SURA / IOOS Testbed for the Evaluation of Wave, Storm Surge and Inundation Models

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Objectives

Provide evaluation of models in or under consideration for “operational use”

• Behavior
  • Accuracy
  • Robustness
  • Execution speed

• Implementation requirements
  • Resolution
  • Parameterization
  • Computer capacity
Objectives

Develop testbed infrastructure to greatly facilitate future model evaluation

- Standards
- Interoperability
- Model evaluation tools (e.g., IMEDS skill assessment)
- Data/model archives and access
Example Questions

Should I use a grid having?
- 10,000 cells
- 100,000 cells
- 1,000,000 cells
- 10,000,000 cells

Under what circumstances?
For what expected benefit?
At what cost?
Example Questions

Am I better off using my computational resources to?
- Run a 3D model (vs a 2D model)
- Increase horizontal resolution
- Run a coupled wave model
- Run ensembles of low resolution models

Under what circumstances?
For what expected benefit?
At what cost?
Example Questions

From the user’s perspective
- Are all models about the same in terms of accuracy, efficiency?
- Is there a preferred model out there?

From the model developer’s perspective
- Why aren’t you using my model?

A bridge between Research & Operations
Conclusions

Considerable time to develop common infrastructure (get on same page)
- Grids
- Forcing
- Data Formats
- Observational data sets
- Parameter sets & methodology

Seeing differences between 3 Unstructured Grid surge models (ADCIRC, FVCOM, SELFE)

Systematic differences btwn UG surge models & SLOSH

Not far enough along with wave models for conclusions

It’s hard to do a testbed well, requires much consensus!

Very positive community building activity
Testbed Geographical Locations

Extratropical Storms in the Gulf of Maine
- 2005 & 2007 Nor’Easters
- Focus on Scituate Harbor, MA
- Little observational data in Scituate Harbor

Tropical Storms in the Gulf of Mexico
- Hurricanes Rita (2005) and Ike (2008)
- Focus on northwestern Gulf of Mexico
- Extensive observational data sets (e.g., >700 water level hydrographs for Ike)
Extratropical - Gulf of Maine Team

ADCIRC + unstructured SWAN
• Joannes Westerink – U Notre Dame

FVCOM + SWAVE
• Bob Beardsley – Woods Hole Oceanographic Institute, co-Lead
• Changsheng Chen – U Mass Dartmouth

SELFE + WWM
• Harry Wang – Virginia Institute of Marine Sciences

SLOSH + SWAN – PV2 hurricane basin, ECETSS
• Don Slinn – U Florida

WWIII & SWAN
• Will Perrie, Bash Toulaney – Bedford Institute of Oceanography

OTHERS
• Jeff Hanson – US Army Corps of Engineers FRF
• Jesse Feyen – NOAA CSDL
• Arthur Taylor, Anne Kramer, Amy Haase – NOAA MDL
• MANY OTHER WORKERS!
Extratropical - Domains

Gulf of Maine with high resolution nesting in Scituate, MA

5620 nodes
10 m – 1 km horiz resolution
<2km in size
2 particular areas of concern flood frequently during Nor’Easters
Scituate Harbor
Gulf of Maine SLOSH Grids

East Coast Extratropical Storm Surge Grid

PV 2 Slosh Hurricane Basin

~2 km horiz resolution near Scituate
Gulf of Maine / Scituate Regular Wave Grids

WW III and SWAN
Series of nested grids
2005 Nor’Easter

Wind (m/s)

Days (May 2005)
2005 Nor’Easter

No Waves
2005 Nor’Easter

No Waves
2005 Nor’Easter

No Waves
2005 Nor’Easter

No Waves
2005 Nor’Easter

No Waves
2005 Nor’Easter

No Waves
2005 Nor’Easter

No Waves
2005 Nor’Easter

No Waves
2005 Nor’Easter

Including Waves
2005 Nor’Easter

Including Waves
2005 Nor’Easter

Including Waves

Sites and sections in the model grid

![Diagram showing wave and current patterns](image)

- Wave-current FVCOM
- Wave-current SELFE

Elevation (m)

2-D velocity (cm/s)

Days (May 2005)
2005 Nor’Easter

Currents

May 25, 05 AM (GMT)

Currents-Waves
Wave Model Resolution (2007)

25 frequencies 24 directions
30 frequencies 36 directions
35 frequencies 72 directions
Extratropical Findings

Scituate Harbor
- Water levels very close between ADCIRC, FVCOM, SELFE for tidal forcing and storm forcing – some differences in inundation behavior
- Velocity fields similar without waves, significantly different with waves coupling (via radiation stress gradient terms)
- Including wave coupling increases flux past and into mouth of Scituate Harbor, although perhaps not into interior
- Results are sensitive to wave model resolution?

Greater Gulf of Maine
- Wave model comparisons are ongoing
Tropical - Gulf of Mexico Team

ADCCIRC + unstructured SWAN
- Joannes Westerink – U Notre Dame

FVCOM + SWAVE
- Bob Weisberg – U South Florida
- Chunyan Li – Louisiana State University

SELFE + WWM
- Harry Wang – Virginia Institute of Marine Sciences

SLOSH + SWAN
- Don Slinn – U Florida

OTHERS
- Jeff Hanson – US Army Corps of Engineers FRF
- Jesse Feyen – NOAA CSDL
- Jamie Rhome, Christina Forbes - NHC
- MANY OTHER WORKERS!
Tropical - Domains

Gulf of Mexico with enhanced resolution along the western Louisiana and Northern Texas coasts where Rita and Ike landed.
Tropical - Domains

Gulf of Mexico with enhanced resolution along the western Louisiana and Northern Texas coasts

~425,000 nodes
Gulf of Mexico SLOSH Grids

Galveston 3 Slosh Basin

Sabin Pass Slosh Basin

GoMx Extratropical Storm Surge Grid
10 Constituent Tidal Amplitudes

![Graphs showing model vs observed tidal amplitude comparisons for UND, USF, and VIMS stations.](image)

- **UND**:
  - $R^2 = 0.82903$
  - $y = 1.0516x$
  - $\sigma = 0.025193$
  - $\epsilon = 0.0038928$
  - $\phi = 0.014289$
  - $E = 0.36684$
  - $\Delta = 0.025$

- **USF**:
  - $R^2 = 0.80334$
  - $y = 0.87554x$
  - $\sigma = 0.024088$
  - $\epsilon = 0.0038376$
  - $\phi = 0.014039$
  - $E = 0.35101$
  - $\Delta = 0.025$

- **VIMS**:
  - $R^2 = 0.81475$
  - $y = 0.90958x$
  - $\sigma = 0.023791$
  - $\epsilon = 0.0034674$
  - $\phi = 0.013611$
  - $E = 0.34597$
  - $\Delta = 0.025$
Hurricane Ike (2008)
Ike surge contours (m) and wind vectors (m/s)

r09 c8+tides Water Surface Elevations + Winds

- 12 hrs
Ike surge contours (m) and wind vectors (m/s)

r09 c8+tides Water Surface Elevations + Winds

- 9 hrs
Ike surge contours (m) and wind vectors (m/s)
Ike surge contours (m) and wind vectors (m/s)
Ike surge contours (m) and wind vectors (m/s)
Intermodel Comparison

Without Waves
USGS-Deployable

SURA-IOOS Intermodel (UltraLite)
USGS-DEPL_SSS-TX-HAR-004

- Observed
- ADCIRC
- SLOSH OWI
- SLOSH 3
- FVCOM
- SELFE

Date in 2008

Water Level (m)

SURA-IOOS Intermodel (UltraLite)
USGS-DEPL_SSS-TX-GAL-002

- Observed
- ADCIRC
- SLOSH OWI
- SLOSH 3
- FVCOM
- SELFE

Date in 2008

Water Level (m)
UN Kennedy

SURA-IOOS Intermodel (UltraLite)
UNDKennedy_W

- Observed
- ADCIRC
- SLOSH OWI
- SLOSH 3
- FVCOM
- SELFE

Water Level (m)

Date in 2008

SURA-IOOS Intermodel (UltraLite)
UNDKennedy_X

- Observed
- ADCIRC
- SLOSH OWI
- SLOSH 3
- FVCOM
- SELFE

Water Level (m)

Date in 2008
UND Kennedy

SURA-IOOS Intermodel (UltraLite)
UNDKennedy_U

- Observed
- ADCIRC
- SLOSH OWI
- SLOSH 3
- FVCOM
- SELFE

Date in 2008

SURA-IOOS Intermodel (UltraLite)
UNDKennedy_V

- Observed
- ADCIRC
- SLOSH OWI
- SLOSH 3
- FVCOM
- SELFE

Date in 2008
Intermodel Comparison

With Waves
Intergrid Comparison

sl18tx
(18061765 Elements, 9,108,128 Nodes)

Standard
(825284 Elements, 424485 Nodes)
Tropical Findings

- FVCOM, SELFE, tides slightly more damped than ADCIRC
- ADCIRC, FVCOM, SELFE capture both parts to hurricane Ike surge – although FVCOM is consistently lower than the other two
- SLOSH misses the geostrophic setup ahead of storm and is consistently below other models
- Enhanced grid resolution does make a difference in local areas, albeit at high cost
- Wave model comparisons ongoing.