Evaluation of Unstructured WAVEWATCH III for Nearshore Application

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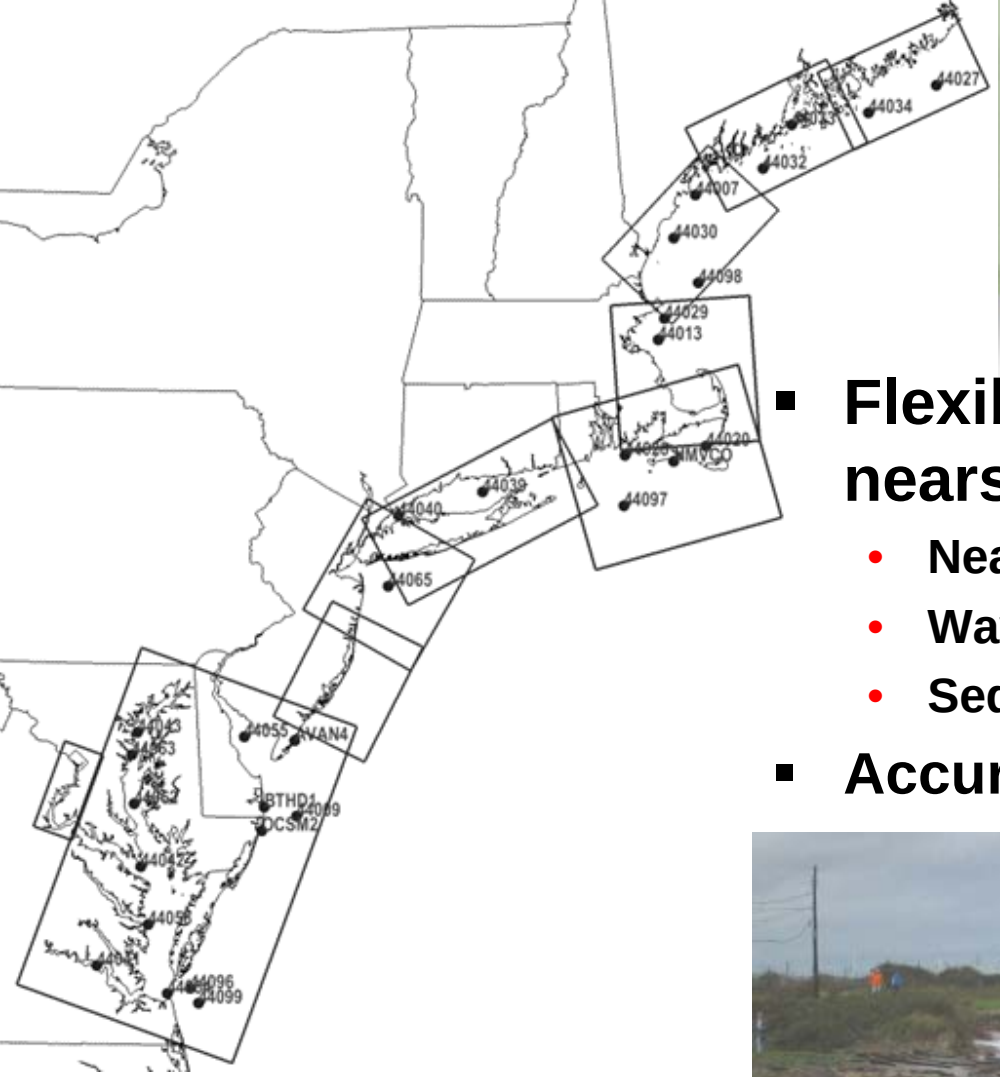
US Army Corps of Engineers

COASTAL AND HYDRAULICS LABORATORY

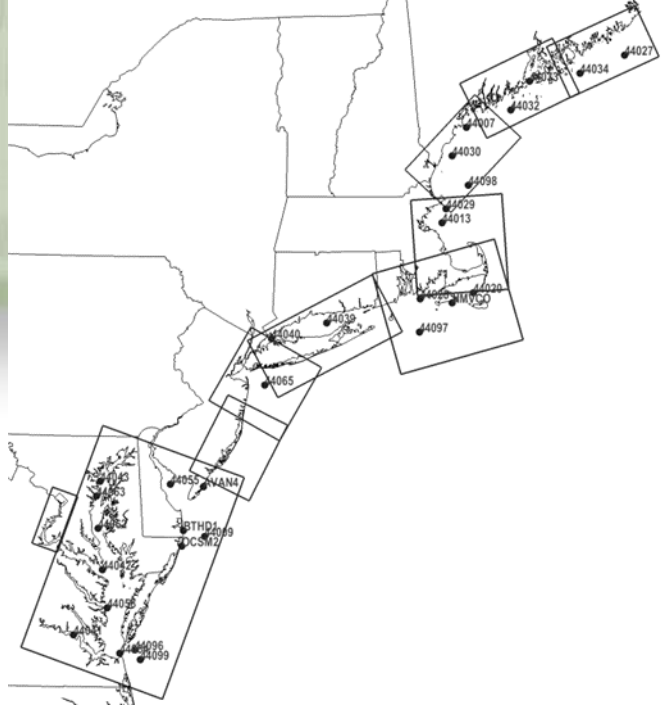


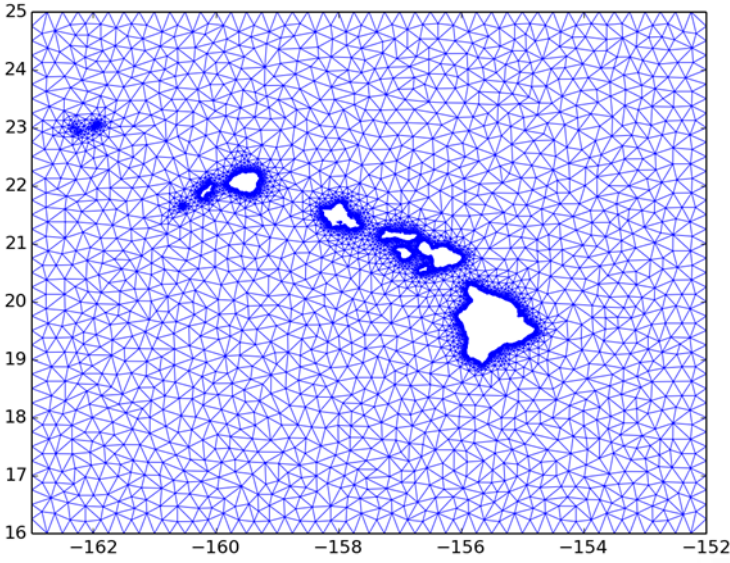
Motivation

- **Flexibility and high resolution for nearshore wave-driven processes:**
  - **Nearshore circulation**
  - **Wave set up**
  - **Sediment transport**
- **Accuracy and Efficiency**

Unstructured WW3

- **Drivers:**
  - **Multi-scale coverage ~ 3 orders of magnitude**
  - **Implicit solution scheme and domain decomposition for efficient computations**
    - **explicit integration scheme limits Δt (1m resolution ~ $\Delta t \approx 0.3\ s$)**
  - **Collaboration with NOAA NCEP: Arun Chawla, Henrique Alves, Andre van der Westhuysen, Ali Abdolali**

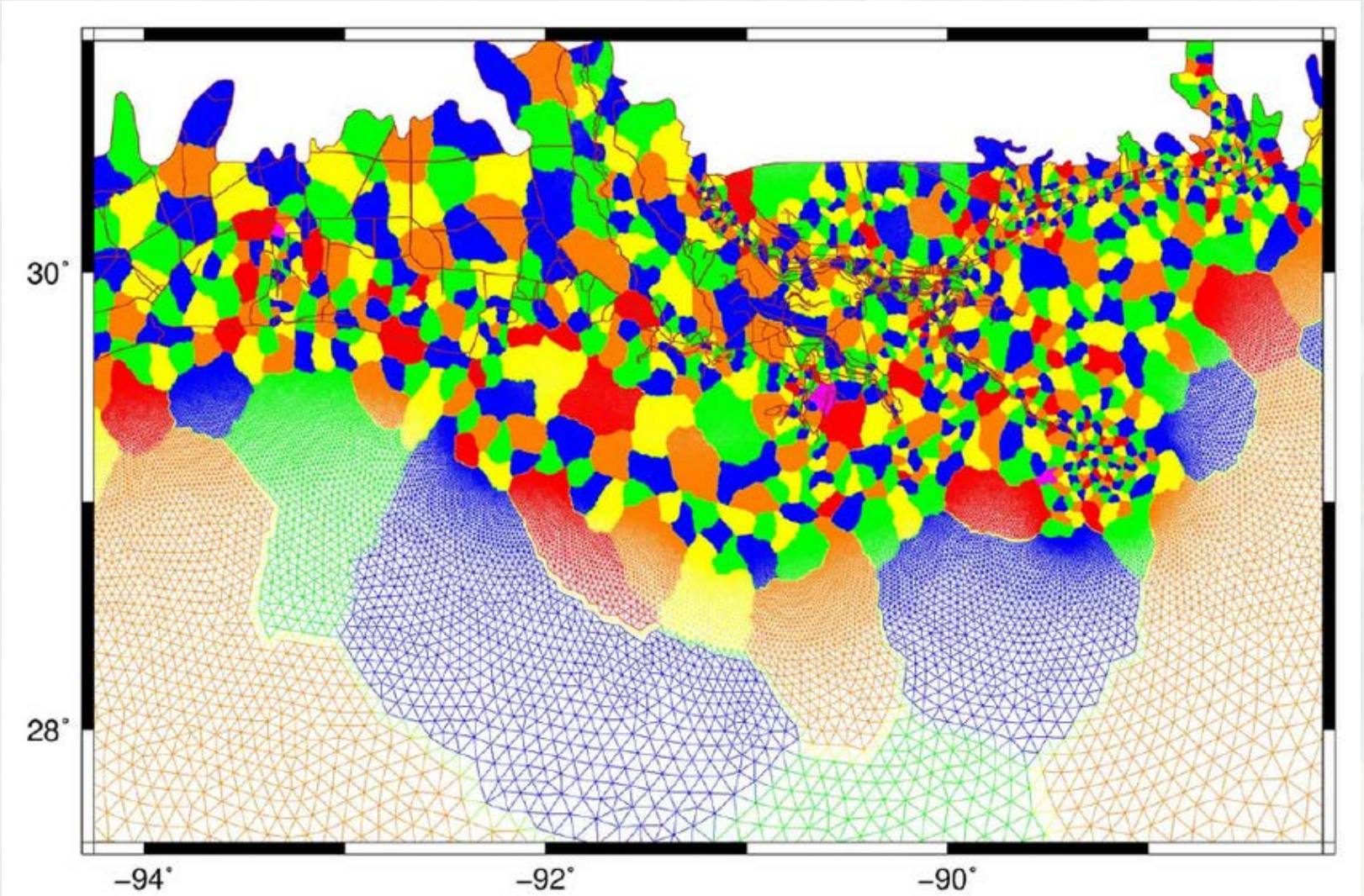




Parallel Computing in WW3

- WW3 was inherently designed to run parallel based on global arrays, but parallel propagation is limited by number of spectral bins
- Constraint relaxed by introducing a Multigrid option (Multigrid decomposition)
- Hybrid approach to parallelization involves spectral partitioning for advection in geographical space and domain decomposition for spectral advection and the source terms integration
- Proposed effort to replace global arrays with local arrays, optimize the model with respect to memory management, and implement parallel output within the domain decomposition framework

Domain Decomposition in ADCIRC/WW3 based on METIS/ParMETIS



PDLIB – Decomposition Library by IT&E GmbH

- PDLIB lib is a versatile parallel data structure and data exchange library that is written in Fortran 2003 and based on the decomposition of METIS/ParMETIS
- PDLIB provides subroutines to synchronize information during the solution procedure among the various sub-domains
- PDLIB had superb scaling on ECMWF/NCEP infrastructure for WWM-III (Roland, 2008) implicit/explicit. The parallelization strategy and numerics are now ported to WW3
- Need to reduce local memory footprint in WW3
- By including ESMF we can have different grids for circulation and waves

New Developments in Numerical Integration of the Wave Action Equation

- Fully implicit integration of the advection part of the WAE
- New convergent action limiter ~ mix of Komen et al. + Hersbach and Janssen
- New integration of the action limiter, e.g. no influence of the limiter on the propagation, only limit the source terms
- No numerical limiters on the wave breaking source term -- limit the wave height with the Miche criterion (Battjes & Janssen does not work on steep slopes)
- New Block-Jacobi and Block-Gauss-Seidel solvers with improved convergence criteria and efficient parallel implementation

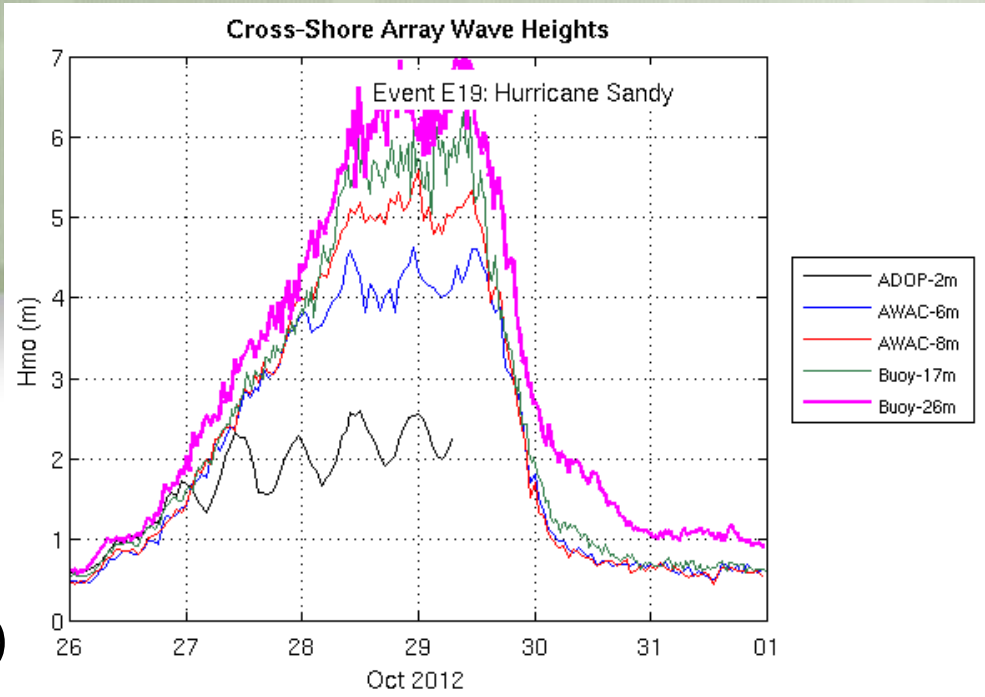
Extension of WW3 Tools for Unstructured Grids

- Software
  - Implicit/explicit domain decomposition
  - PolyMesh ~ mesh generation
  - PDLIB ~ parallel decomposition
- Calibration/Validation Suite
  - Laboratory
  - Analytical cases
  - US East Coast and Gulf of Mexico
  - US Great Lakes
  - USACE Field Research Facility, Duck, NC
  - Mediterranean

USACE Field Research Facility (FRF)

- Outer Banks of North Carolina
- Cross-shore array of directional wave measurements:
  - Buoys: 26 and 17 m depth
  - AWACs: 11, 8, 6, 4.5, and 3.5 m depth
- Winds and water levels at end of 560 m pier
- Regular bathymetry surveys

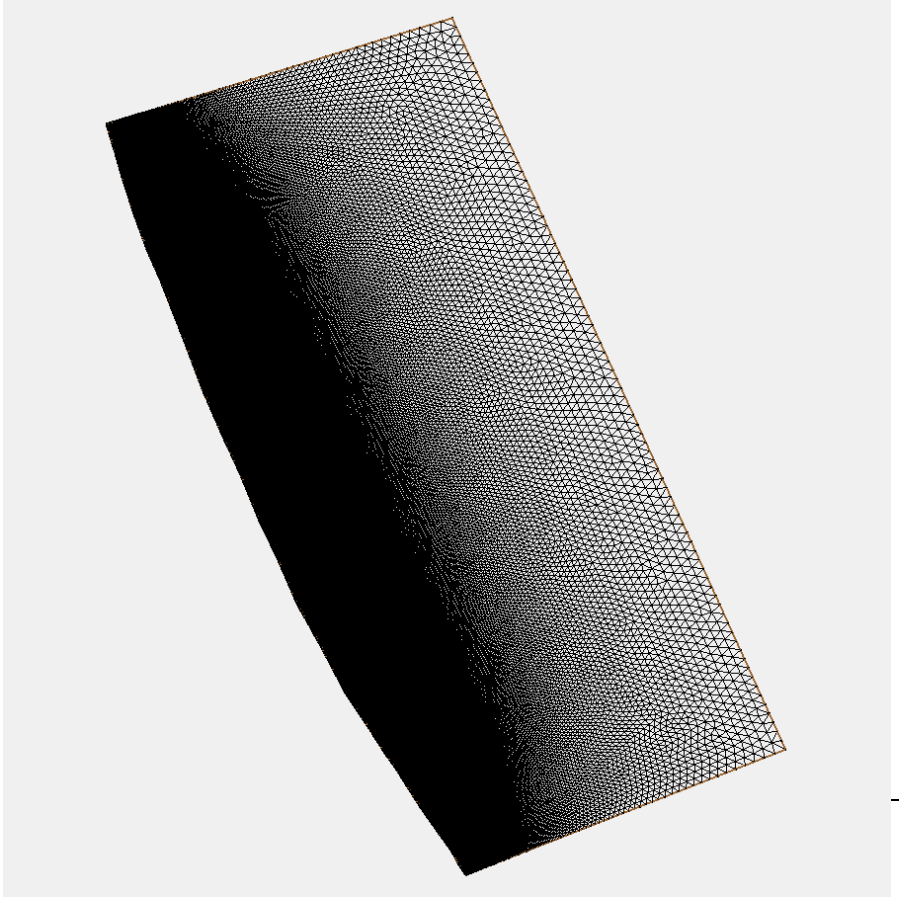
Storm Selection

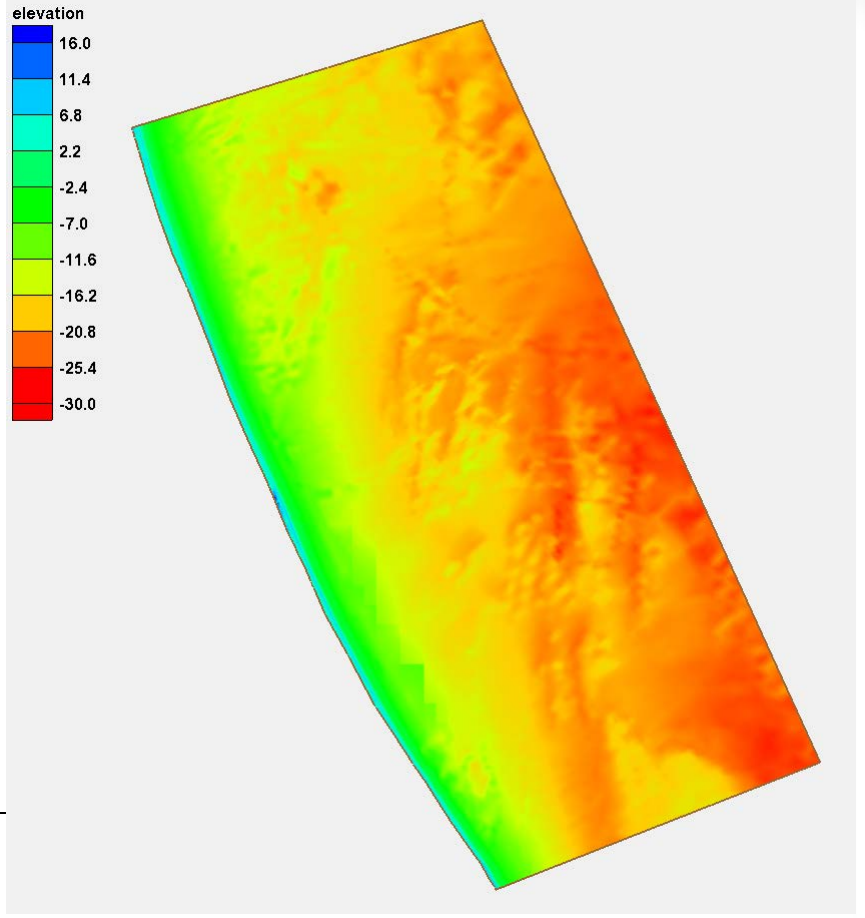


- Identified four storms:
  - Hurricane Irene (Aug 2011)
  - Nov 2011
  - Hurricane Sandy (Oct 2012)
  - Feb 2013
- Criterion
  - Two largest events (Irene & Sandy ~ 7 m waves)
  - Combined sea/swell event, 2.75 m waves (Nov 2011)
  - Slanting fetch, 5 m waves (Feb 2013)
  - Cross-shore array & offshore buoy operational
  - Future: BathyDuck (2015, extratropical + H. Joaquin), full year simulation

FRF Unstructured Grid

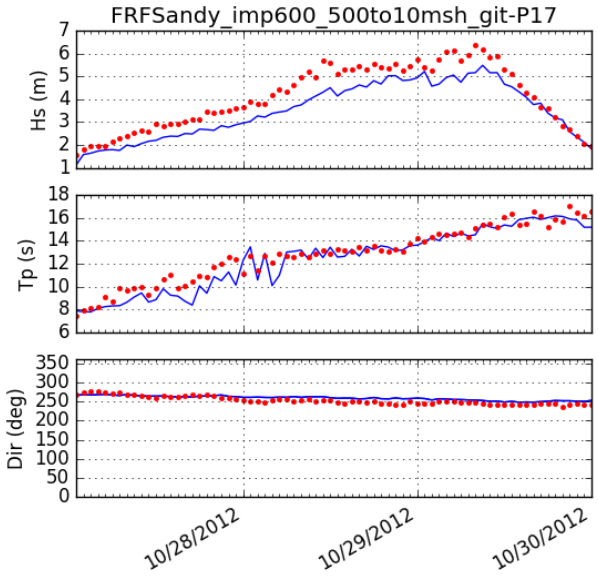
- 440k nodes, resolution 500–10 m
- 20 km x 50 km, 26-m depth to shore



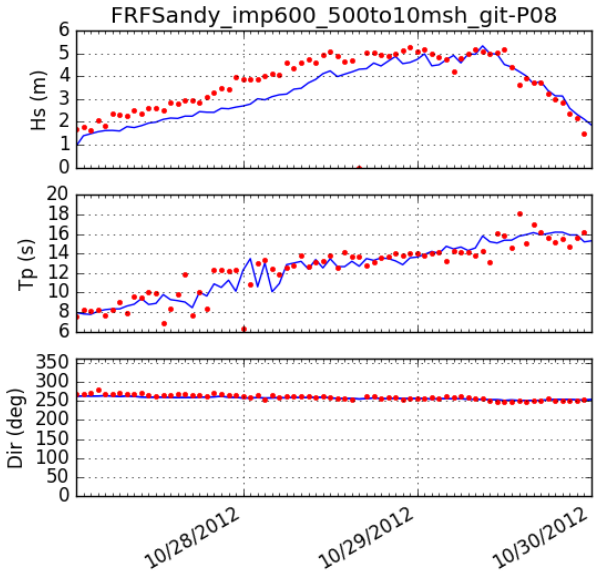


Field Benchmarking – H. Sandy FRF

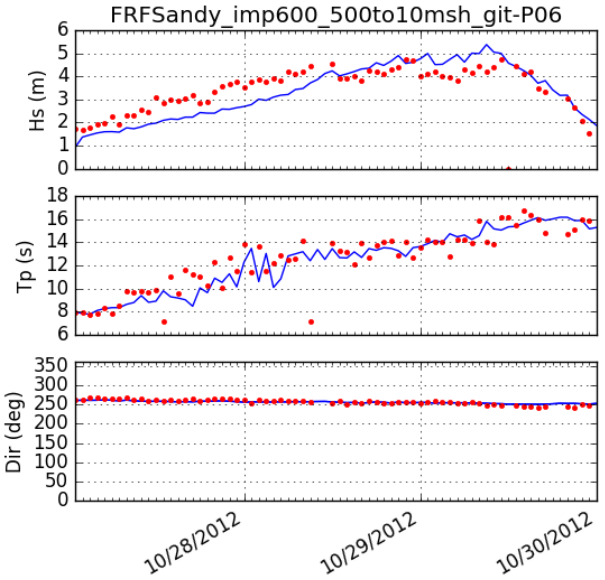
ST4, JONSWAP Friction, 300 s implicit time step



17 m depth



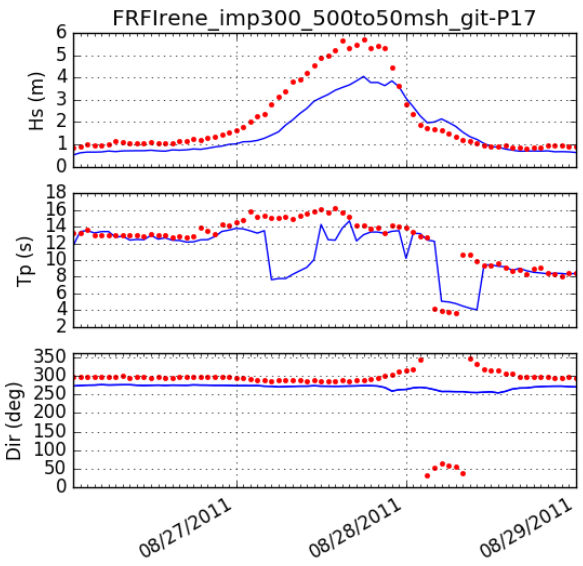
8 m depth



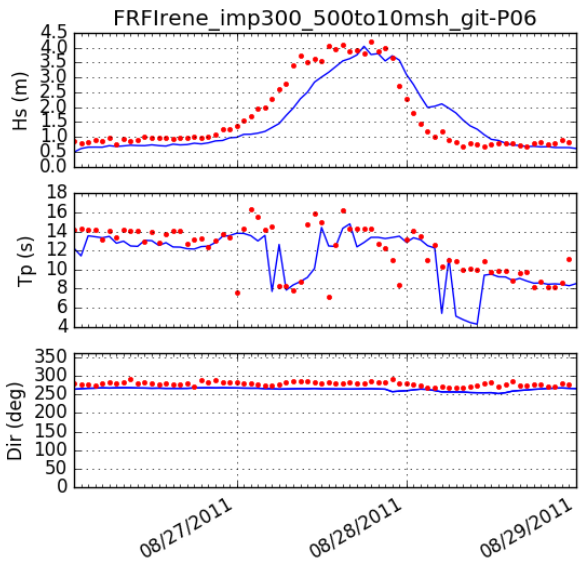
6 m depth

Field Benchmarking – H. Irene FRF

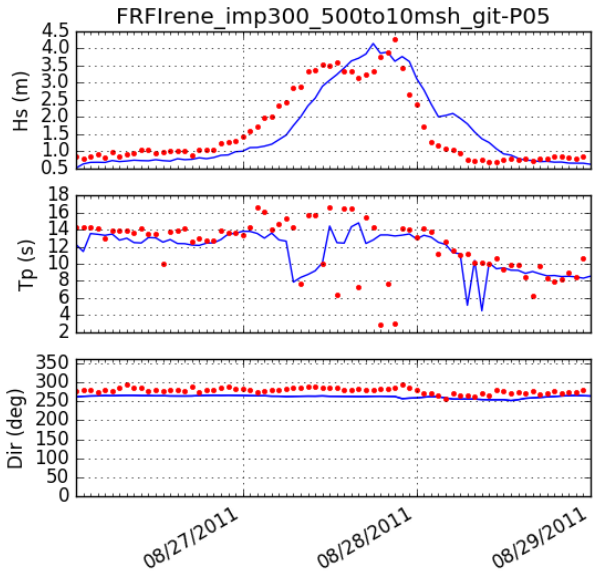
ST4, JONSWAP Friction, 300 s implicit time step



17 m depth



6 m depth

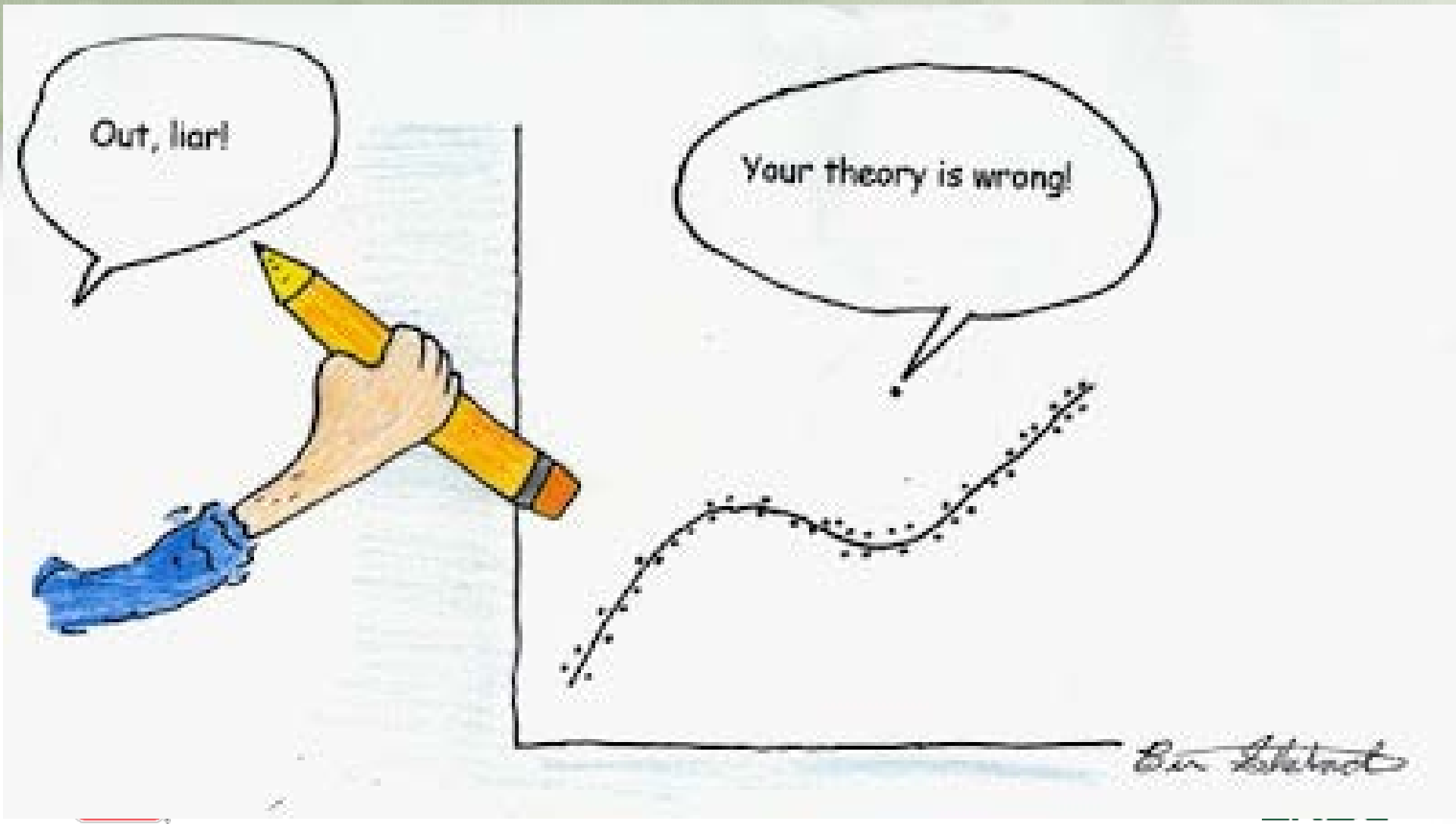


5 m depth

Errors

- Wave Height:
  - Bias: -0.31 m
  - RMS: 0.60 m
- Peak Period
  - Bias: -0.22 s
  - RMS: 1.7 s

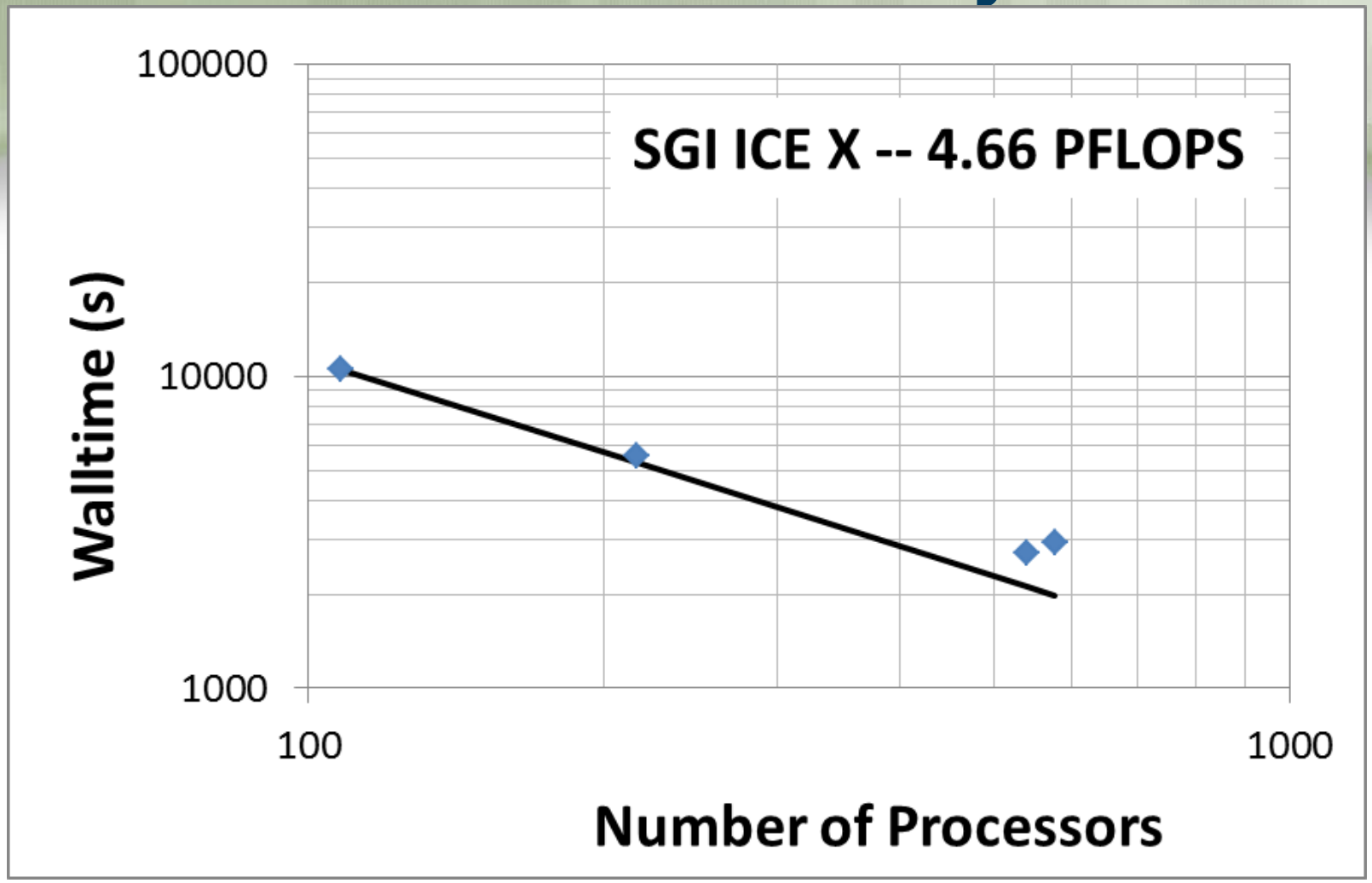
Irene



Errors

- Wave Height:
  - Bias: -0.31 m (without Irene -0.29 m)
  - RMS: 0.60 m (without Irene 0.47 m)
- Peak Period
  - Bias: -0.22 s (without Irene -0.02 s)
  - RMS: 1.7 s (without Irene 0.87 s)

Parallel Efficiency



Summary

WAVEWATCH III is a viable option for nearshore application:

- Implicit solver + domain decomposition
- Explore lateral boundary conditions
- Couple with CSTORM (circulation)
- Investigation bottom friction and wave breaking
- Run a year-long validation