Evaluation of Unstructured WAVEWATCH III for Nearshore Application

Jane McKee Smith, Tyler Hesser, Mary Anderson Bryant
USACE Research and Development Center, Coastal and Hydraulics Lab
Aron Roland
BGS IT&E GmbH
and Mathieu Dutour Sikiric
Laboratory of Satellite Oceanography, Department of Environmental and Marine Research Rudjer Bosković Institute

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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 $\Delta t$ (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 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

Out, liar!

Your theory is wrong!
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

SGI ICE X -- 4.66 PFLOPS

Walltime (s)

Number of Processors
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