DEC 3rd Fact Finding Meeting:
What do we know about storm protection and the role of Piermont Marsh?
Piermont, Wed Jan 7, 2014

How and how effective can vegetation dissipate storm surge, wave, & flooding?
Modeling for Protection-, Risk- and Marsh-Management Decisions

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Coastal Communities are Struggling with Ways to Reduce Coastal Flooding due to Storm Surge and Sea Level Rise

Hurricane Andrew (1992) – A Cat-5 Hurricane

Hurricane Katrina (2005) Cat-3

Super-storm Sandy (2012) Cat-1

Hurricane Sandy
Inundation is caused by storm surge plus......

- Dynamic coupling of tides and waves with surge can be important
- Precipitation and river flow can add considerably to coastal flooding and affect currents and salinity
- Sea Level Rise
- Climate change is causing more intense and frequent (?) hurricanes and accelerated sea level rise
1% Annual Probability Inundation Map in Miami by 2080-2100 (including 100cm Sea Level Rise)

Dynamic Climate+Coastal Models

“Bathtub” model (max surge + SLR)
The Big Picture after Sandy in NYC

- Tremendous interest in the role of coastal wetlands in reducing storm surge and inundation
- But, how well does coastal wetlands reduce storm surge?
What role does Piermont Marsh play in reducing flooding?
What are the relative roles of various species?
Can Ecosystem Service (Healthy Marshes and Mangroves) be used to dissipate storm surge and coastal flooding?

Yes. It depends on many things:

- Vegetation type, height, density, and distribution
- Local bathymetry and topography
- Local climate and weather – wind and pressure deficit
- Local hydrodynamic condition – waves and currents
- Local salinity and temperature and water quality
- Sediment supply
  - Is rate of SLR ~ rate of sediment accretion?
- Available space for vegetation migration
  - Will seawalls and other structures block vegetation migration?
Vegetation Resolving Hydrodynamic Modeling

- Improves modeling of the influence of vegetation on storm surge, without using the empirical Manning’s coefficient
- Quantifies the influence of vegetation on storm surge
- Investigates vegetation’s performance during real storms

Some example publications:


How does vegetation affect surge & wave?

- Vegetation plays a major role in coastal circulation and wave processes.
- Source of drag in the water column from profile drag and skin friction, reducing mean flow and dissipate wave energy and wave height.
- Profile drag and skin friction drag depend on flow speed as well as Frontal Area and Wetted Area of vegetation.
- Source of turbulence from wake production and shear, affecting turbulent kinetic energy.
- Sink of turbulence through dissipation.
Incorporation of vegetation processes into a 3D model

- CH3D-SSMS (Sheng et al. 2010, Sheng and Liu 2011, Sheng et al. 2012), already includes bottom stress, wind effects, wave effects, radiation stresses, and vortex forces
- Permits the inclusion of vegetation effects such as profile drag, skin friction drag, and vertical Reynolds stresses
- Includes wave effects of vegetation through two-way coupling to SWAN (Booij et al. 1999; Suzuki et al. 2012)

- How does this 3D model compare to simpler 2D model to simulate the effects of vegetation? Ref. #2
- How can the influence of vegetation be quantified? Ref. #1
- What is the effect of vegetation during a real hurricane? Ref. #3
Vegetation Model Validation (Ref. #1)

- Neumeier (2007) experiment
- Real *Spartina anglica*
- 32 cm deep water
- 19 cm tall canopy
- 1200 stems/m²

$r^2 = 0.98$, $\text{rms error} = 0.59$ cm/s

$r^2 = 0.95$, $\text{rms error} = 0.015$ cm/s
How well does coastal vegetation reduce storm surge?

Likely varies with:
- Canopy height (cm)
- Canopy width (km)
- Canopy density (stems/m²)

Consider a storm: Cat. 2, 6.71 m/s (15 mph) forward speed

Consider the following canopy conditions:
- Height (50, 75, 100, 125 cm)
- Width (0.5, 1, 1.5 km)
- Density (100, 200, 300 stems/m²)

Run the vegetation-resolving modeling system and compare the resulting TIV (Total Inundation Volume) and Vegetation Dissipation Potential (VDP) for various vegetation conditions in a square basin with the following transect.
Vegetation Dissipation Potential (VDP)

\[ VDP = 1 - \frac{(TIV)_v}{(TIV)_0} = 1 - \frac{\iiint_{\text{Landward area}} H_v \, dx\,dy}{\iiint_{\text{Landward area}} H_0 \, dx\,dy} \]
Do storm characteristics affect dissipation rates? Yes, likely depends upon
- Storm forward speed
- Storm intensity
Effect of Vegetation during Hurricane Ike (2008)

- Ike passed just to the west of Anahuac, McFaddin, and Moody National Wildlife Refuges, as shown by the purple track.
Vegetation reduced flooding during H. Ike

<table>
<thead>
<tr>
<th></th>
<th>Vegetation Free</th>
<th>Vegetation Resolving</th>
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</thead>
<tbody>
<tr>
<td>Domain wide RMSE</td>
<td>60.6</td>
<td>36.0</td>
</tr>
<tr>
<td>Domain Wide Average % Error</td>
<td>11.9%</td>
<td>7.6%</td>
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<tr>
<td>Chambers County RMSE</td>
<td>108.4</td>
<td>61.2</td>
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<tr>
<td>Chambers County Average % Error</td>
<td>17.9%</td>
<td>9.6%</td>
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</tbody>
</table>
Wetlands of Miami-Dade County, Florida
Vegetation reduces flooding in Miami-Dade County (maximum inundation map during Hurricane Andrew)

Vegetation Free

Mangroves – Case 1:
300 stems/m², 150 cm
Increasing density and height further reduces flooding

<table>
<thead>
<tr>
<th>Case Name</th>
<th>Vegetation Type</th>
<th>Vegetation Height (cm)</th>
<th>Vegetation Density (stems/m²)</th>
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<tbody>
<tr>
<td>Case 1</td>
<td>Mangrove</td>
<td>150</td>
<td>300</td>
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<td>Case 2</td>
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<tr>
<td>Case 4</td>
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What Happened to Piermont during Sandy (2012)
Assuming 25 m/sec wind from the East…
How can we use the vegetation resolving modeling to predict the effectiveness of Piermont Marsh in protecting people from future flooding risk?

• Conduct a forensic study of H. Sandy to assess the role of Piermont Marsh;
• Conduct modeling in conjunction with the USGS SWATH field program in Piermont Marsh;
• Calculate the flooding risk under current climate and future climate, using ensembles of storms