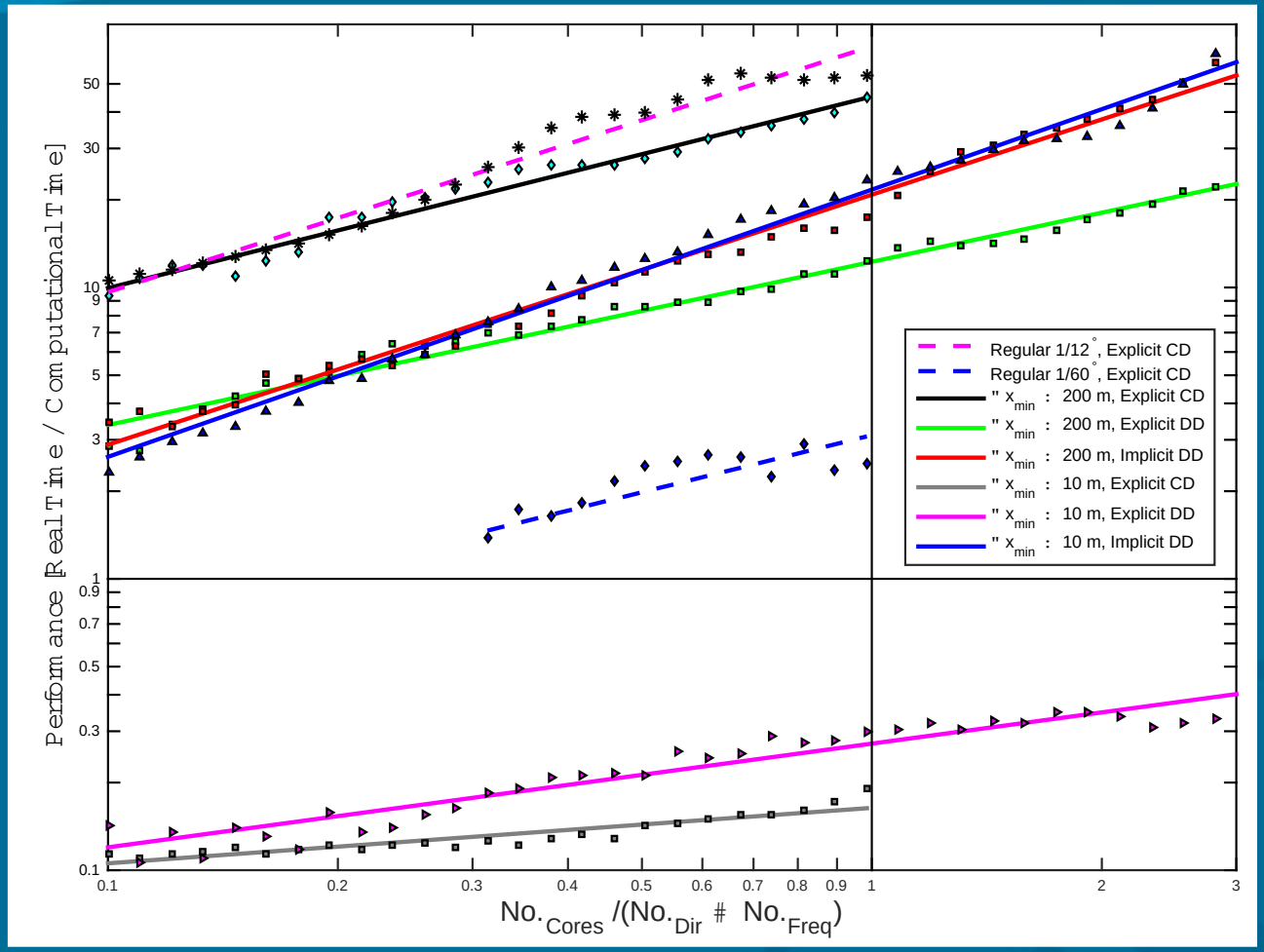
```
module WMESMFMD
...
subroutine CreateImpMesh ( gcomp, rc )
...
! Allocate and fill the node id array.
!/PDLIB      if ( LPDLIB == .FALSE. ) then
         allocate(nodeIds(NX))
         do i = 1,NX
            nodeIds(i)=i
         enddo
!/PDLIB      else
!/PDLIB!        Allocate global node ids, including ghost nodes (npa=np+ng)
!/PDLIB         allocate(nodeIds(npa))
!/PDLIB         do i = 1,npa
!/PDLIB            nodeIds(i)=iplg(i)
!/PDLIB         enddo
!/PDLIB      endif
...
!/PDLIB      if ( LPDLIB == .FALSE. ) then
         allocate(nodeCoords(2*NX))
         do i = 1,NX
            do j = 1,2
               pos=2*(i-1)+j
               nodeCoords(pos)=XYB(i,j)
            enddo
         enddo
!/PDLIB      else
!/PDLIB         allocate(nodeCoords(2*npa))
!/PDLIB         do i = 1,npa
!/PDLIB            do j = 1,2
!/PDLIB               pos=2*(i-1)+j
!/PDLIB               nodeCoords(pos)=XYB(iplg(i),j)
!/PDLIB            enddo
!/PDLIB         enddo
!/PDLIB      endif
```

WW3 recent developments

In collaboration with USACE

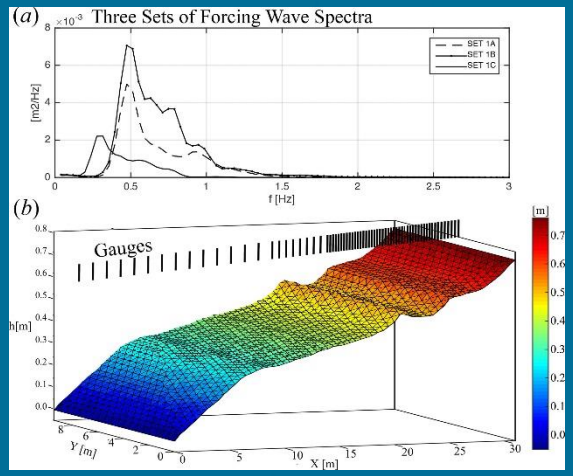
WW3: V6.07

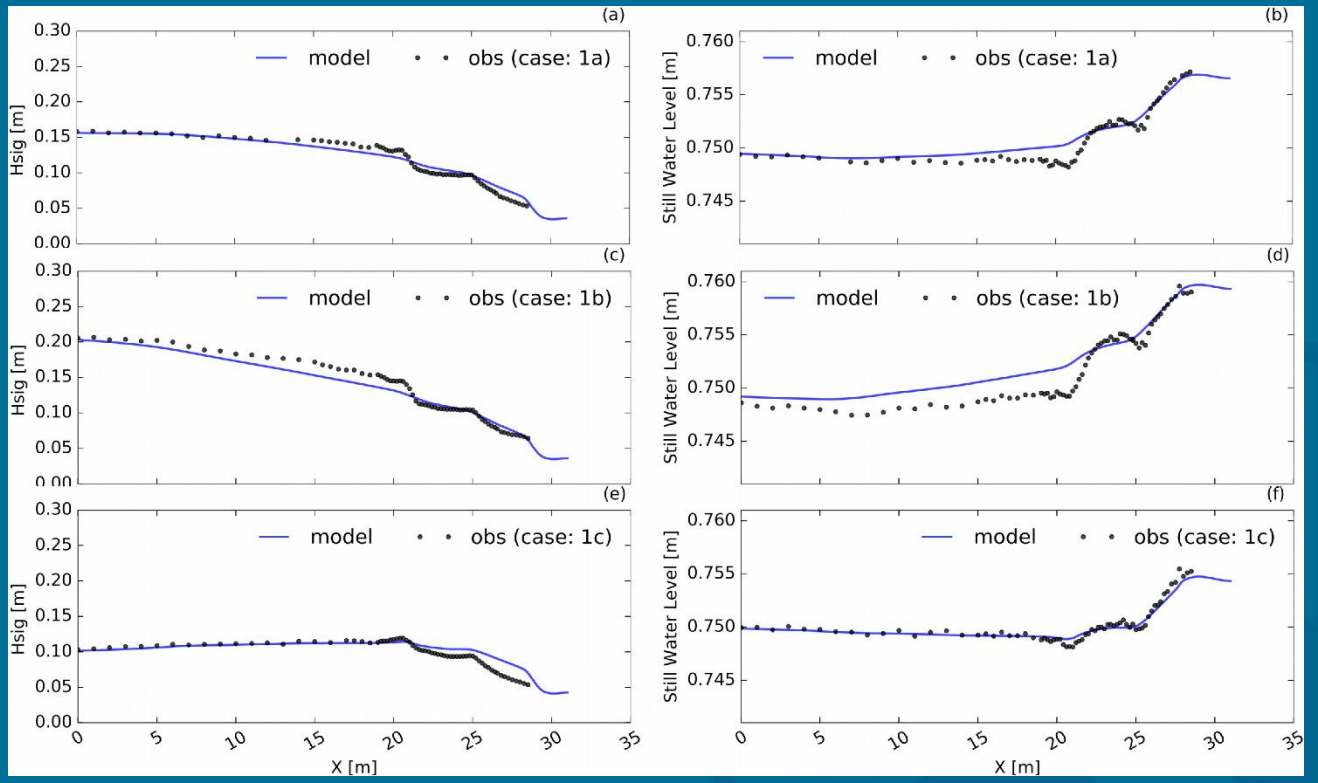
- Equipped with Domain Decomposition parallelization
- Implicit Solver



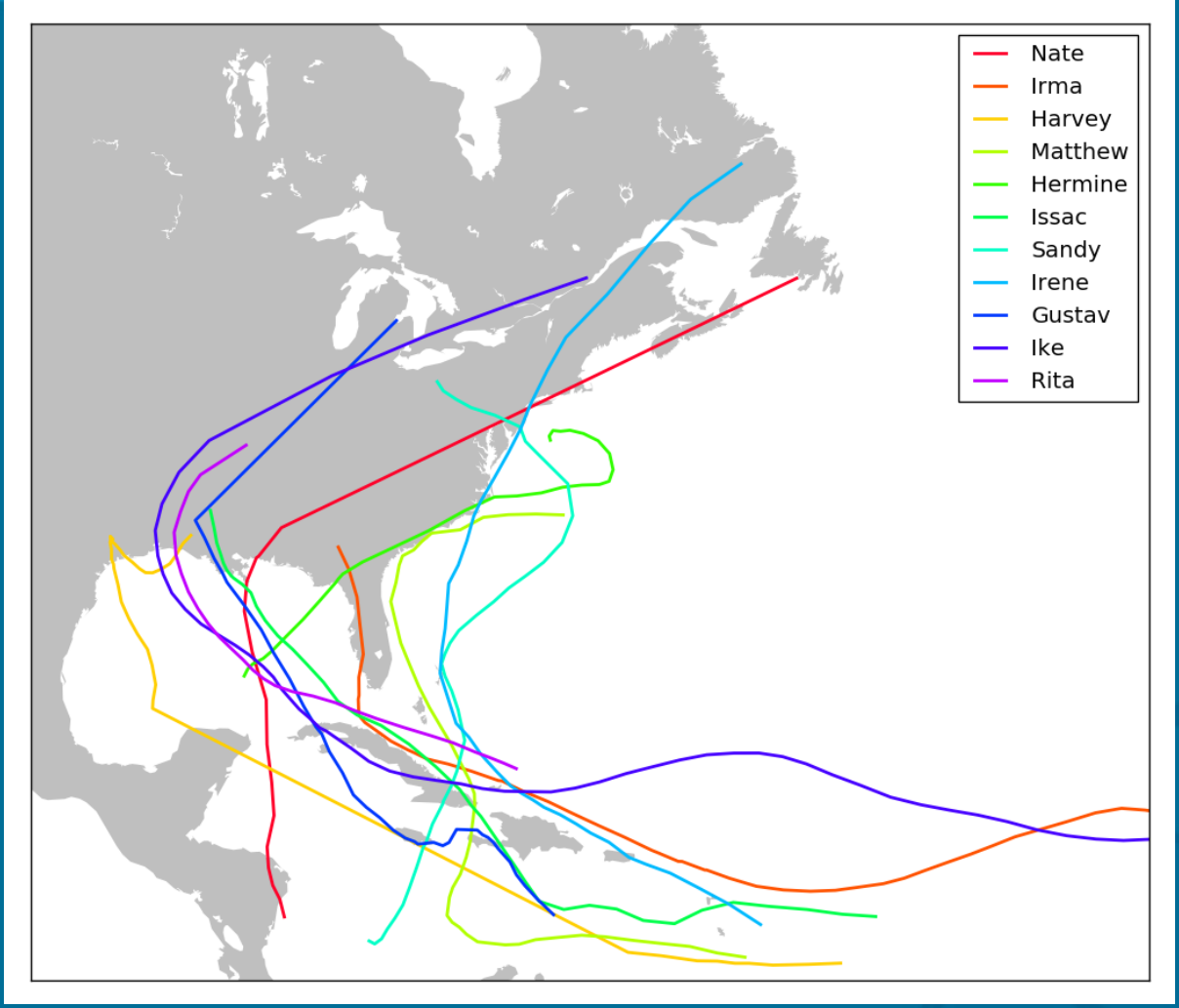
Abdolali A., Roland, A., Van Der Westhuysen, A., Meixner, J., Chawla, A., Hesser, T., Smith, J.M. and M. Dutour Sikiric (2019), Large-scale Hurricane Modeling Using Domain Decomposition Parallelization and Implicit Scheme Implemented in WAVEWATCH III Wave Model, Ocean Modeling, Under Review

Coupled ADCIRC-WW3 validation
Laboratory flume (Boers, 1996)



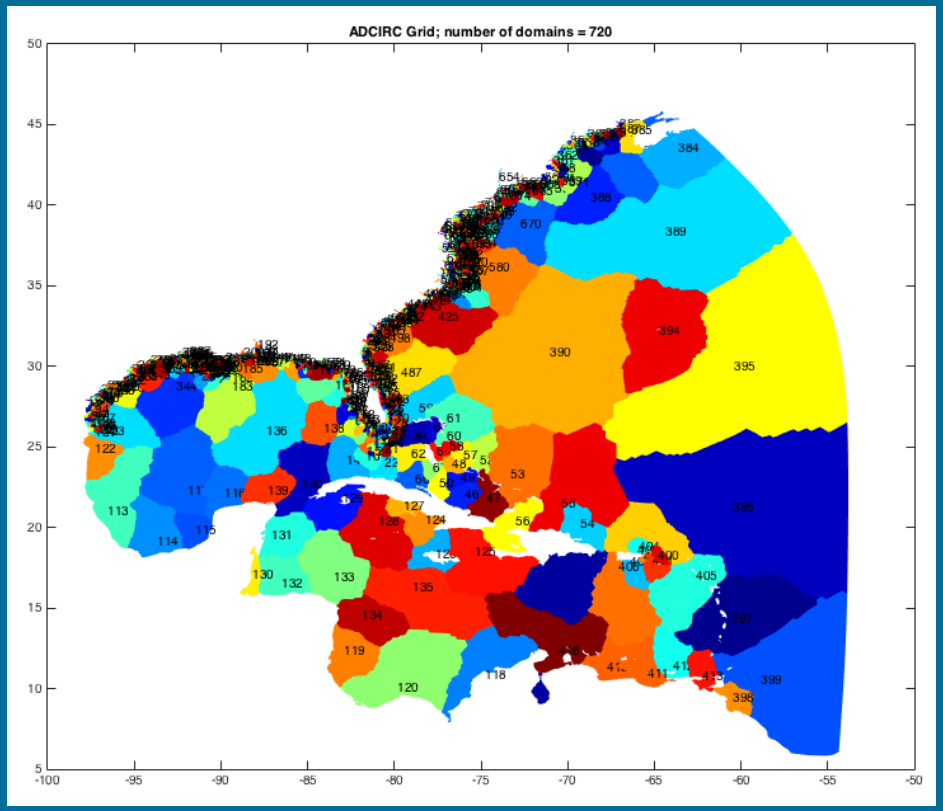


Storm selection for field validation

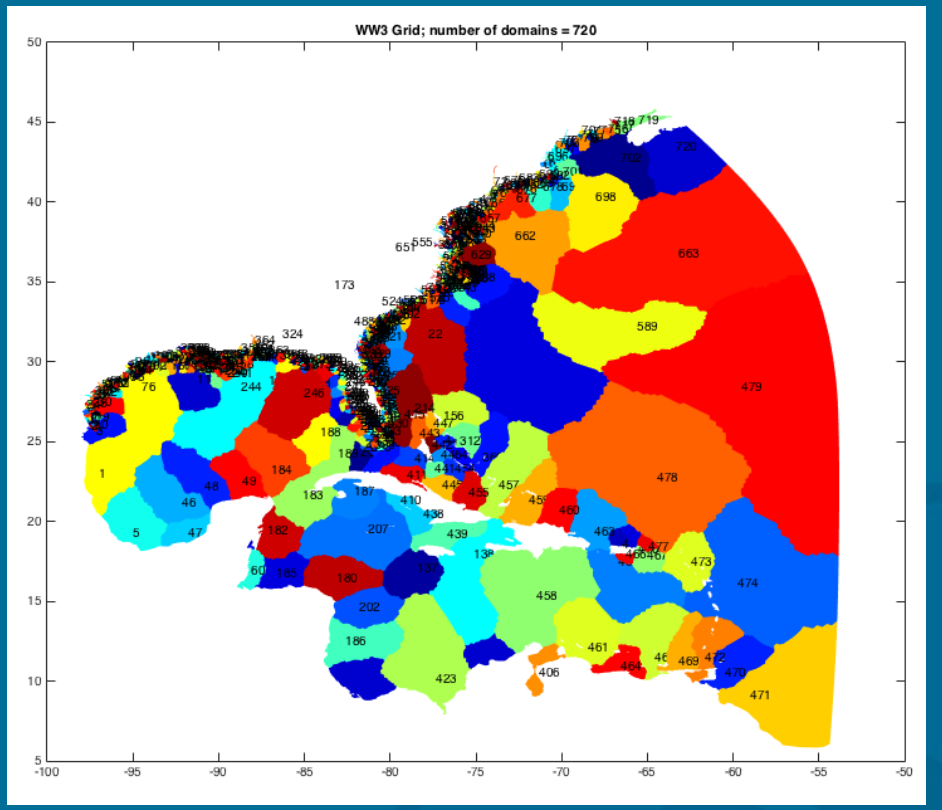


Coupled ADCIRC-WW3 validation
Hurricane Ike (Sept 3-14, 2008)

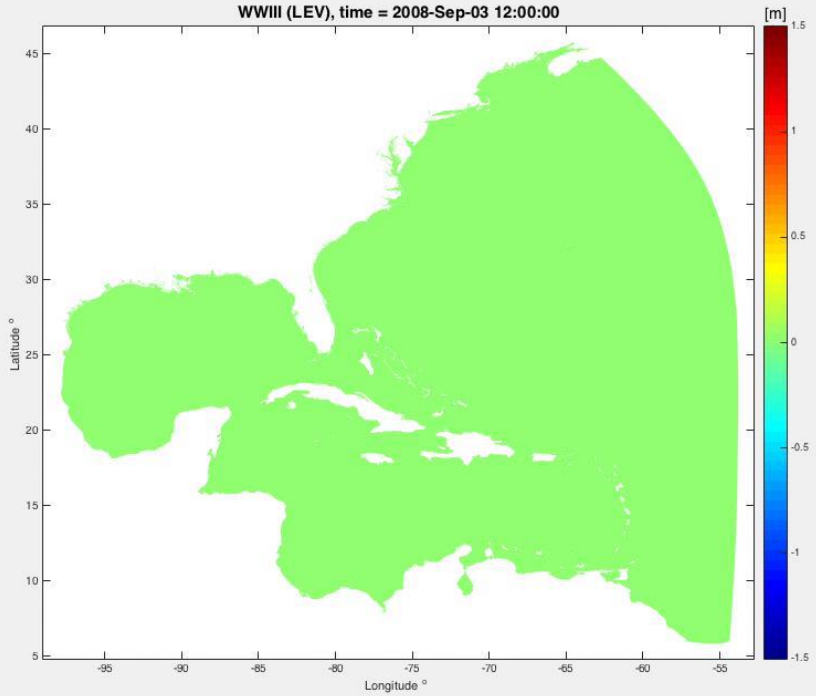
ADCIRC DD: 720 cores

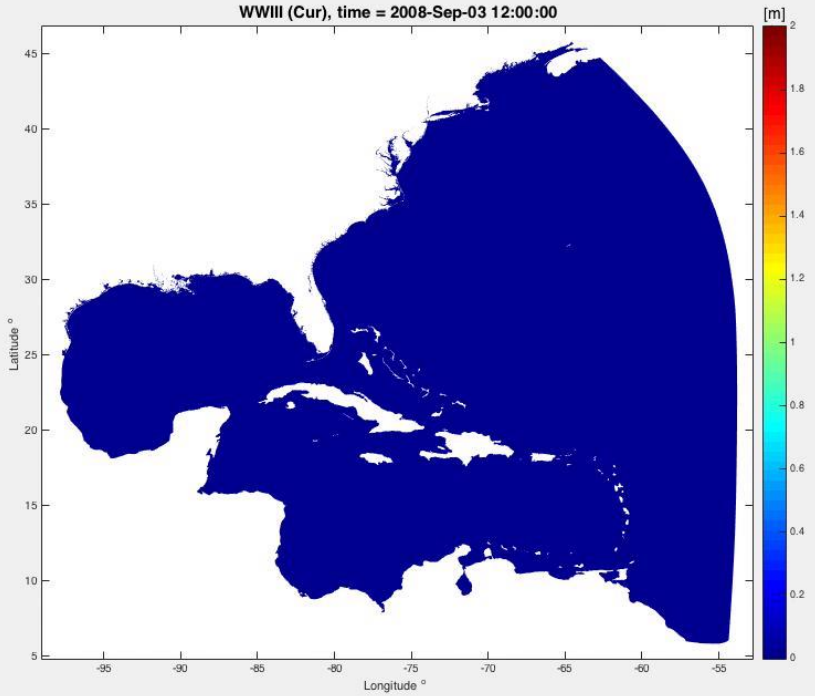


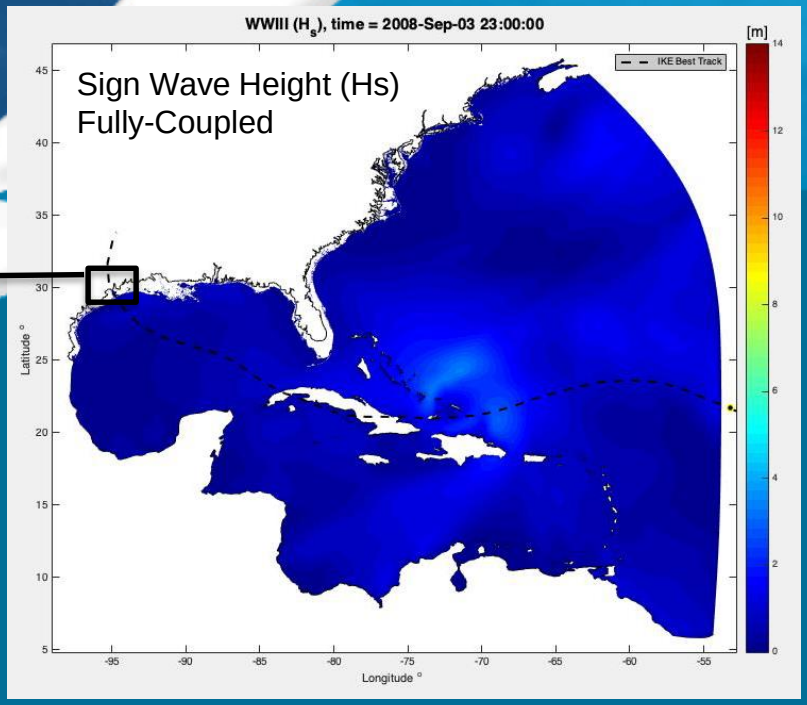
WW3 DD: 720 cores

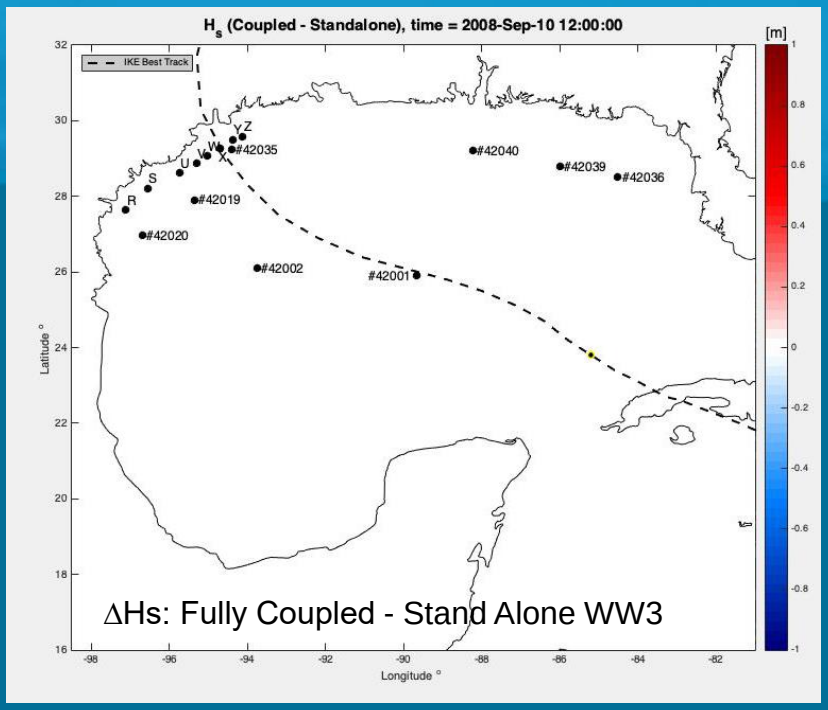


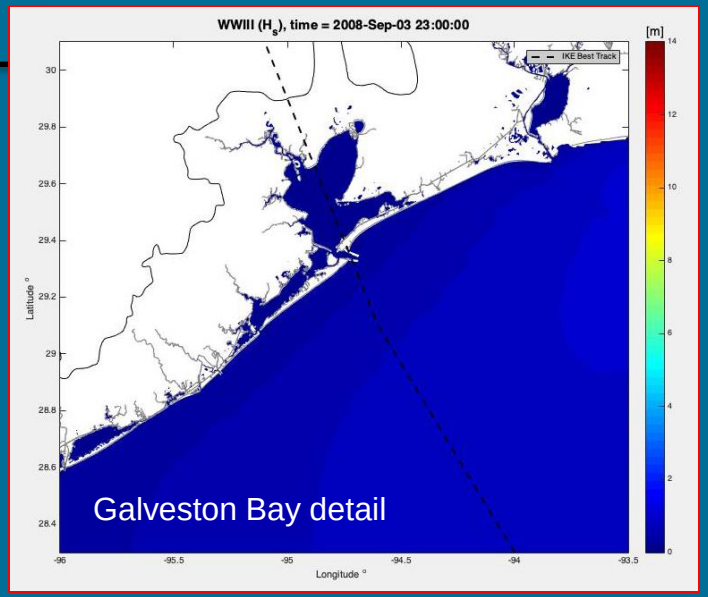
Hurricane Ike (Sept 3-14, 2008)
ADCIRC-WW3: Water Level and Current

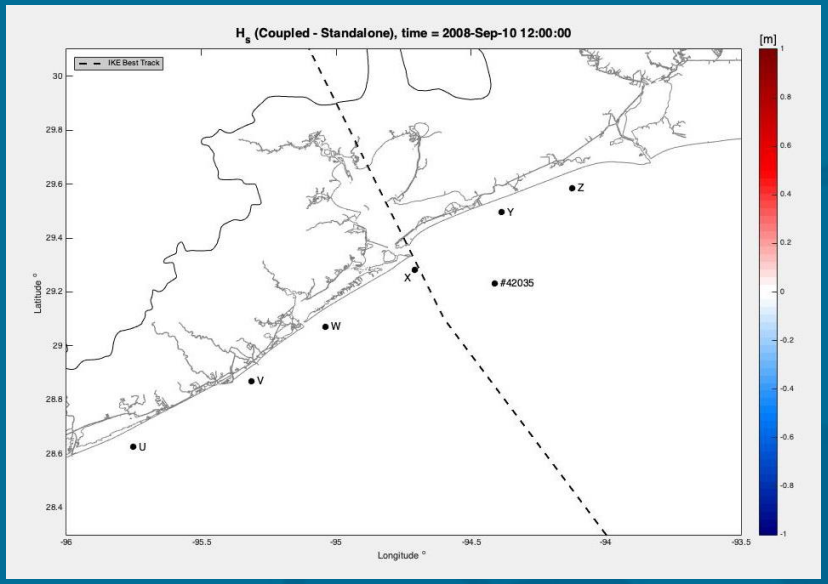





WWIII (Hs), time = 2008-Sep-03 23:00:00
Sign Wave Height (Hs)
Fully-Coupled
IKE Best Track
[m]
Latitude °
Longitude °

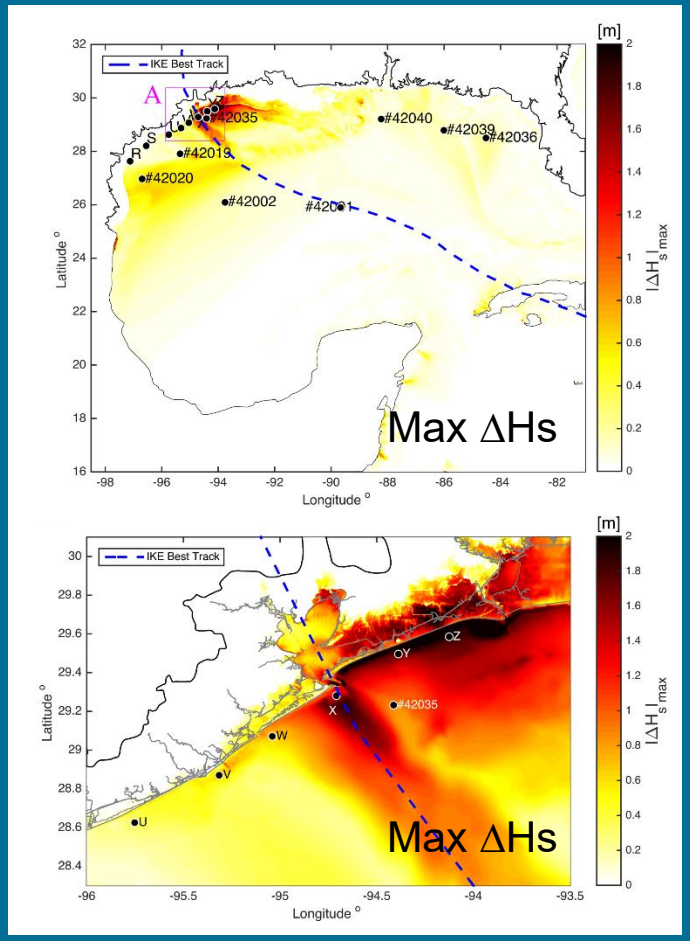

Hs (Coupled - Standalone), time = 2008-Sep-10 12:00:00
IKE Best Track
#42035
#42040
#42039
#42036
#42019
#42020
#42002
#42001
ΔHs: Fully Coupled - Stand Alone WW3
[m]
Latitude °
Longitude °

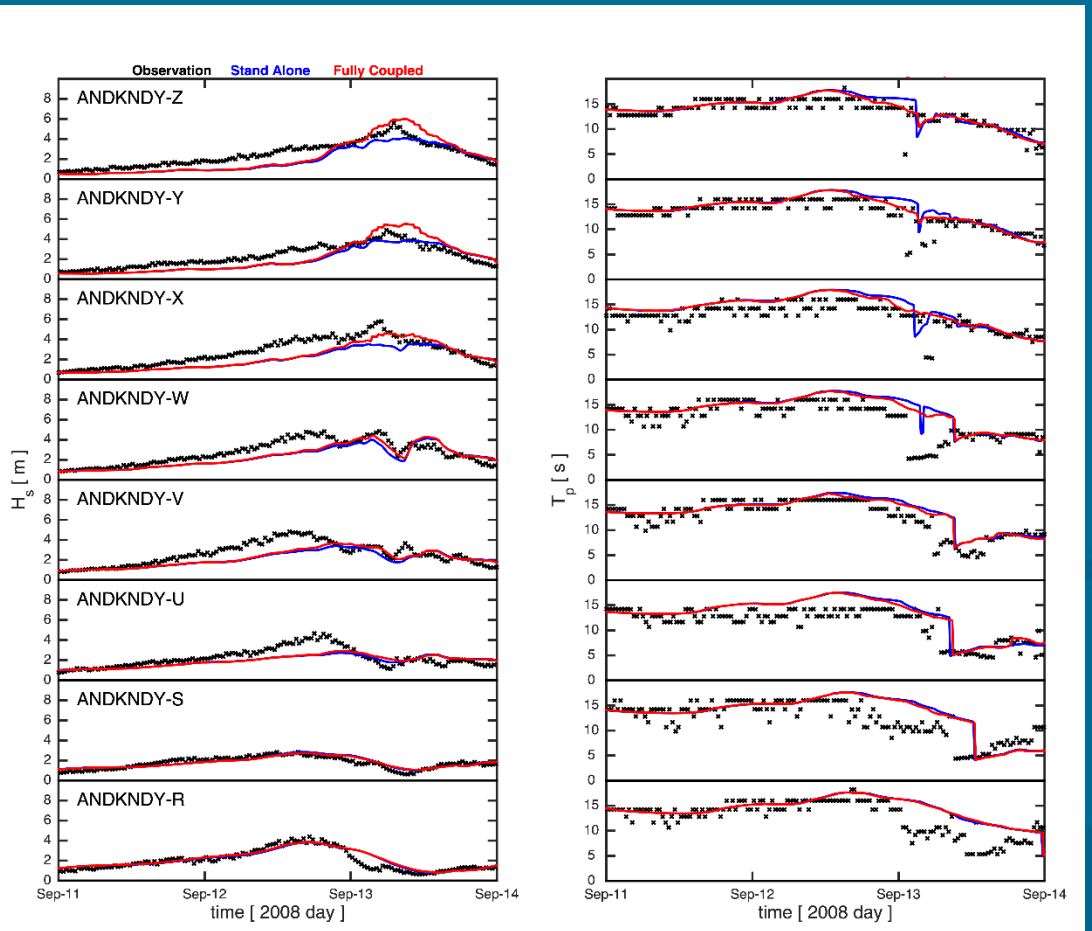

WWIII (Hs), time = 2008-Sep-03 23:00:00
IKE Best Track
Galveston Bay detail
[m]
Latitude °
Longitude °


Hs (Coupled - Standalone), time = 2008-Sep-10 12:00:00
IKE Best Track
#42035
[m]
Latitude °
Longitude °

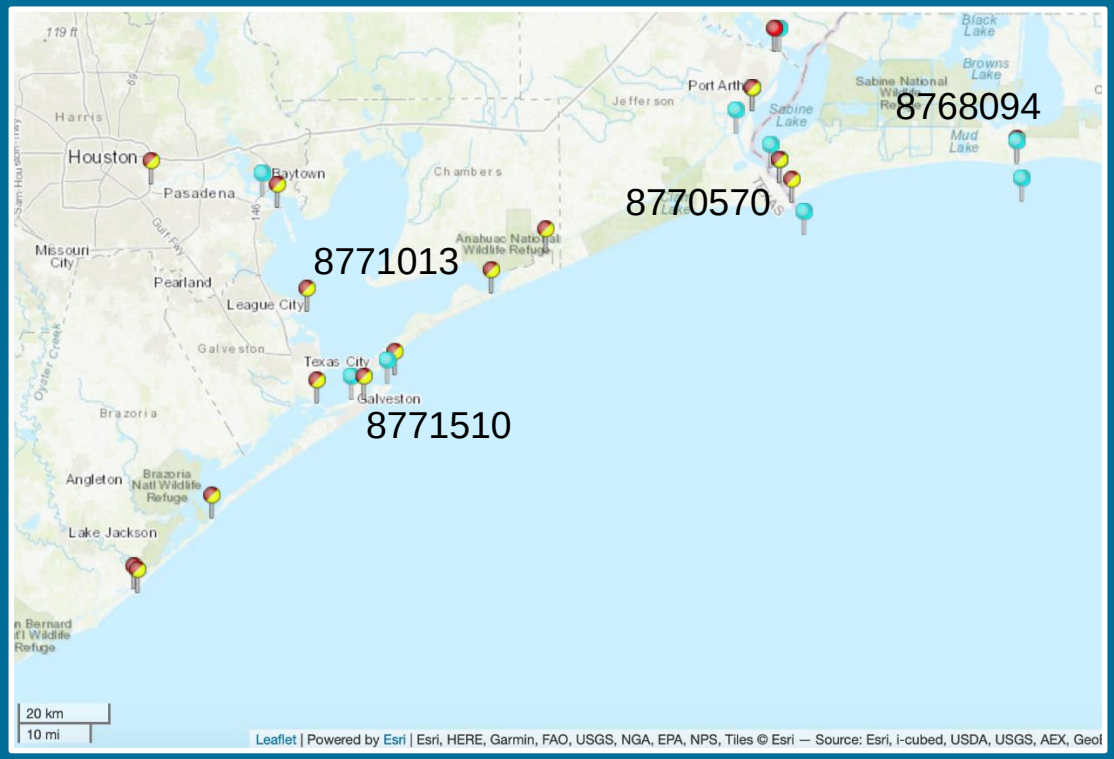
Hurricane Ike (Sept 3-14, 2008)

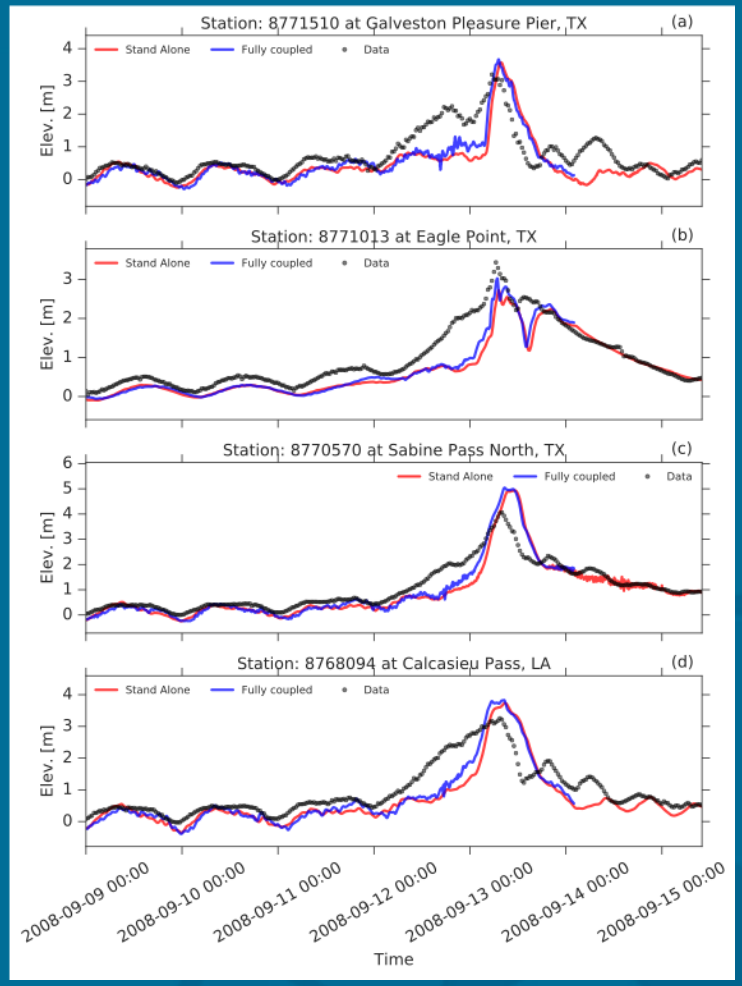
ADCIRC-WW3: Wave height validation (Galveston)



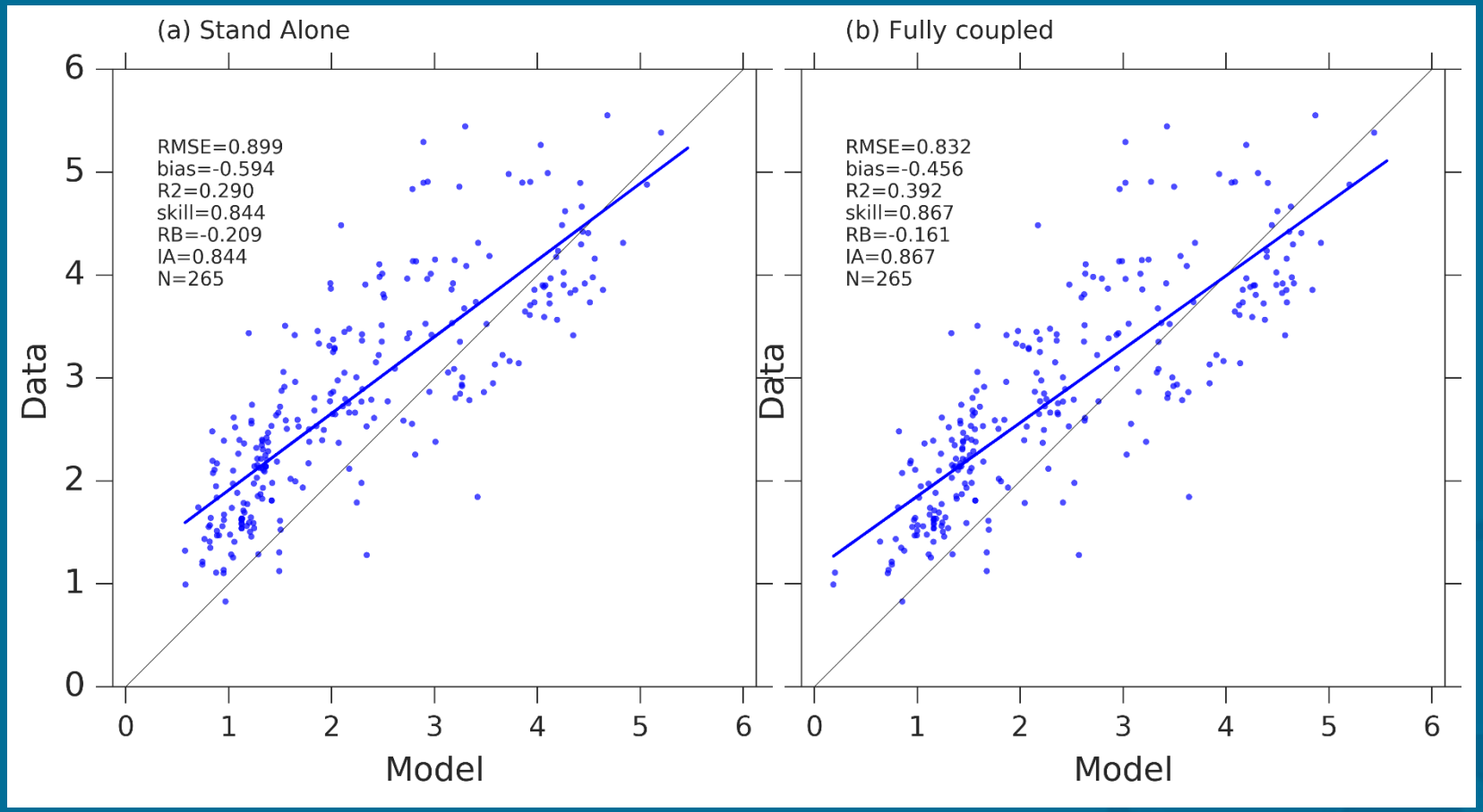


Hurricane Ike (Sept 3-14, 2008)
ADCIRC-WW3: Water Level and Current





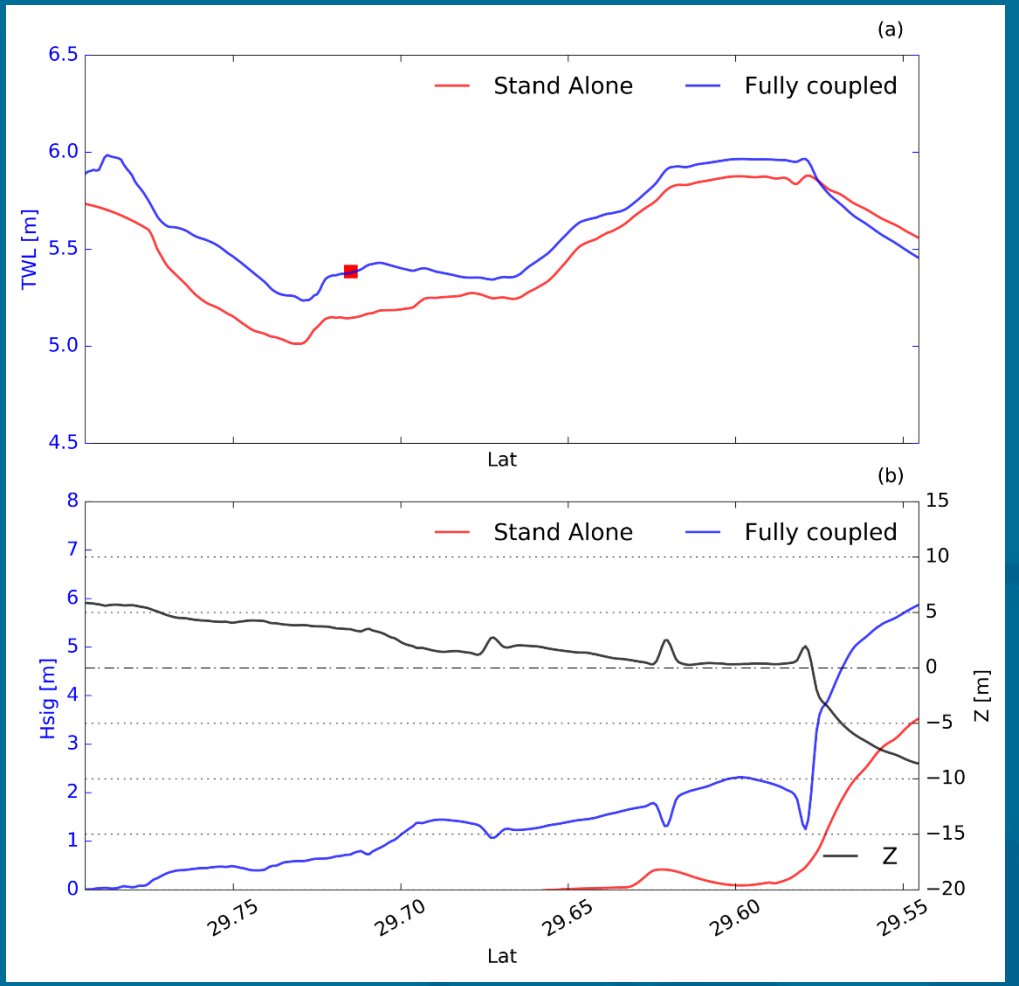
90% Accuracy: Scatterplot analysis



Output along cross-shore transect

Transect east of Galveston Bay

Note the patterns of increased TWL in regions of strong wave breaking – at coastline, and also inland at the inundation edge



Conclusions

1. Unstructured WAVEWATCH III and the ADCIRC surge model have been coupled using the versatile NUOPC/ESMF framework.
2. Coupled ADCIRC-WW3 model has validated for the standard laboratory flume case of Boers (1996) with good results.
3. System has been applied to U.S. East- and Gulf Coasts on large parallel framework (720+720 cores).
4. Field validation for Hurricane Ike (2008), using one-way forcing from HWRF, shows significant impacts on nearshore/overland wave heights and total water level, improving model performance.

References

Abdolali A., Roland, A., Van Der Westhuysen, A., Meixner, J., Chawla, A., Hesser, T., Smith, J.M. and M. Dutour Sikiric (2019), Large-scale Hurricane Modeling Using Domain Decomposition Parallelization and Implicit Scheme Implemented in WAVEWATCH III Wave Model, Ocean Modeling (Under Review)

S. Moghimi, A. Van der Westhuysen, A. Abdolali, E. Myers, S. Vinogradov, z. Ma, F. Liu, A. Mehra,N. Kurkowski (2019), Development of a Flexible Coupling Framework for Coastal Inundation Studies (Submitted).

Saeed Moghimi, Sergey Vinogradov, Edward P Myers, Yuji Funakoshi, Andre J Van der Westhuysen, Ali Abdolali, Zaizhong Ma, Fei Liu, (2019) Development of a Flexible Coupling Interface for ADCIRC Model for Coastal Inundation Studies. NOAA Technical Memorandum NOS CS 41.

R. Bakhtyar, K. Maitaria, P. Velissariou, B. Trimble , H. Mashriqui, S. Moghimi, A. Abdolali, A.J. Van der Westhuysen , Z. Ma, T. Flowers, 2019, "A new 1D/2D Coupled Modeling Approach for a Riverine-Estuarine System under Storm Events: Application to Delaware River Basin", (Submitted).