High Resolution Numerical Models of Tidal Marshes in the Delaware Bay

Ramona Stammermann
Dept. of Civil, Architectural & Environmental Engineering, Drexel University, Philadelphia, PA

Michael Piasecki
Dept. of Civil Engineering, City College New York, New York City, NY
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- Summary
Importance of Delaware Bay Wetlands

- Wetlands influence health and function of adjacent water bodies and provide habitat for flora and fauna
  - „Kidneys“ of the Delaware Bay → filters harmful materials
  - Home of a variety of animals including mussels, crabs, fish, birds
  - One of the biggest and most important resting places for migratory birds on the US East Coast
  - Provide a coastal defense line against stormsurges
  - Provide recreational space for everybody
Delaware Bay Wetlands

- Some wetlands are deteriorating
  - Erosion
  - Sudden wetland dieback

- Reasons mostly not entirely understood
  - Starvation >> not enough sediment input from the bay?
  - Change in composition of ecosystem
    - Different types of vegetation
    - Decrease of bottom stabilizing mussel colonies

>> Numerical models to learn more about processes in marsh systems
Research Objectives

Num. Modeling of transport processes in tidal marshes

• influence of marsh geometry on hydrodynamics and transport processes
• influence of sediment availability in Delaware Estuary on sediment distribution patterns on tidal flats and in tidal channels of adjacent marsh systems
• influence of storm events on erosion and deposition patterns
Model system Marina

**Pre processor software**
Janet: grid generation; Gismo: GIS for Modeling (DTM etc.)

**Marina2D**

- **SaltTransportModel2D**
  - Salinity

- **HeatTransportModel2D**
  - Temperature

**CurrentModel2D**
- Hydrodynamics

**WaveHypModel**
- Waves

**SedimentTransportModel2D**
- Morphodynamics

**Post processor software**
Davit: visualization, analysis

*By Smile Consult GmbH, Hannover, Germany*
Model Area – Delaware Estuary
Create Boundary Conditions for Marsh Model

Location of Blackbird Creek Marsh

15726 nodes
28831 elements
min L = ~ 50 m
max L = ~5500 m
Challenges for high resolution marsh modeling

• Marshes are large and very inaccessible
  ➢ makes field measurements difficult, costly and time consuming
  ➢ not much data for initial and boundary conditions available
  ➢ need to develop methods to compensate for lack of data

• Methods
  ➢ no high resolution bathymetry
    >> cross sectional measurements to determine general shape and depths of tidal channels
    >> use model to iterativeley swing in and smooth bathymetry
  ➢ LiDAR data with high vertical error above dense vegetation
    >> RTK points as reference data to determine an adjustment factor for topography
  ➢ No high resolution sediment inventory
    >> use model itself to iteratively determine grain size distribution
Extraction of tidal channels

DTM Flooded contours: $-0.5m < z < 0.5m$

export outline as polygons

extract significant channels

- channels that can be resolved with
  $\geq 3$ elements with $\geq 3m$ side length
Grid Generation

Triangulation

Polygons

Basic Triangulation

After Advancing Front Refinement

Detail
Bombay Hook – Model grid

695,390 elements
max L = 1000 m
min L = 3.0 m

Bathymetry

Model Grid
Reference Stations
Water Levels

Water level at Leatherberry Flats

Water level at Dock Site
Mud flats 2005
Mud flats 2010
Hydrodynamics
change of channel geometry – with channel
Hydrodynamics

change of channel geometry – no channel
Tracer experiment
Start in marsh
Tracer experiment
Start in bay
Tracer Experiment Block overview
Tracer Experiment Block
original geometry
Tracer Experiment Block
Block 1
Tracer Experiment Block

Block 2
Tracer Experiment Block
Block 1 & 2
Blackbird Creek Model Grid

Bathymetry

Model Grid

260,547 Elements
Max L = 285 m
Min L = 3.5 m
Initial sediment distribution
Blackbird Creek

• Procedure
  ➢ Simulate hydrodynamics only
  ➢ Extract shear stress
  ➢ Determine $D_{50}$ with inverse Shields equation

• Results
  ➢ Coarser sediment in channels
  ➢ Extreme coarse in areas where assumptions of initial bathymetry are wrong
  ➢ Further adjustment of initial bathymetry
Sediment composition

\[ \alpha = \frac{d_{90} - d_{10}}{d_{50}} \]

- Low variability of grain sizes in shallow areas
  >> mainly fine sediments (silt/clay/fine sand)
  >> \( a = 0.4 \) in depths < 2m

- Higher variability in deeper areas
  >> mix of sediments (silt – coarse sand)
  >> \( a = 0.4 - 2 \) in depths > 2m

Delaware Estuary Science & Environmental Summit 2013,
Cape May, NJ
Sediment Transport
Erosion and Deposition after 3 days

With vegetation

Without vegetation

after improving initial conditions
Summary

• Tracer experiments useful to determine general transport paths
• High grid resolution in combination with many processes (hydrodynamic, sediment transport, heat transport, salt transport) results in low model efficiency
  ➢ important to find balance between spatial accuracy and efficiency
• Importance of accurate topographic data
  – Height of tidal flats determines when flooding starts
• Erosion/deposition patterns show
  – importance of good initial bathymetry data
    ➢ here: bathymetry based on interpolation between cross sectional measurements
      ➢ in first days of model run bathymetry reacts strongly to hydrodynamic conditions and adjusts
  – Importance of vegetation
    ➢ without vegetation high velocities - resulting in larger unrealistic erosion/deposition patterns on tidal flats
Acknowledgements

National Estuarine Research Reserve Graduate Research Fellowship

Graduate Research Assistantship

This research was supported, in part, under National Science Foundation Grants CNS-0958379 and CNS-0855217 and the City University of New York High Performance Computing Center.
Questions?
Suspended Sediment

- **$D_{50} = 0.05 \text{ mm}$**
  - Concentration: 0.7 g/l

- **$D_{50} = 0.1 \text{ mm}$**
  - Concentration: 0.2 g/l

- Suspended sediment concentration dependent on sediment composition on the ground
  - The finer the $d_{50}$, the higher the concentration
  - Need to adjust initial $d_{50}$ to reach desired sediment concentration in water column for sensitivity studies

**Problem:**
- The finer the $d_{50}$, the more erosion >> unrealistic
  - Limiting the erodible layer cuts off supply at some point
    - >> No long term results yet that show significant deposition on tidal flats

- Settling velocity calculated based on $d_{50}$ >> consistently too high
  - >> Material settles completely during slack tide
Elevation Adjustment

Vegetation error

before

after

difference