

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



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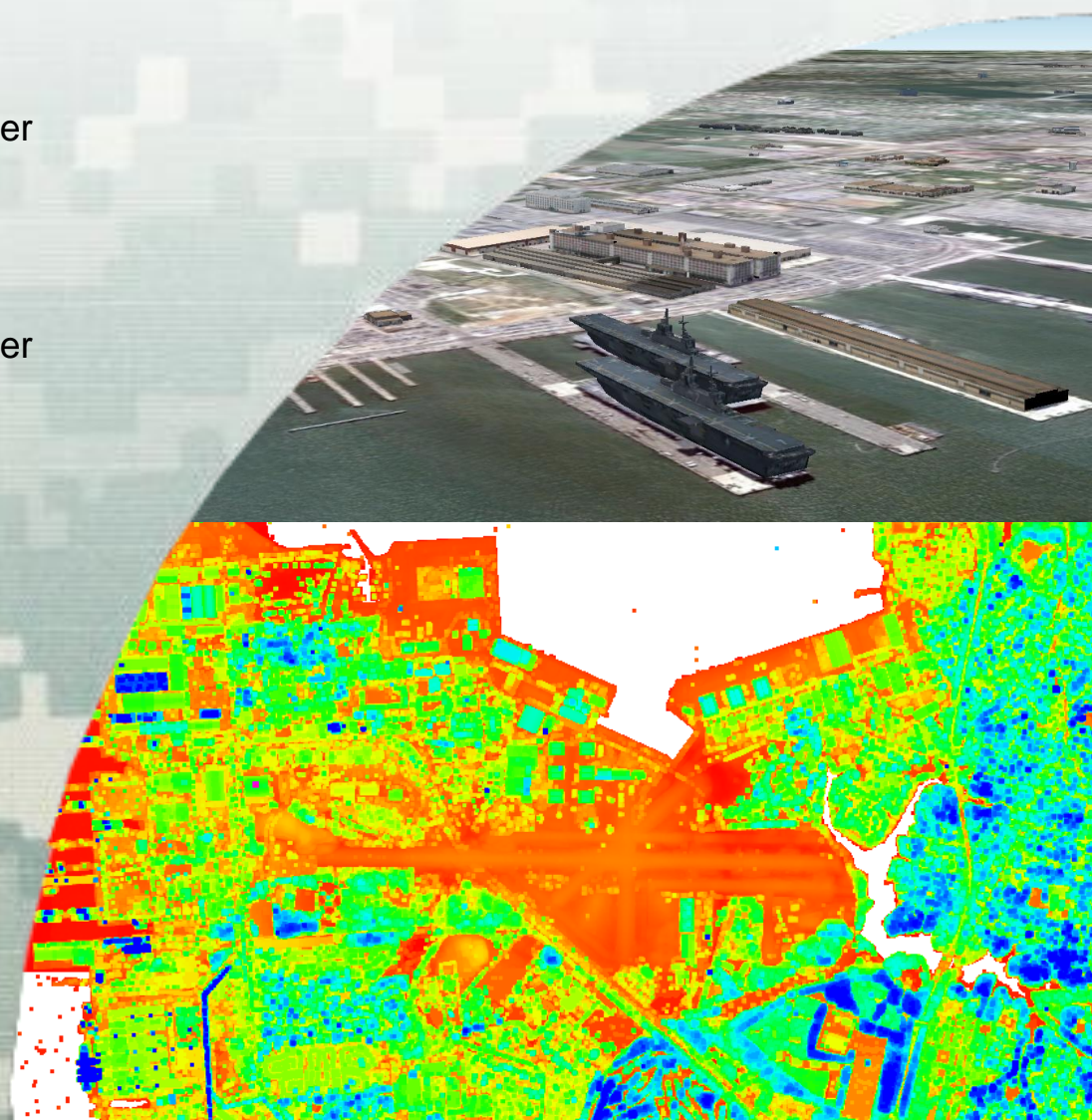
**ICCE 2012**

**Santander, Spain**

**July 4, 2012**

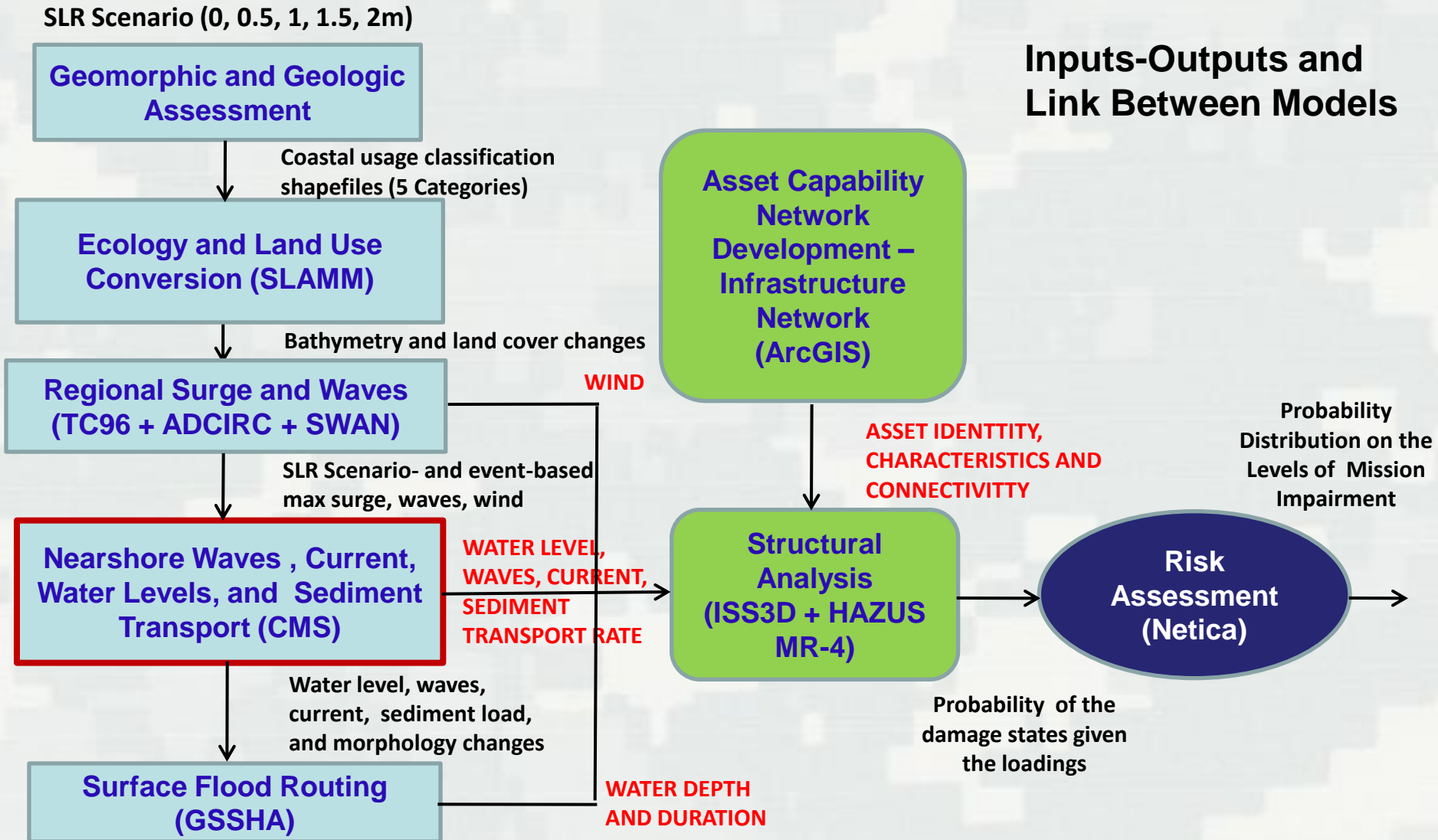


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# STRATEGIC ENVIRONMENTAL RESEARCH AND DEVELOPMENT PROGRAM (SERDP)

## Model Network for Risk Assessment



# Outline

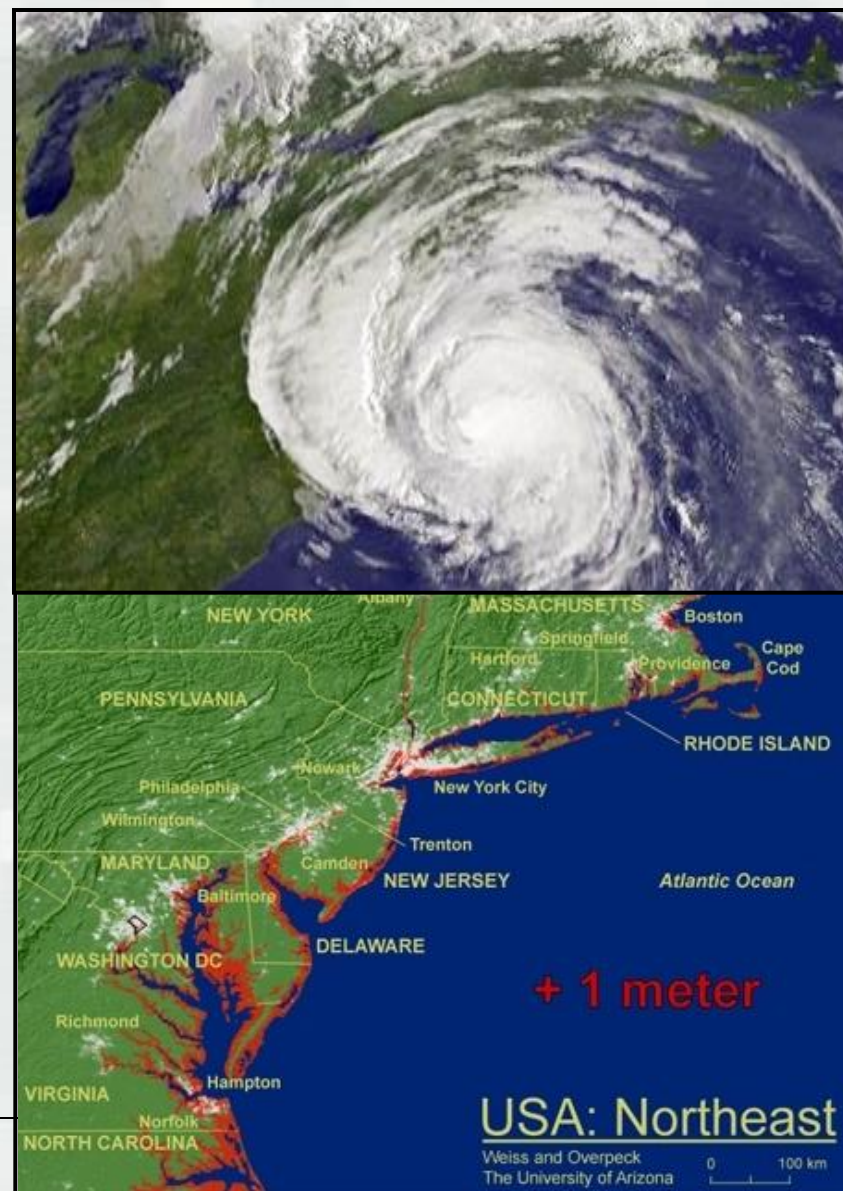
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- **Introduction**
- **Model and data**
- **Hurricane Isabel**
- **Synthetic storms**
- **Summary**



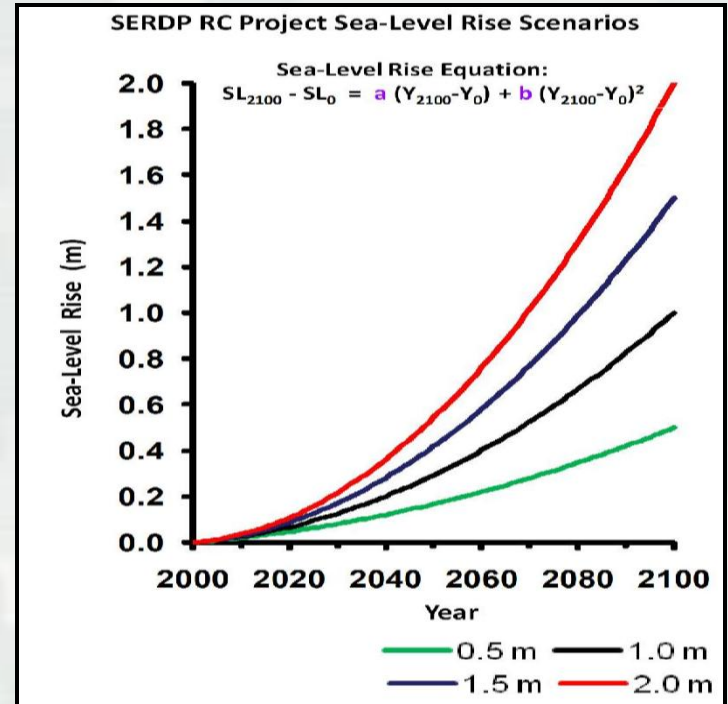
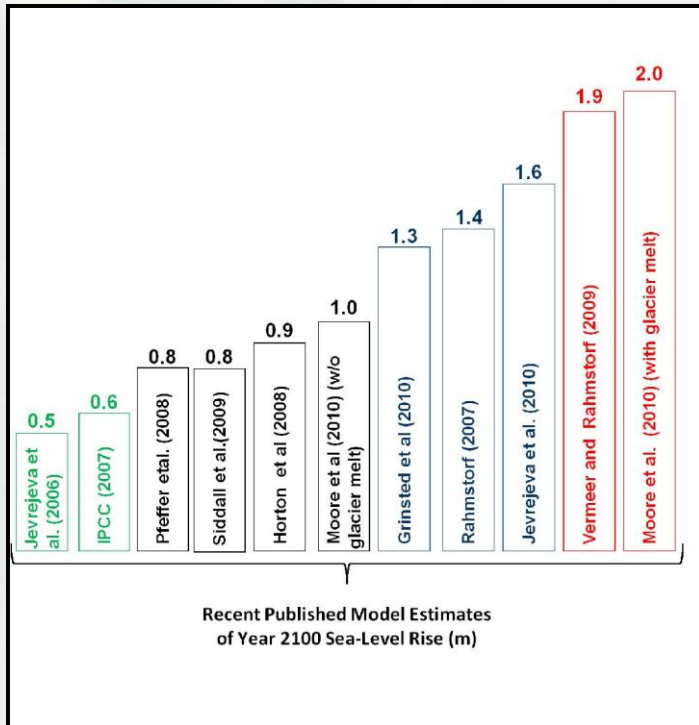
# Introduction

- 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

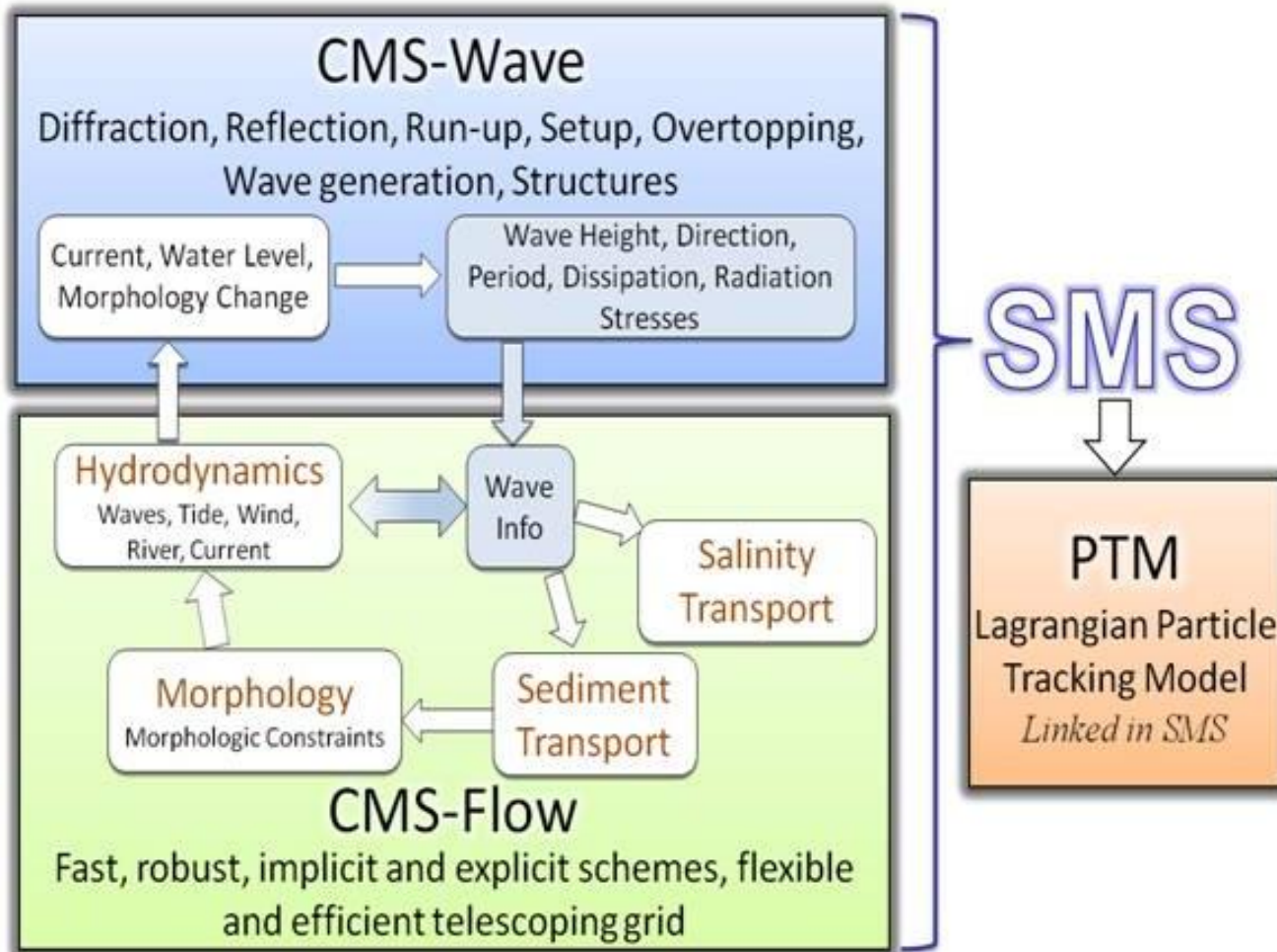
- Sea Level Rise (local MSL between 2000-2100)



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)

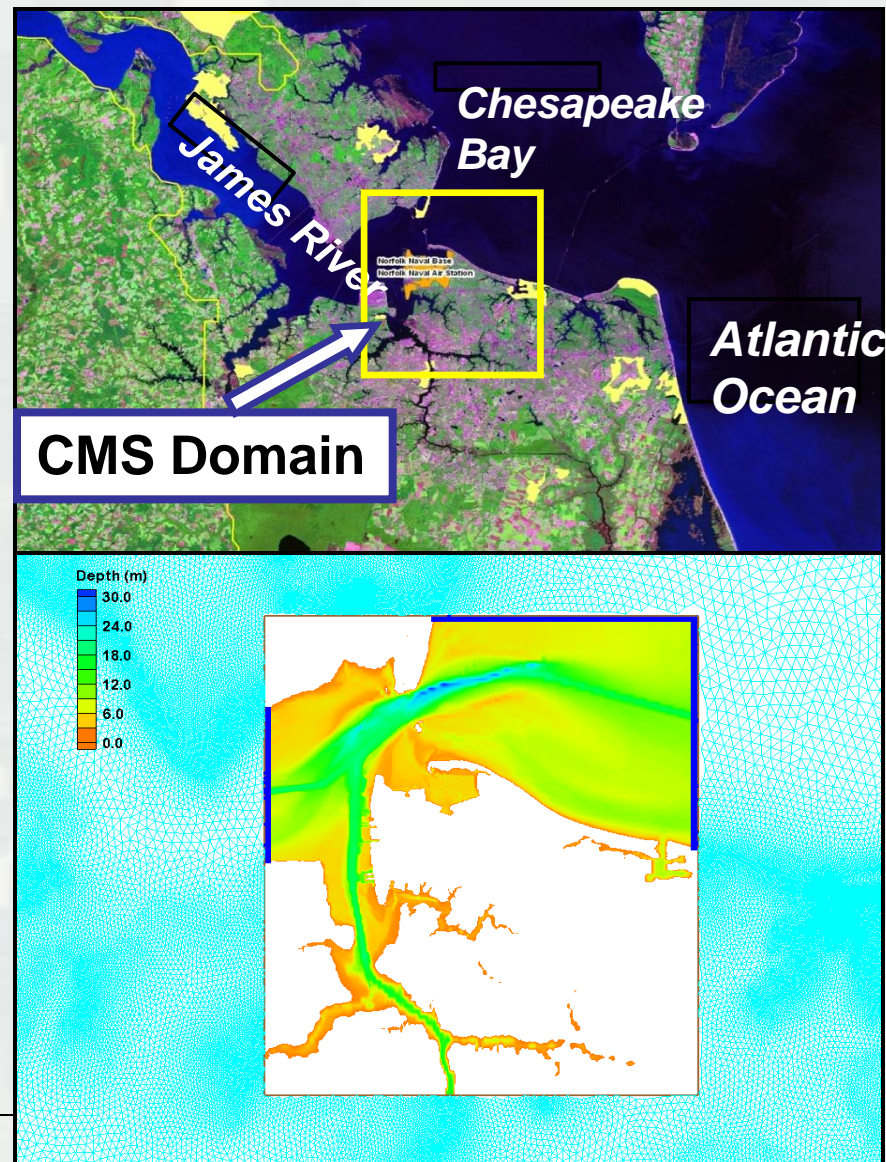




# Study Domain

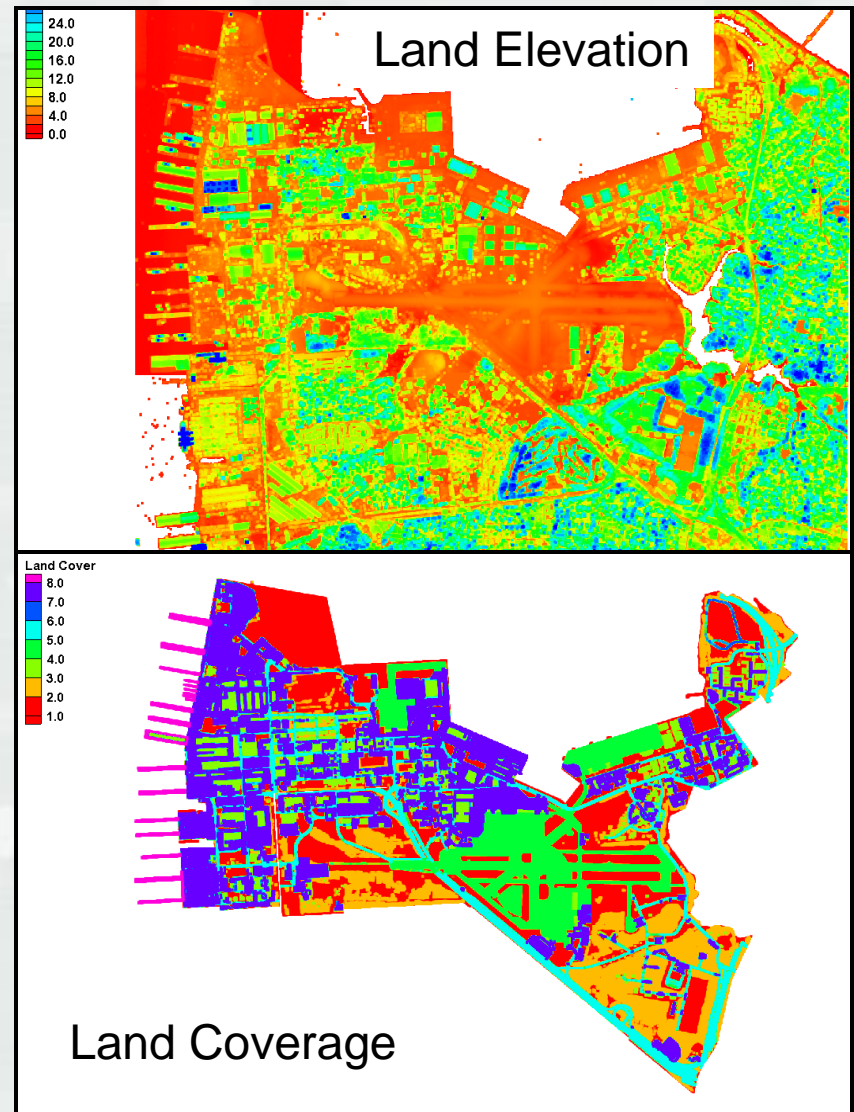
- Naval Station Norfolk
- Navigation channels
- Domain Size: 20 x 24 km
- No of Cells: ~ 530,000
- Cell Size: 10 ~ 300 m
- Land Surface Elevation (MSL):

-11 ~ 30 m



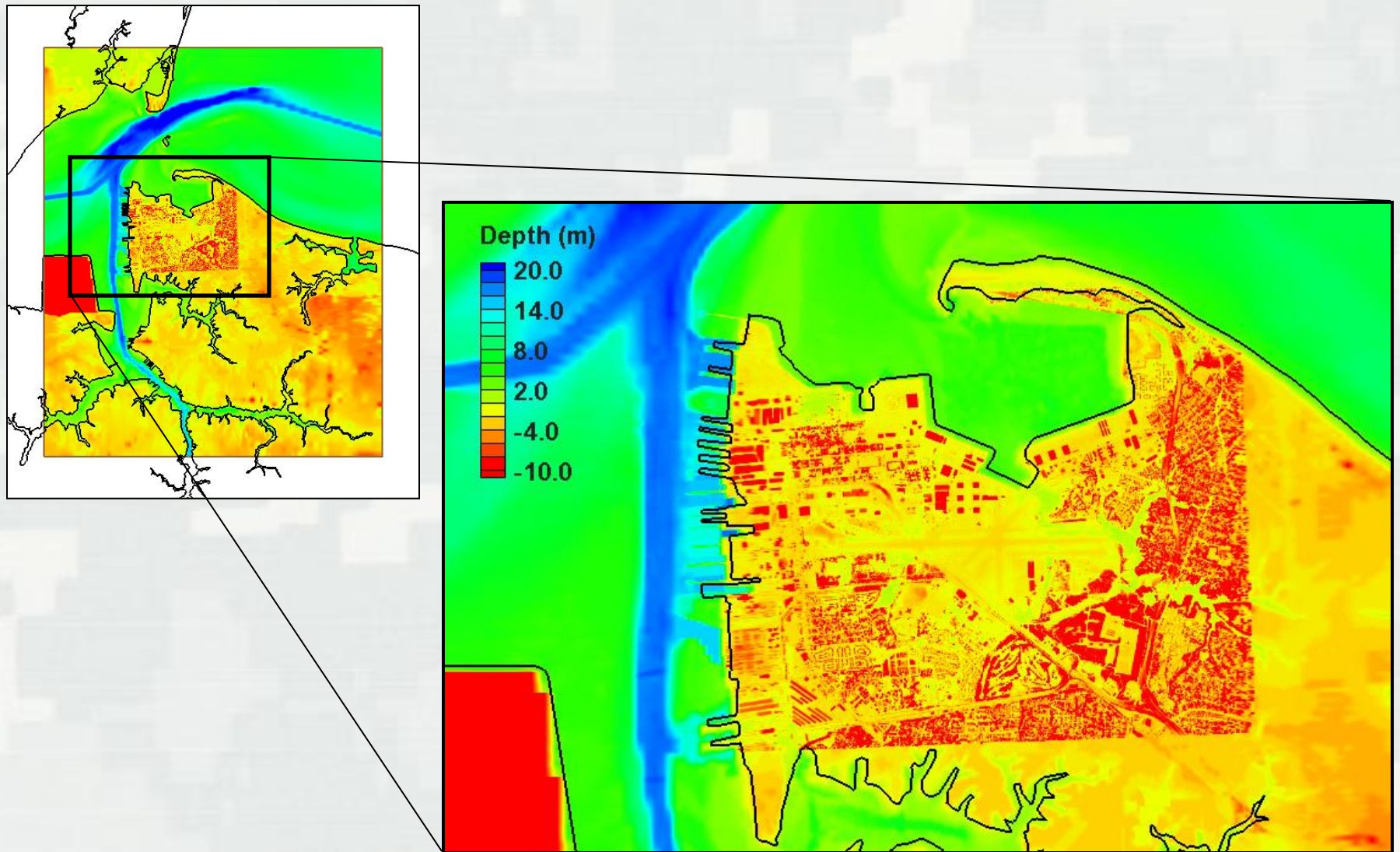
# CMS Configuration

- **Bathymetry, land surface elevation**  
  
1 m resolution LIDAR data
- **Sediment grain size and bottom friction**  
  
5 m resolution land coverage features



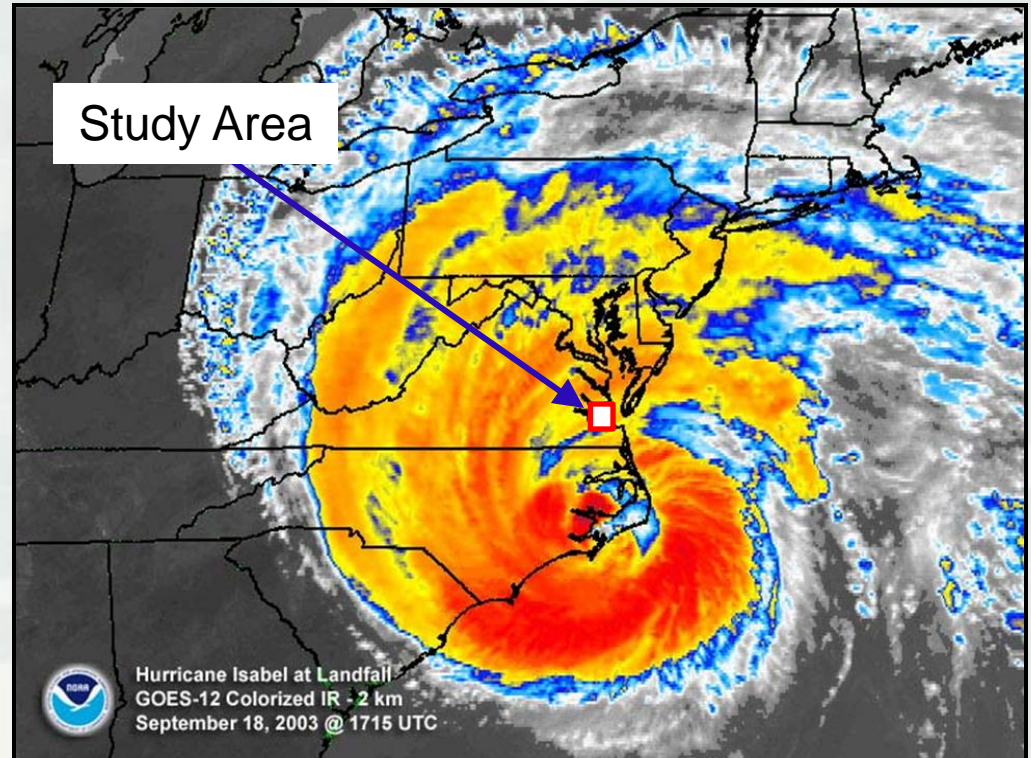


# CMS Bathymetry (Naval Station Norfolk)



# 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**

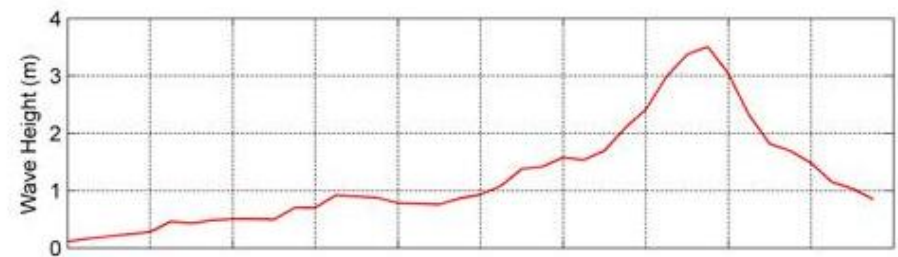
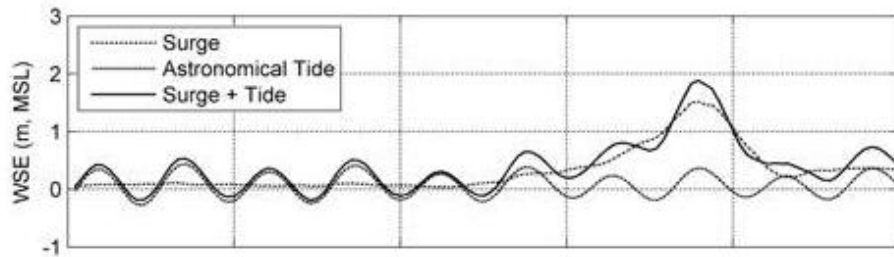




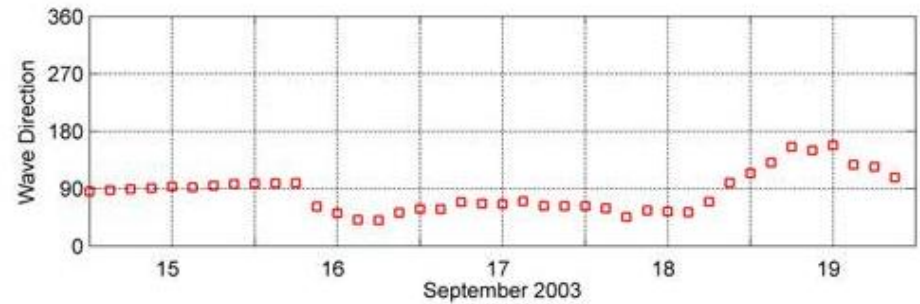
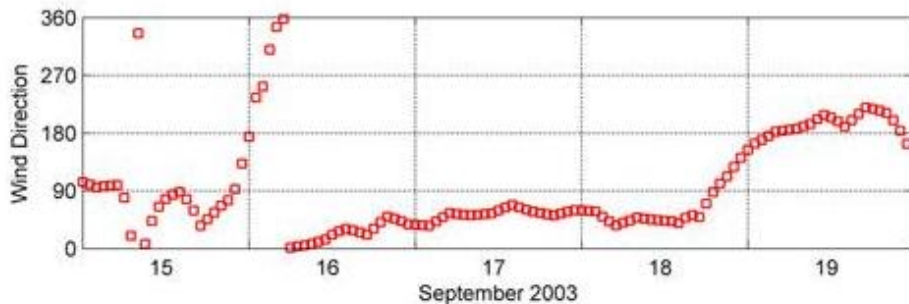
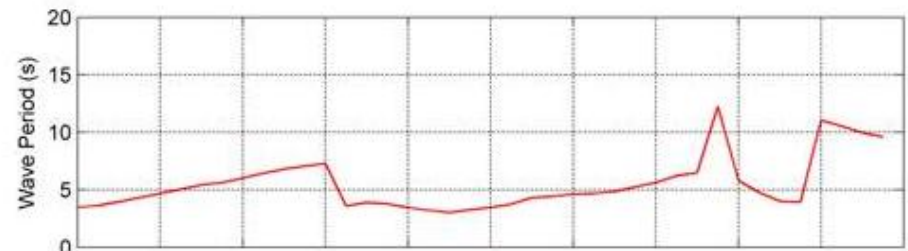
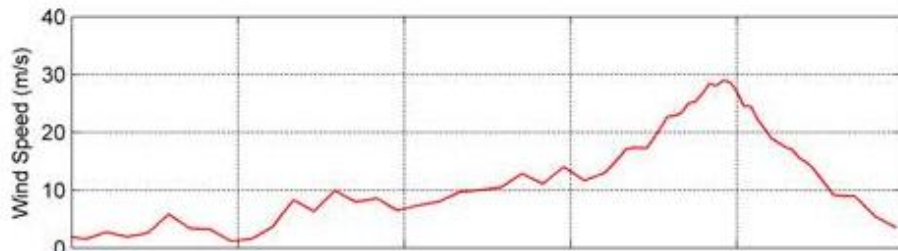
# Surge, Waves, and Wind of Hurricane Isabel (Norfolk Area)

Surge: ADCIRC Tide: Sewells Point

Waves: SWAN

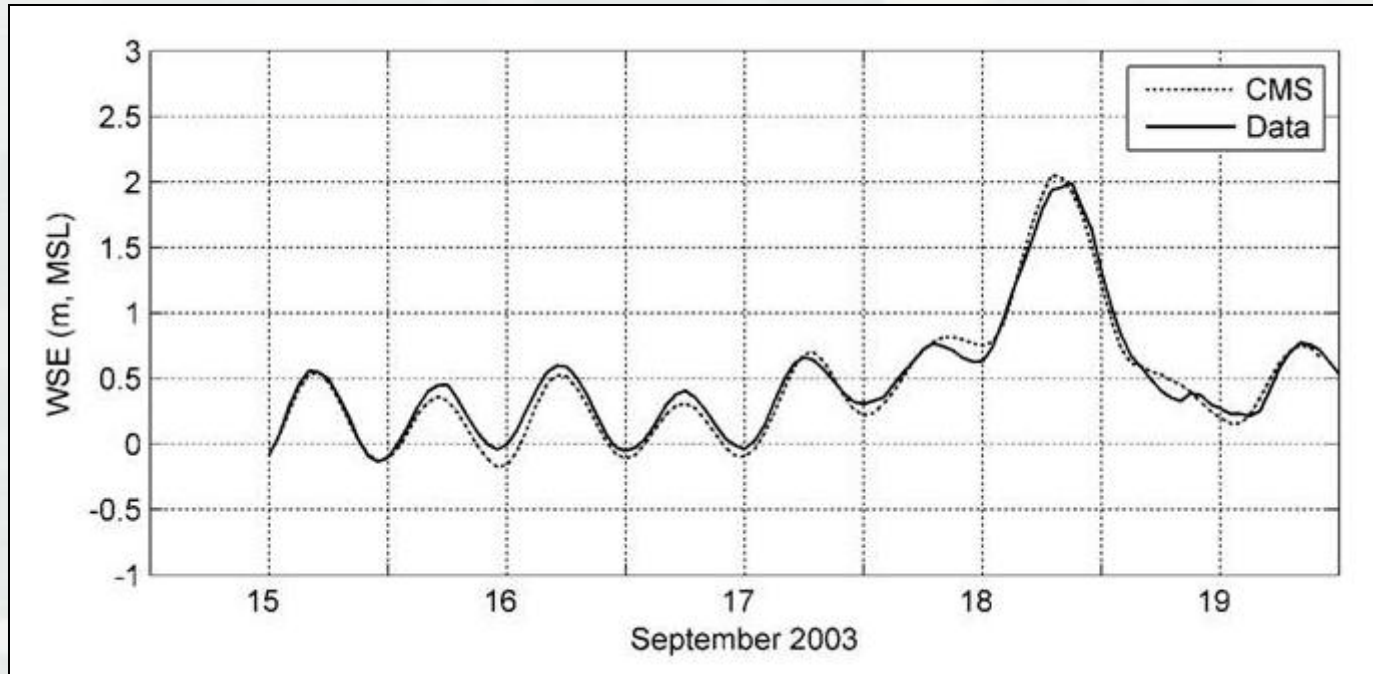


Wind: PBL



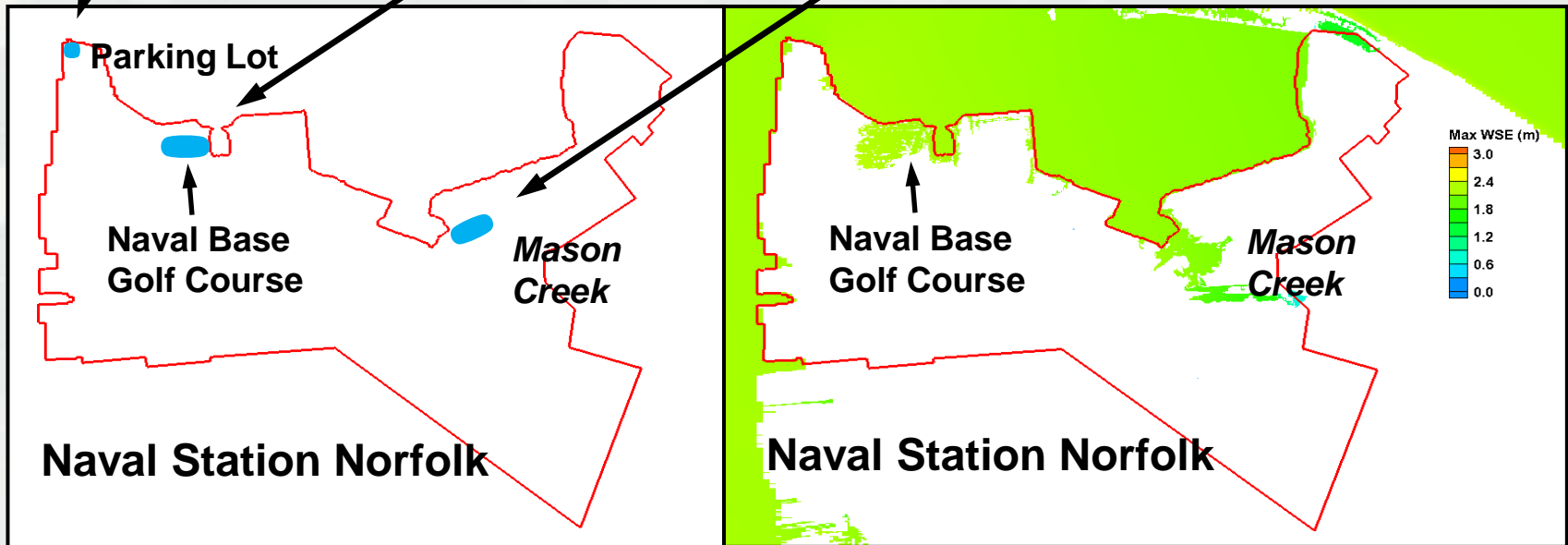


# CMS Validation (Water Surface Elevation)

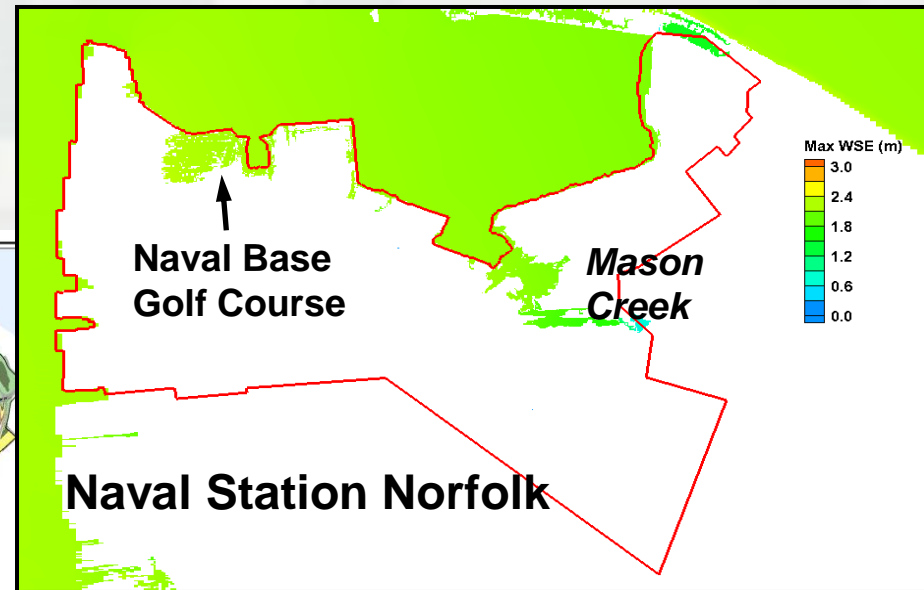
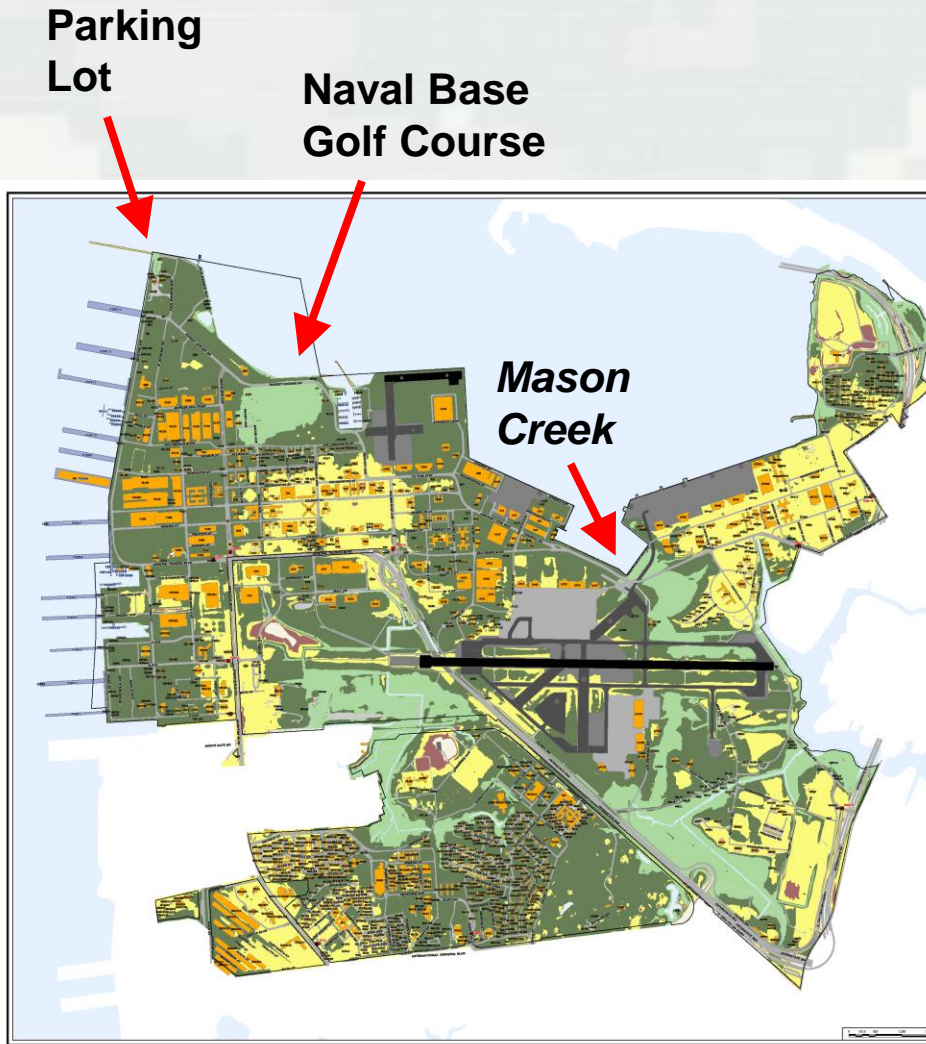


<b>Correlation Coefficient:</b>	<b>0.99</b>
<b>Root Mean Square Error (RMSE):</b>	<b>0.076 m</b>
<b>Relative RMSE:</b>	<b>3.6%</b>

# CMS Validation (Land Inundation)



# CMS Validation (Land Inundation)



Storm Surge Map

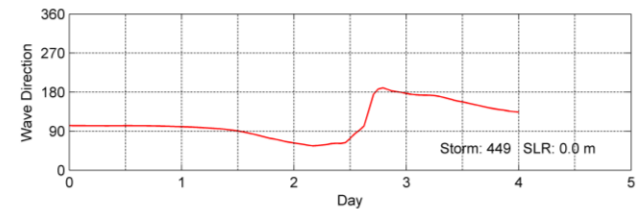
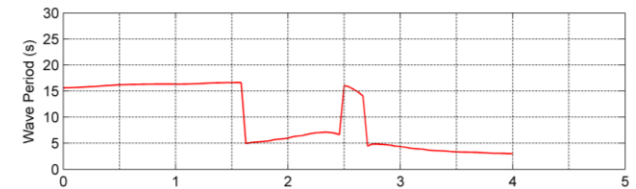
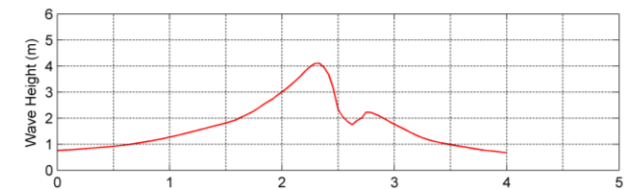
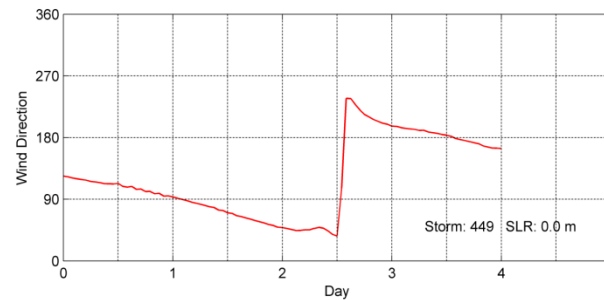
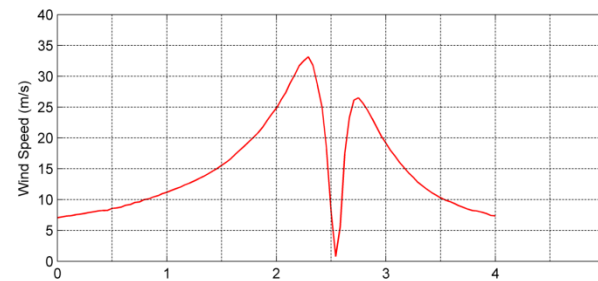
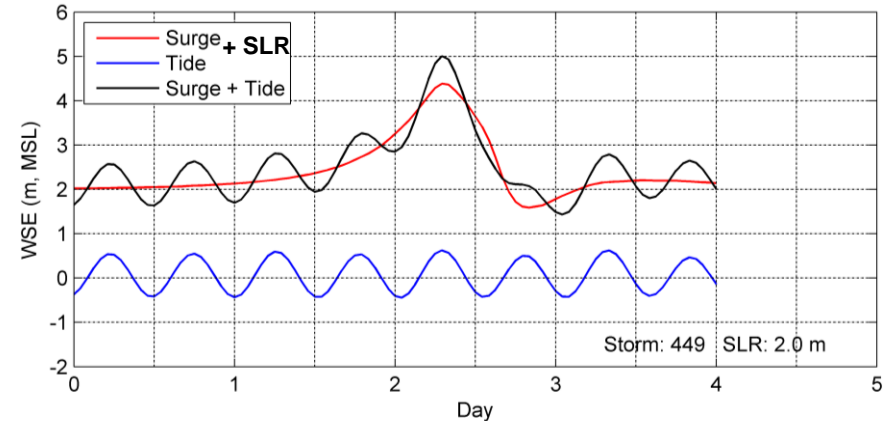


# Synthetic Storms

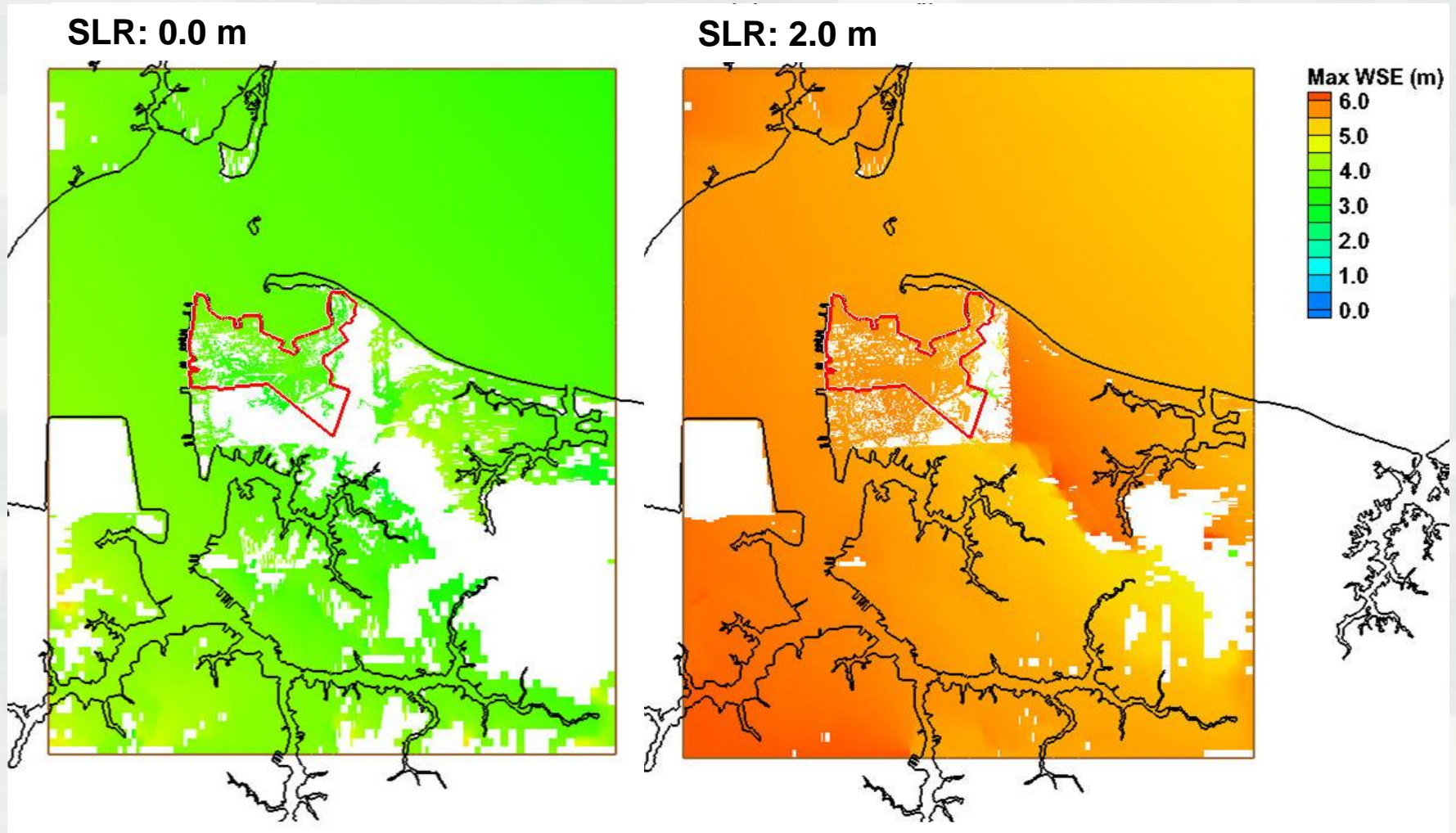
- 50-year return storm  
100-year return storm  
northeaster

- Forcing

tide  
surge  
wind  
waves



# Peak Surge (100-year return storm)



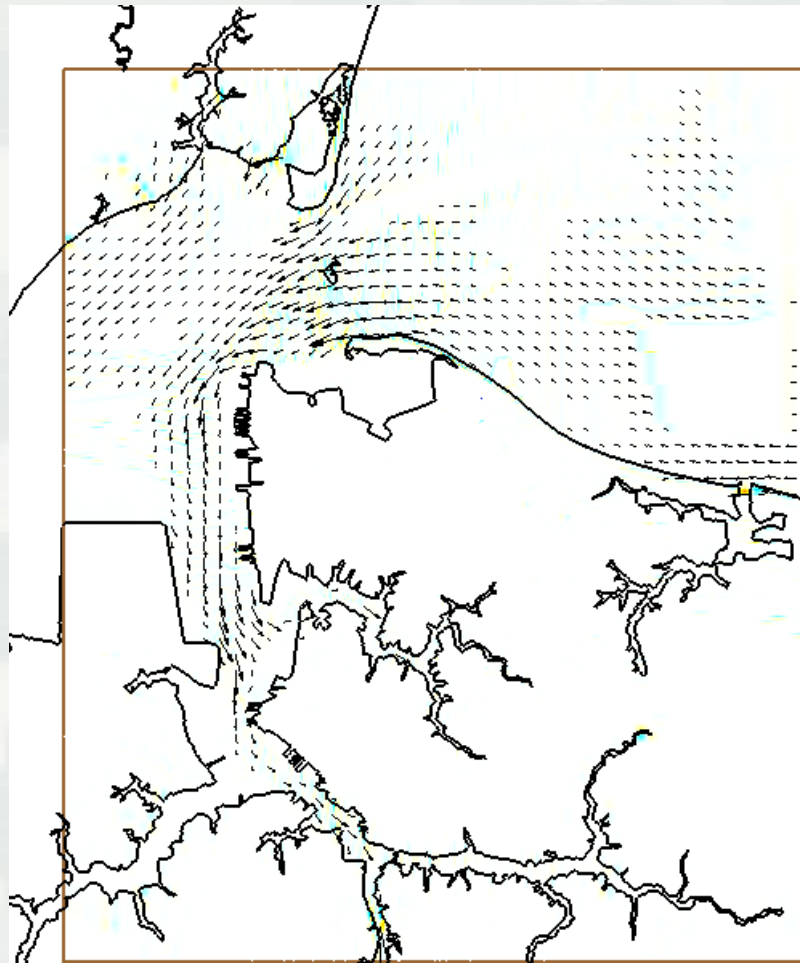
# Area Flooded in Naval Station Norfolk (100-year return storm)

SLR (m)	50-Year Return Storm		100-Year Return Storm		Northeaster	
	Area (10 <sup>6</sup> m <sup>2</sup> )	%	Area (10 <sup>6</sup> m <sup>2</sup> )	%	Area (10 <sup>6</sup> m <sup>2</sup> )	%
0.0	1.176	8.11	9.076	62.57	1.662	11.46
0.5	2.720	18.75	10.219	70.45	3.839	26.47
1.0	4.948	34.11	10.762	74.20	7.326	50.51
1.5	8.198	56.52	11.078	76.37	9.811	67.64
2.0	10.014	69.04	11.317	78.02	10.626	73.26

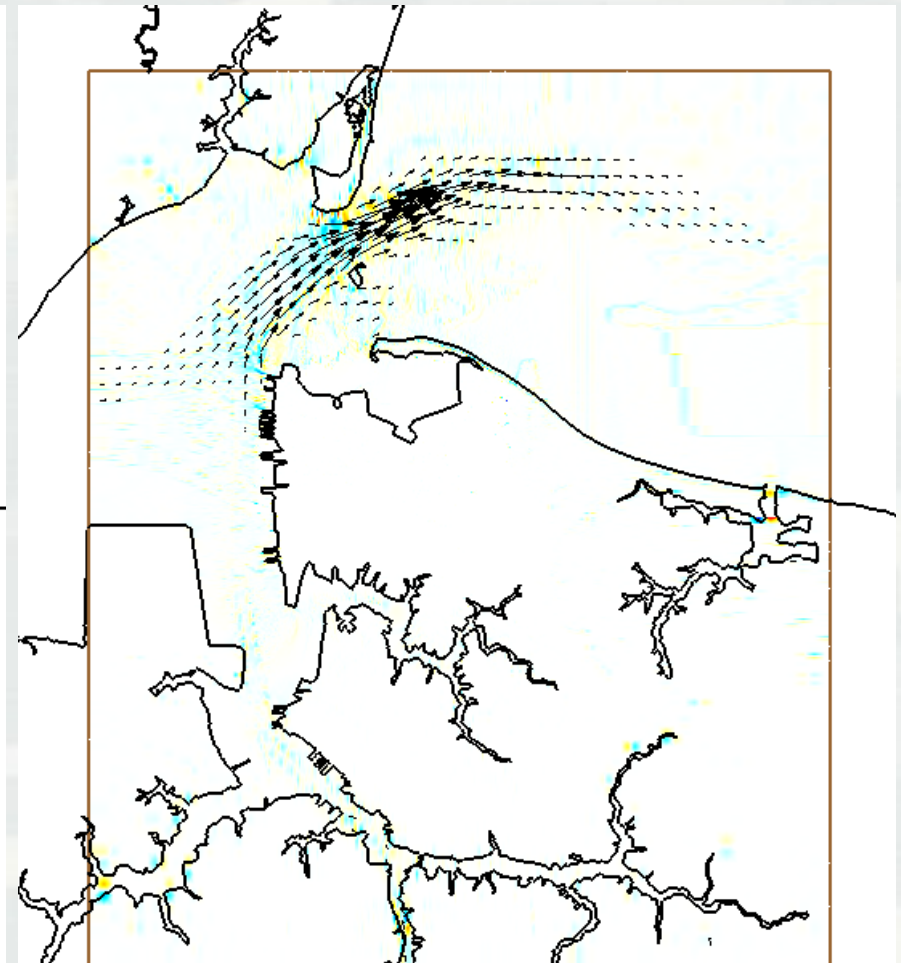
Scenario	100-year (0-m SLR)	100-year (2-m SLR)
Flow + Waves	9.076	11.317
No Waves	9.029	11.307
No Wind	8.525	11.308



# Sediment Transport (100-year return storm, 2.0 m SLR)

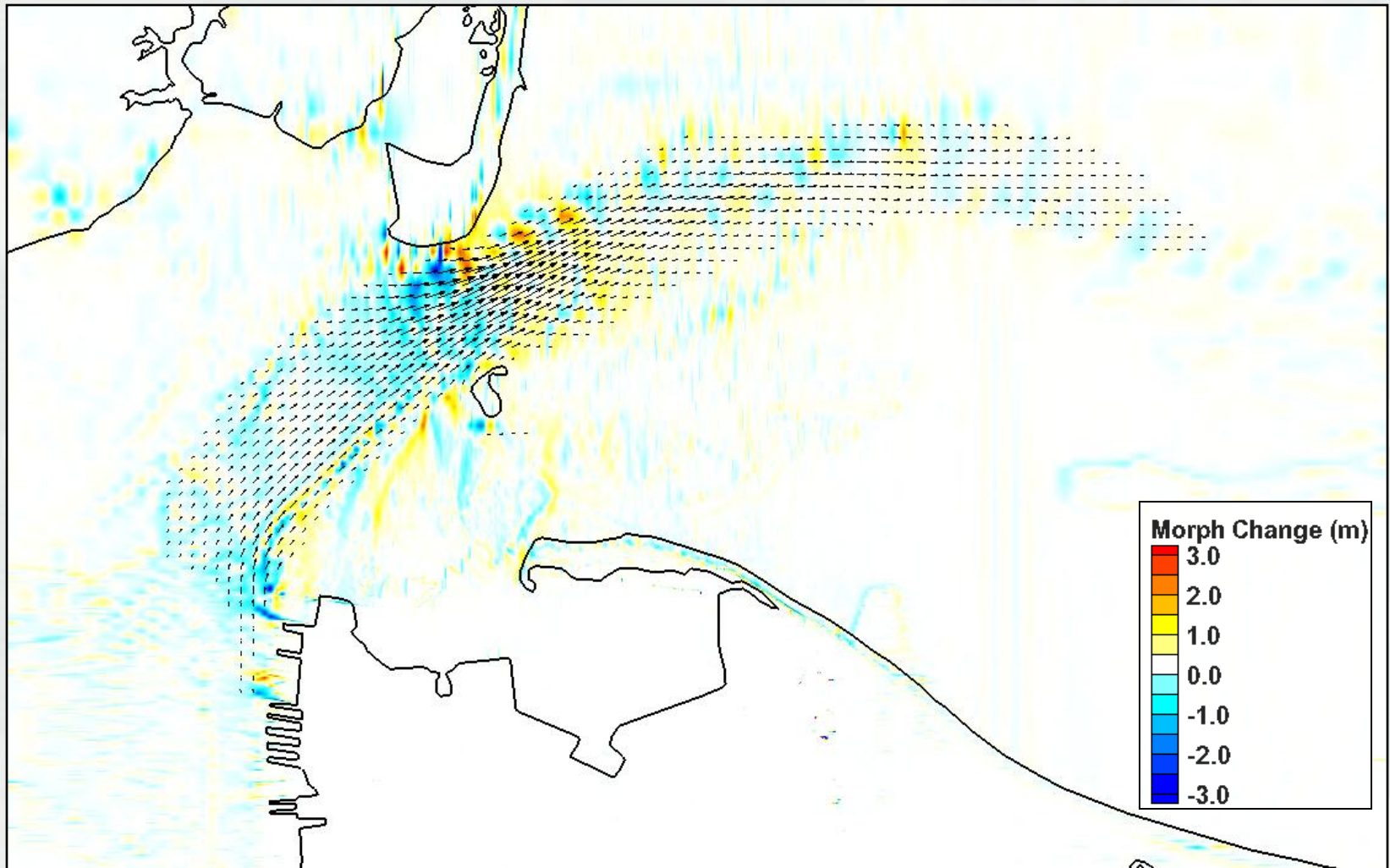


Hour 54

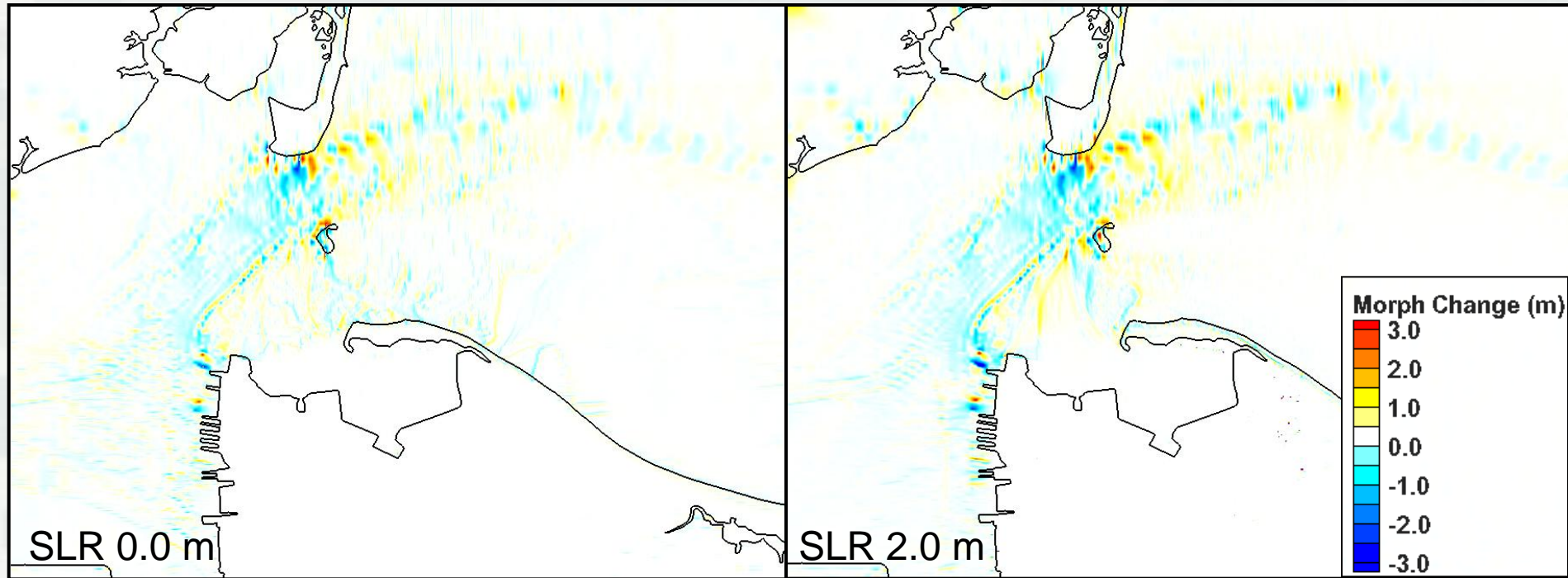


Hour 65

# Averaged Sediment Transport (100-year return storm, 2.0 m SLR)

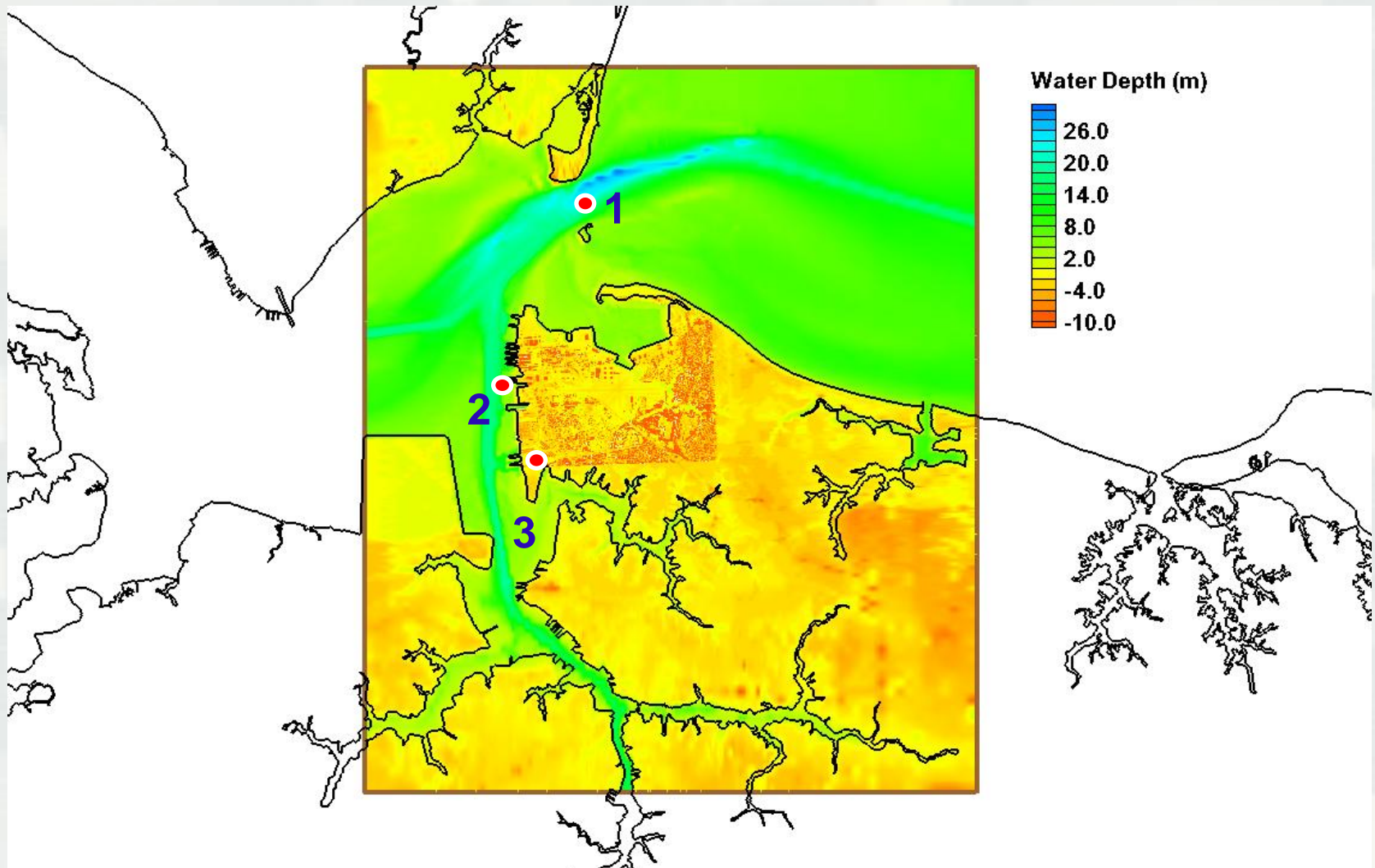


# Morphology Change (100-year return storm)

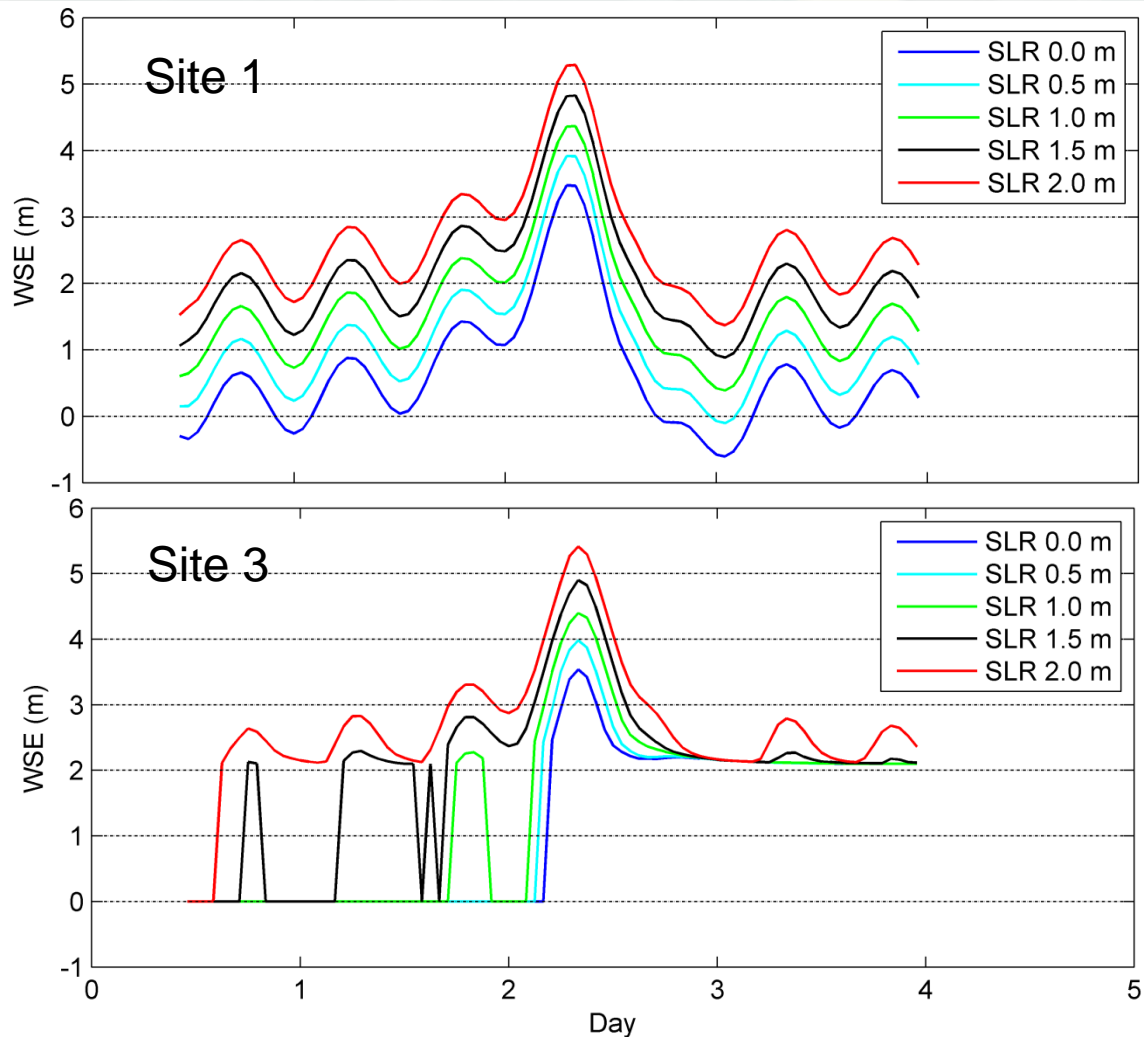




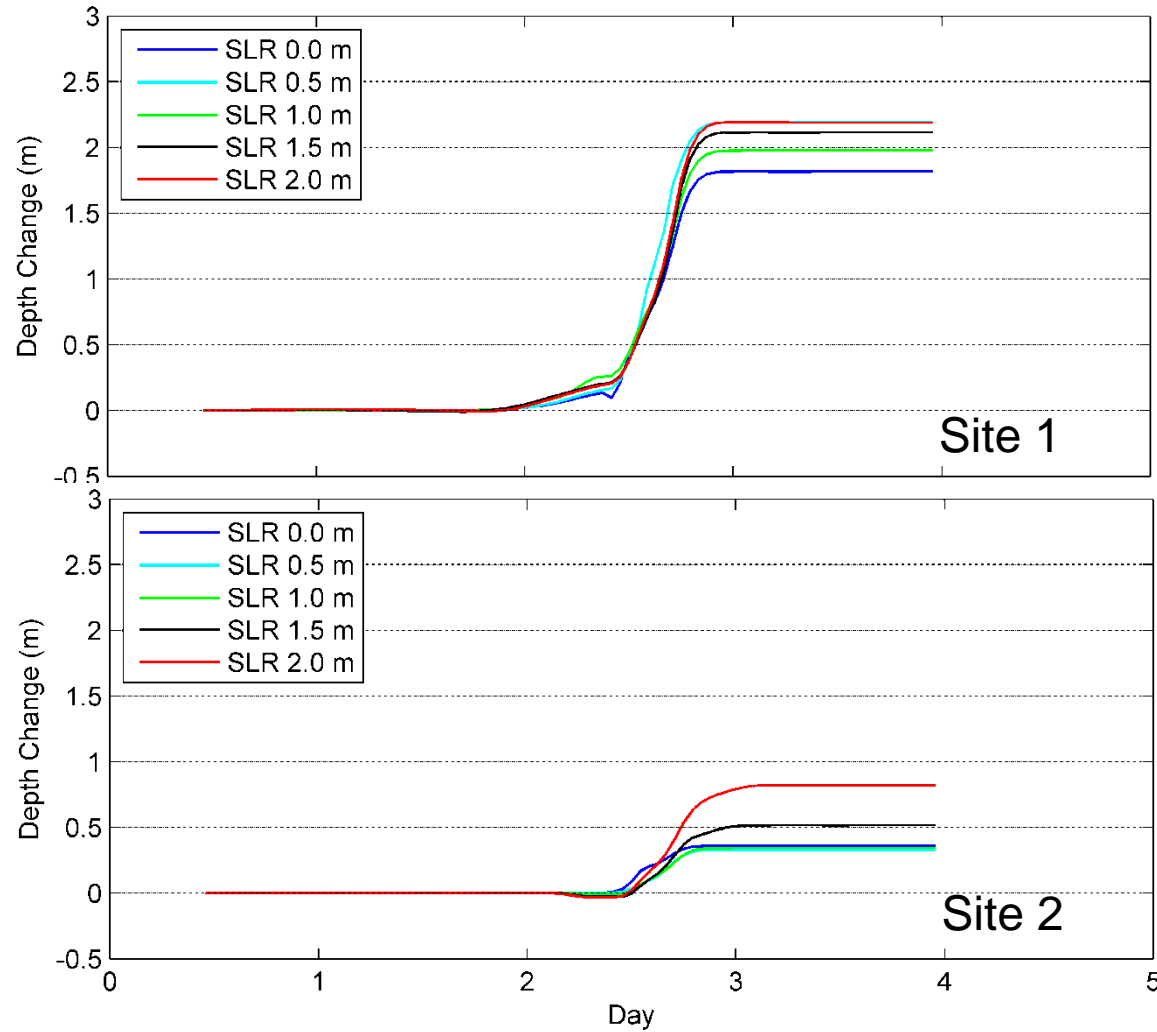
# Time Series at Selected Locations



# Water Surface Elevation



# Depth Change in Channels





# Summary

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- 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!

