Large Scale Hydrodynamic Studies in the Northern Gulf of Mexico

Presented by:
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Acknowledgements

- Peter Bacopoulus
- Matt Bilskie
- Ammarin Daranpob
- Stephen Medeiros
- David Coggin
- Mike Salisbury
- Hugh Roberts
- John Atkinson
- Zach Cobell
- Shan Zou
Initial Talking Points

We have developed a models for coastal inundation throughout the entire western panhandle and Alabama and for Franklin, Wakulla & Jefferson counties

We apply the model and present the results to assess model skill

We are about to begin production of new FEMA DFIRMs
Carrabelle / New / Crooked River
Vertical Feature Extraction

• Find significant impediments
  – Roads
  – Natural terrain features
  – Man made terrain features
• Use automation to find features that the eye doesn’t catch
  – Irregular
  – Generally terrain, not structures
• Include features as mesh element edges

David Coggin
PADCIRC Model

- **Parallelized Advanced Circulation, Two-Dimensional Depth-Integrated** (PADCIRC-2DDI...henceforth, PADCIRC)
  
  - Long-wave, coastal and ocean circulation model (e.g., astronomic tides, wind/pressure forced flow, channels with inflows)
  
  - Solves the shallow water equations through the Generalized Wave Continuity Equation formulation
  
  - Finite element based (i.e., unstructured grids)
  
  - Permits wetting/drying, weir structures (e.g., roadways), culverts and piers
  
  - Allows for linking with wave models
  
  - Also a version that is fully coupled with SWAN
Shallow Water Equations

Continuity Equation: \[
\frac{\partial \zeta}{\partial t} + \frac{\partial U H}{\partial x} + \frac{\partial V H}{\partial y} = 0
\]

Deviation from Reference Datum

Depth-Integrated Velocity: x-direction

Depth-Integrated Velocity: y-direction

Momentum Equation (x Direction):
\[
\frac{\partial U}{\partial t} + U \frac{\partial U}{\partial x} + V \frac{\partial U}{\partial y} - fV = - \frac{\partial}{\partial x} \left[ \frac{p_s}{\rho_0} + g(\zeta - \alpha \eta) \right] + \frac{1}{H} M_x + \frac{\tau_{sx}}{\rho_0 H} - \tau_x U
\]

Momentum Equation (y Direction):
\[
\frac{\partial V}{\partial t} + U \frac{\partial V}{\partial x} + V \frac{\partial V}{\partial y} + fU = - \frac{\partial}{\partial y} \left[ \frac{p_s}{\rho_0} + g(\zeta - \alpha \eta) \right] + \frac{1}{H} M_y + \frac{\tau_{sy}}{\rho_0 H} - \tau_y V
\]
Model Skill Assessment Strategy

• Stability
• Gauge & HWM Data
  – Phasing of surge
  – Tidal signal
  – Width/shape of the storm tide hydrograph
  – Peak elevations

Hugh Roberts
John Atkinson
Zach Cobell
Shan Zou
Wind Forcing

• Provided by Oceanweather, Inc.
• Nested
Wave Forcing

• Independently computed with SWAN
  – Slinn Engineering

• Temporal coverage during entire storm
Surface Characteristics

- Bottom roughness
- Anisotropic reduction of wind stress
- Local shielding from vegetative canopy
System Summary

- [http://webstokes.ist.ucf.edu](http://webstokes.ist.ucf.edu)
- **Current Resources ~6.6TFlops (linpack)**
  - 98 blades at 908 cores (x86_64)
  - ~2TB of memory
  - ~48TB of storage (raw)
  - Infiniband: 144 DDR sockets
- **Recent Acquisition ~10.1 TFlops (linpack)**
  - 139 blades at 1400 cores (x86_64)
  - ~4TB of memory
  - ~54TB storage (raw)
  - Infiniband: 144 DDR + 72 QDR sockets
  - 15 expansion slots
  - Additional Nvidia S2070 GPU units
PADCIRC-2DDI Run Times

- 256 processors
  - ~8,500 nodes per core
- 4 day storm simulation
  - ~4 hours of wall clock time
Hurricane Ivan
9/13/2004 0:00 – 9/17/2004 0:00
HURRICANE IVAN
Sept. 2 – 24, 2004
HIGHEST WINDS: 165 mph
LOWEST PRESSURE: 910 mbar
Comparison of Gauge Peaks to ADCIRC Simulation

Ivan (with waves)

y = 0.9697x
R² = 0.7419
Hurricane Katrina
8/25/2005 12:00 – 8/30/2005 0:00
HURRICANE KATRINA
Aug. 23-30, 2005
HIGHEST WINDS: 175 mph
LOWEST PRESSURE: 902 mbar
Comparison of Gauge Peaks to ADCIRC Simulation
Katrina (with waves)

$y = 0.9754x$
$R^2 = 0.8869$
Comparison of Measured HWM to ADCIRC Simulation
Katrina (with waves)

\[ y = 0.9455x \]

\[ R^2 = 0.4608 \]
Summary

A faithful representation of the physical system, forcing processes (wind, pressure, tides, riverine flows, waves) and of the flow itself (through grid resolution and accurate algorithms) is critical to a truly predictive astronomic and storm tide model.

Demonstrated that a large-scale (~2.2M nodes) model can run efficiently with skill.
Ecological Effects of Sea Level Rise in the Northern Gulf of Mexico (EESLR-NGOM)

The Team

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Dewberry, Inc.
Jerry Sparks
Susan Taylor
Ryan Towell

The Goal
To assess the ecological impacts of SLR with an interdisciplinary and applications-based approach.
Ecological Effects of Sea Level Rise in the Northern Gulf of Mexico (EESLR-NGOM)

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Davina Passeri
Daina Smar

University of Central Florida
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http://champs.cecs.ucf.edu
EESLR-NGOM Outline

• Discussion of EESLR-NGOM Project Process.
• How does sea level rise impact surge & tides?
• What if we take a dynamic vs. static approach?
  → Let’s examine this for SLR of 15.2 cm, 30.5 cm, & 1.0 m (6 in., 1.0 ft., & 3.28 ft.).
• Conclusion and implication.
Marsh, Oyster & SAV Assessments

Collected Earth Data

ASTER NDVI

Gage Station

NOAA Tidal Data

USGS Surface Water Data

LiDAR

EESLR-NGOM Project Process

Water surface elevation (m)

Gage Height (m)

Elevation (m)
EESLR-NGOM Project Process

Field/Lab Experiments

Surface Roughness

Sediment Cores and Grain Size Distribution

Total Suspended Solids
Apalachicola, FL

Deviation from MSL (m)


0 50 100 150 200

Percent Finer

Grain Size (mm)

100 80 60 40 20 0

Percent Finer

0 0.0001 0.001 0.01 0.1 1

Grain Size (mm)

10 1 0.1 0.01 0.001 0.0001

Apalachicola, FL
EESLR-NGOM Project Process

Biomass Density Sample

Field/Lab Experiments

Marsh Organs
EESLR-NGOM Project Process

Downscaled General Circulation Model

Intensity-Duration-Frequency Curve

30-Yr, 24-Hr Design Storm
Model Domain

Apalachicola River

Preliminary Results

Finite Element Mesh

Elevation (m)

-5.0
-3.5
-2.0
-1.5
-1.0
-0.5
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0

USGS Station ID 02359170

Apalachicola River
NOAA Station 8728690

EESLR-NGOM Project Process

Model Forcing Data

Astronomic Tide

Rating Curve

Time-Series Flow Rate Near NOAA Station 8728690

37,465 elements
18,928 nodes
Max. elevation ≈ 10 m
Max. depth ≈ 8 m

USGS Station 02359170

Gage Height (m)

0
200
400
600
800
1000
1200
1400
1600
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
17-Jun 18-Jun 19-Jun 20-Jun

Discharge (cms)

0
200
400
600
800
1000
1200
1400
1600
0123

Flow rate (cms)

8:30 PM 8:30 AM 8:30 PM

Tide only
Tide-inflow
Tide-inflow-present storm
Tide-inflow-future storm

0
-500
-1000
500
1000
1500
2000
2500

8:30 PM 8:30 AM 8:30 PM
SLR Application

• SLR tests included 15.2 cm, 30.5 cm, & 1 m (Think 6 in., 1 ft., & ≈3.28 ft.)

• Static = existing maximum was elevated by SLR computational node by node max for surge or tides

• Dynamic = max was simulated w/SLR included
  • Simulated surge from top five storms
    + SLR incorporated as steric effect
  • Simulated astronomic tides
    + SLR incorporated as steric effect
0.2% (500-year) floodplain
Top 5 contributing storms
Surge w/1.0 m SLR

Static
Surge w/1.0 m SLR

Dynamic
Surge w/1.0 m SLR

Static
Surge w/1.0 m SLR

Dynamic
Surge w/1.0 m SLR

Static
Surge w/1.0 m SLR

Dynamic
Tides w/30.5 cm SLR

Static
Tides w/30.5 cm SLR

Dynamic
Tides w/30.5 cm SLR

Static
Tides w/30.5 cm SLR

Dynamic
Tides w/30.5 cm SLR

Static
Tides w/30.5 cm SLR

Dynamic
Floodplain impacted by SLR

<table>
<thead>
<tr>
<th>Sea level rise (m)</th>
<th>Approach</th>
<th>Area (km²)</th>
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<tbody>
<tr>
<td><strong>Astronomic tides</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.152</td>
<td>Static</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>Dynamic</td>
<td>41</td>
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<td>0.305</td>
<td>Static</td>
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<td><strong>Storm surge</strong></td>
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<tr>
<td>0.152</td>
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<td>58</td>
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<td>247</td>
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<tr>
<td></td>
<td>Dynamic</td>
<td>360</td>
</tr>
</tbody>
</table>
Conclusion

• Tide & surge inundation are nonlinearly related to sea level rise (SLR)

Implication

• We are applying a dynamic approach with EESLR-NGOM to identify impacted areas*

* The following slides demonstrate a biologically dynamic relationship in a coastal marsh region.
MLW in coastal St. Johns: Present Sea
MLW in coastal St. Johns: 30.5 cm SLR
Calculation procedure

MLW & MHW
are determined via analysis of simulated tidal record

Biomass production
is determined by applying biomass curve spatially

\[ E_n \text{ elevation} \]
\[ D_n \text{ relative elevation} = f(E_n; \text{MLW}_n \& \text{MHW}_n) \]

\[ B_n \text{ production} = f(D_n; a_n, b_n \& c_n) \]

Tidal modeling & analysis

Biomass curve from field experiments
Biomass production: Present sea state
Biomass production: 30.5 cm SLR.
Managed accretion

Natural Accretion + Thin Layer Disposal

\[ E_n \text{ elevation} \]
\[ \text{obtained from DEM of hydrodynamic model} \]

\[ D_n \text{ relative elevation} \]
\[ D_n = f(E_n; \text{MLW}_n \& \text{MHW}_n) \]

\[ B_n \text{ production} \]
\[ B_n = f(D_n; a_n, b_n, c_n) \]

- Tidal modeling & analysis
- Biomass curve from field experiments
Biomass production w/managed accretion: 30.5 cm SLR.
To paraphrase a climate science motto:

“The sea level is rising, the best we can do now is to manage the unavoidable and avoid the unmanageable.”
10th International Conference on Hydroscience & Engineering

http://iche2012.org

November 4 - 7, 2012 at the Rosen Plaza Hotel

The Water Cycle Under a Changing Climate: Using Hydroscience and Engineering for a Sustainable Future