Numerical Modeling of Coastal Inundation and Sedimentation by Storm Surge, Tides and Waves at Norfolk, Virginia, USA

Honghai Li and Lihwa Lin
Engineering and Research Development Center
Coastal and Hydraulics Laboratory

Kelly Burks-Copes
Engineering and Research Development Center
Environmental Laboratory

ICCE 2012
Santander, Spain
July 4, 2012
STRATEGIC ENVIRONMENTAL RESEARCH AND DEVELOPMENT PROGRAM (SERDP)
Model Network for Risk Assessment

SLR Scenario (0, 0.5, 1, 1.5, 2m)

Geomorphic and Geologic Assessment

Coastal usage classification shapefiles (5 Categories)

Ecology and Land Use Conversion (SLAMM)

Bathymetry and land cover changes

Regional Surge and Waves (TC96 + ADCIRC + SWAN)

SLR Scenario- and event-based max surge, waves, wind

Nearshore Waves, Current, Water Levels, and Sediment Transport (CMS)

Water level, waves, current, sediment load, and morphology changes

Surface Flood Routing (GSSHA)

WATER LEVEL, WAVES, CURRENT, SEDIMENT TRANSPORT RATE

Asset Capability Network Development – Infrastructure Network (ArcGIS)

ASSET IDENTITY, CHARACTERISTICS AND CONNECTIVITY

Structural Analysis (ISS3D + HAZUS MR-4)

Probability Distribution on the Levels of Mission Impairment

Risk Assessment (Netica)

Probability of the damage states given the loadings

Inputs-Outputs and Link Between Models
Outline

• Introduction
• Model and data
• Hurricane Isabel
• Synthetic storms
• Summary
Introduction

- Coastal hazards, coastal storms and sea level rise, pose threat to military installation asset and mission capability sustainability

- Conduct quantitative modeling and risk assessment to understand climate change effects on coastal installation conditions

- Advance knowledge of risk assessment and transfer technologies on risk assessment into military community of practice
Sea Level Rise Scenarios

- Sea Level Rise (local MSL between 2000-2100)

Four equally-weighted sea level scenarios were specified by SERDP (0.5 m increments):

0.5, 1.0, 1.5, 2.0 m
Coastal Modeling System (CMS)

- CMS-Wave
  - Diffraction, Reflection, Run-up, Setup, Overtopping, Wave generation, Structures
  - Current, Water Level, Morphology Change
  - Wave Height, Direction, Period, Dissipation, Radiation Stresses

- Hydrodynamics
  - Waves, Tide, Wind, River, Current

- Morphology
  - Morphologic Constraints

- Sediment Transport

- CMS-Flow
  - Fast, robust, implicit and explicit schemes, flexible and efficient telescoping grid

- PTM
  - Lagrangian Particle Tracking Model
  - Linked in SMS
- Naval Station Norfolk
- Navigation channels
- Domain Size: 20 x 24 km
- No of Cells: ~ 530,000
- Cell Size: 10 ~ 300 m
- Land Surface Elevation (MSL): 
  -11 ~ 30 m
CMS Configuration

- Bathymetry, land surface elevation
  1 m resolution LIDAR data
- Sediment grain size and bottom friction
  5 m resolution land coverage features
CMS Bathymetry (Naval Station Norfolk)
Hurricane Isabel

- Category 5 Hurricane in the 2003 Atlantic hurricane season
- Significant storm surge along the James River
- Worst flood damage in some areas of Virginia
Surge, Waves, and Wind of Hurricane Isabel (Norfolk Area)

Surge: ADCIRC  Tide: Sewells Point  Waves: SWAN

Wind: PBL
CMS Validation (Water Surface Elevation)

Correlation Coefficient: 0.99
Root Mean Square Error (RMSE): 0.076 m
Relative RMSE: 3.6%
CMS Validation (Land Inundation)

Naval Station Norfolk
Naval Base
Golf Course
Mason Creek
Parking Lot
CMS Validation (Land Inundation)

Parking Lot

Naval Base
Golf Course

Mason
Creek

Storm Surge Map

Naval Base
Golf Course

Mason
Creek

Naval Station Norfolk
Synthetic Storms

- 50-year return storm
- 100-year return storm
- northeaster

Forcing
- tide
- surge
- wind
- waves
Peak Surge (100-year return storm)
## Area Flooded in Naval Station Norfolk (100-year return storm)

<table>
<thead>
<tr>
<th>SLR (m)</th>
<th>50-Year Return Storm</th>
<th>100-Year Return Storm</th>
<th>Northeaster</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area (10^6m²)</td>
<td>%</td>
<td>Area (10^6m²)</td>
</tr>
<tr>
<td>0.0</td>
<td>1.176</td>
<td>8.11</td>
<td>9.076</td>
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<tr>
<td>0.5</td>
<td>2.720</td>
<td>18.75</td>
<td>10.219</td>
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<tr>
<td>1.0</td>
<td>4.948</td>
<td>34.11</td>
<td>10.762</td>
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<tr>
<td>1.5</td>
<td>8.198</td>
<td>56.52</td>
<td>11.078</td>
</tr>
<tr>
<td>2.0</td>
<td>10.014</td>
<td>69.04</td>
<td>11.317</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario</th>
<th>100-year (0-m SLR)</th>
<th>100-year (2-m SLR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow + Waves</td>
<td>9.076</td>
<td>11.317</td>
</tr>
<tr>
<td>No Waves</td>
<td>9.029</td>
<td>11.307</td>
</tr>
<tr>
<td>No Wind</td>
<td>8.525</td>
<td>11.308</td>
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</tbody>
</table>
Sediment Transport
(100-year return storm, 2.0 m SLR)
Averaged Sediment Transport
(100-year return storm, 2.0 m SLR)
Morphology Change
(100-year return storm)
Time Series at Selected Locations
Water Surface Elevation

Site 1

Site 3
Depth Change in Channels

Site 1

Site 2
Summary

• Synthetic storms (100-year) cause the peak surge level of 3.6 m and 5.4 m MSL under the 0-m and 2-m SLR scenarios, respectively.

• Tropical and extratropical storms induce extensive coastal inundation around the military installations. The three synthetic storms inundate approximately 60-80% of Naval Station Norfolk under the 2-m SLR scenario.

• Waves and wind contribute to area changes in inundation, but the effect is not significant.

• Changes in water surface elevation have a linear response to sea level rise scenarios, but changes in morphology do not strictly follow the linear response pattern.

• Sediment movement and corresponding morphology change mostly occur in the navigation channels and the maximum depth changes are more than 3.0 m. The amount of depth change increases as the value of SLR goes up.

• The calculated bed volume changes show that the storms induce a net volume loss within the channel area, an indication of channel flushing in the study area.
Thank You!

Questions?