High Resolution Numerical Models of Tidal Marshes in the Delaware Bay

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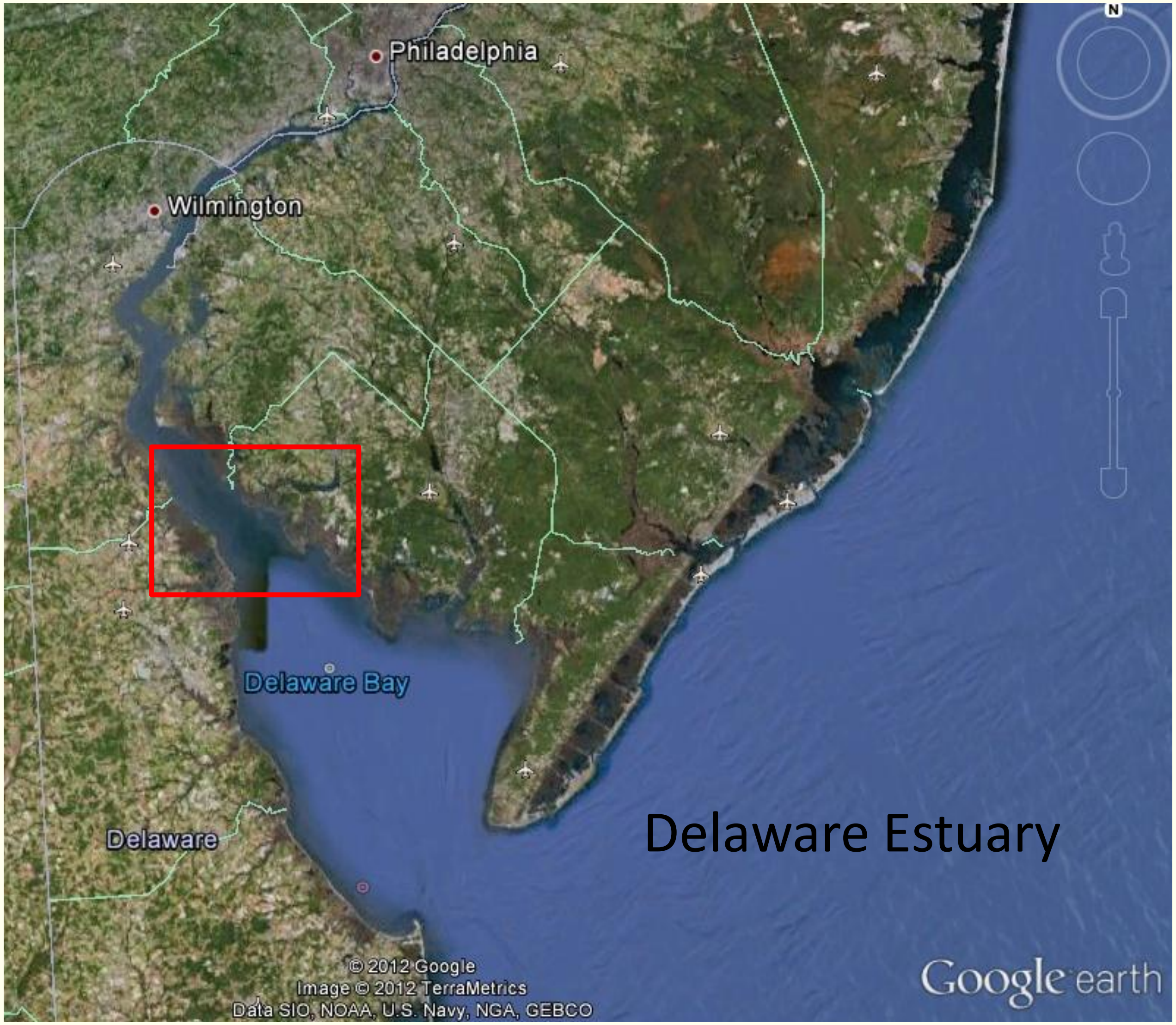
Philadelphia
Wilmington
Delaware Bay
Delaware
Delaware Estuary
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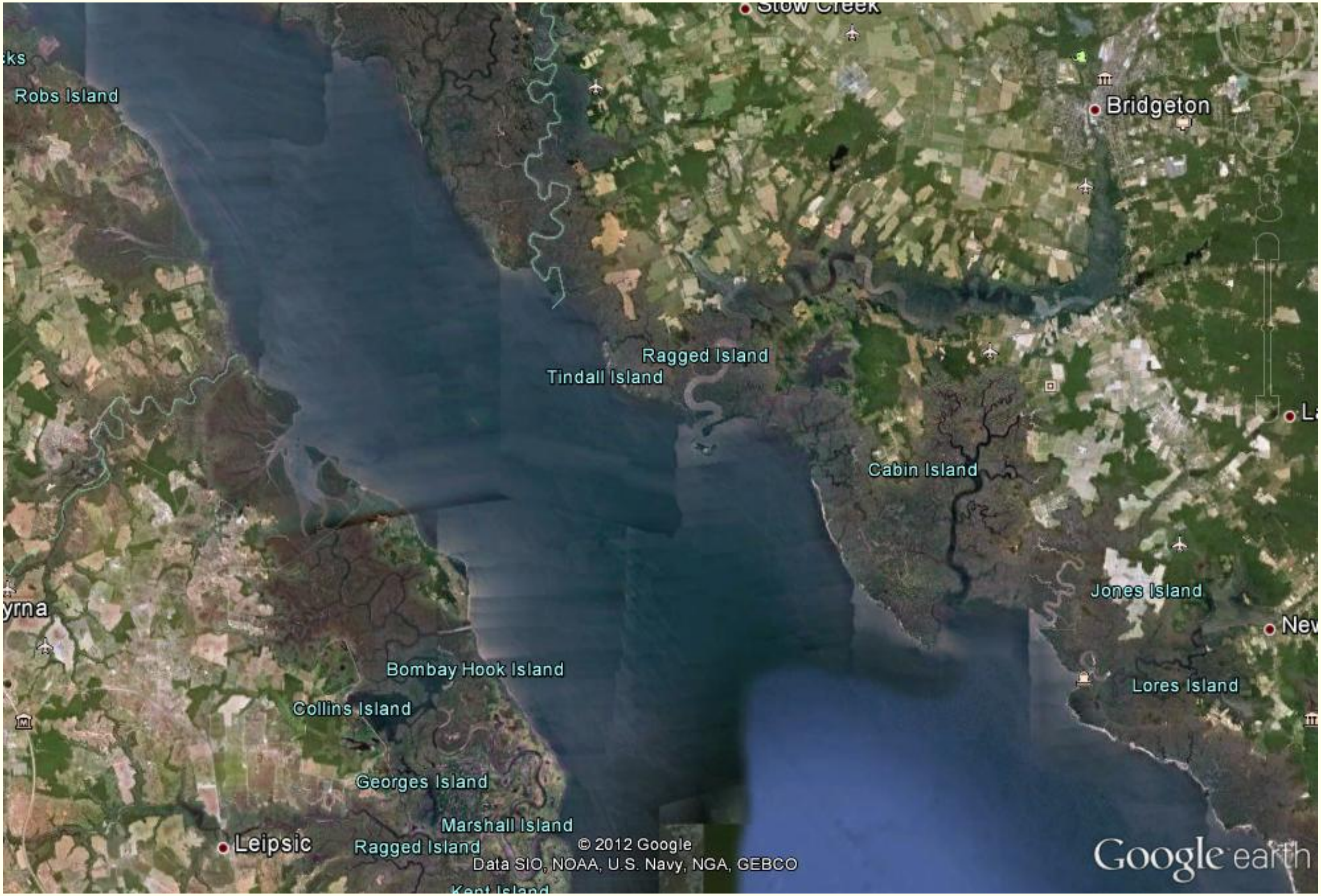
Stow Creek
Robs Island
Bridgeton
Ragged Island
Tindall Island
Cabin Island
Jones Island
Lores Island
Bombay Hook Island
Collins Island
Georges Island
Marshall Island
Ragged Island
Leipsic
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Importance of Delaware Bay Wetlands

- 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
    - Diffferent 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

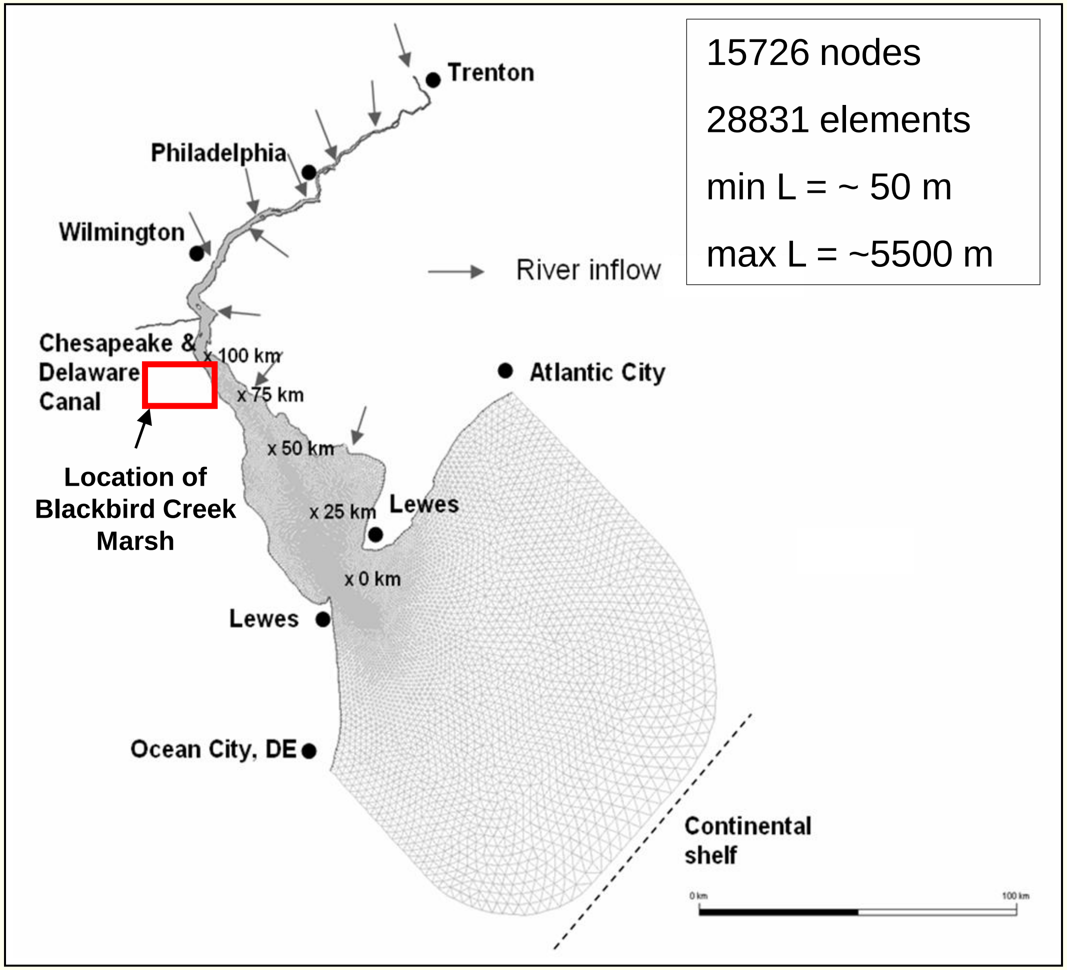
* By Smile Consult GmbH, Hannover, Germany

Post processor software

Davit: visualization, analysis

Model Area – Delaware Estuary

Create Boundary Conditions for Marsh Model



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

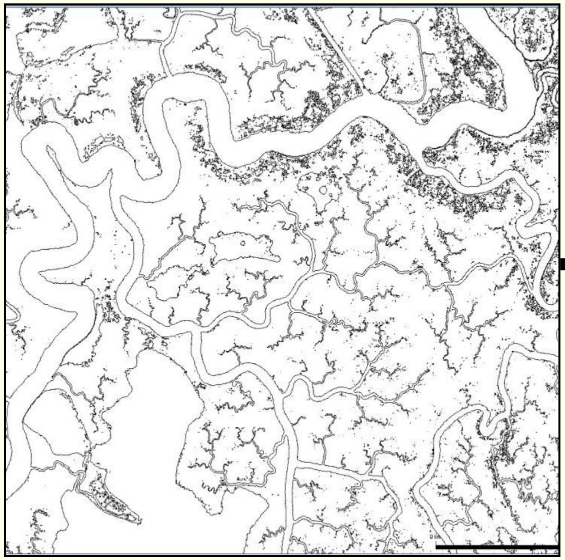
↓

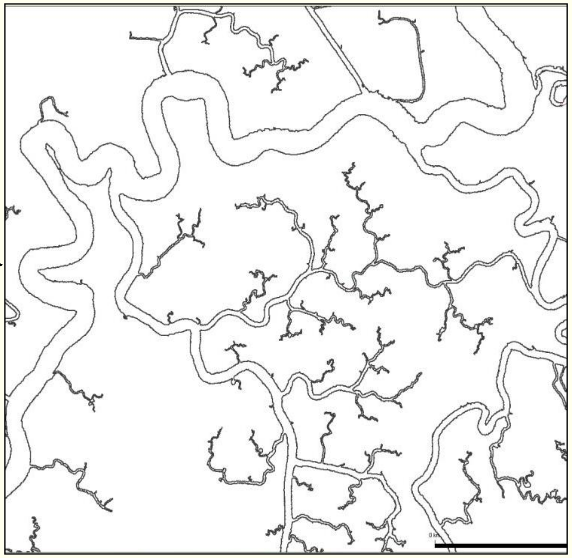
export outline as polygons

↓

extract significant channels

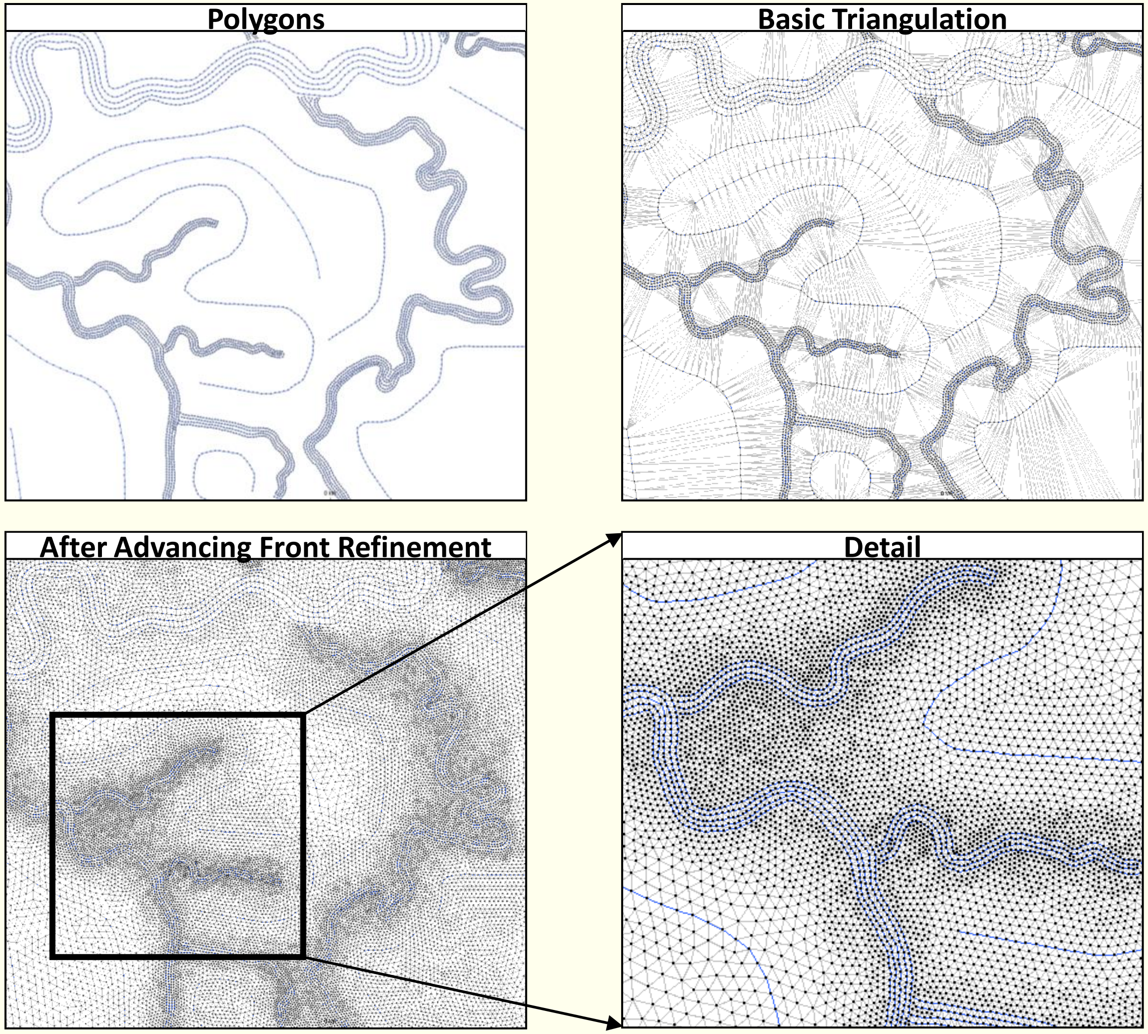
- **channels that can be resolved with ≥ 3 elements with ≥ 3m side length**



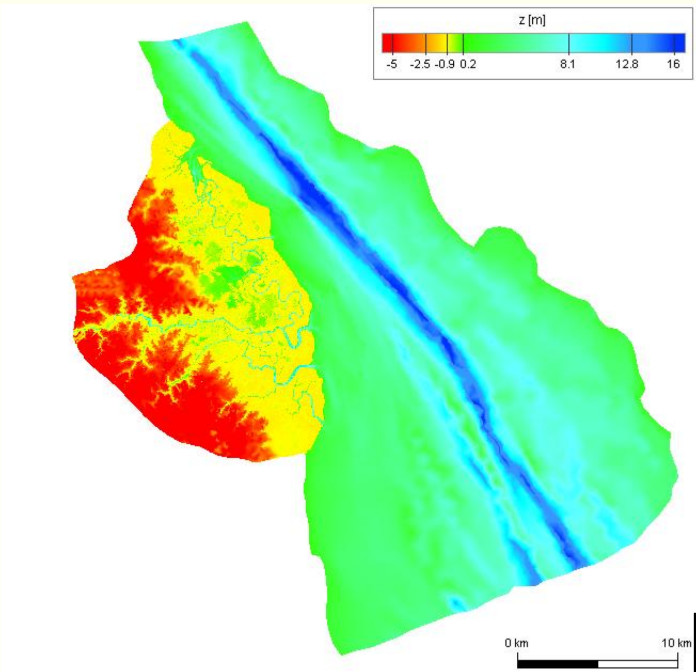


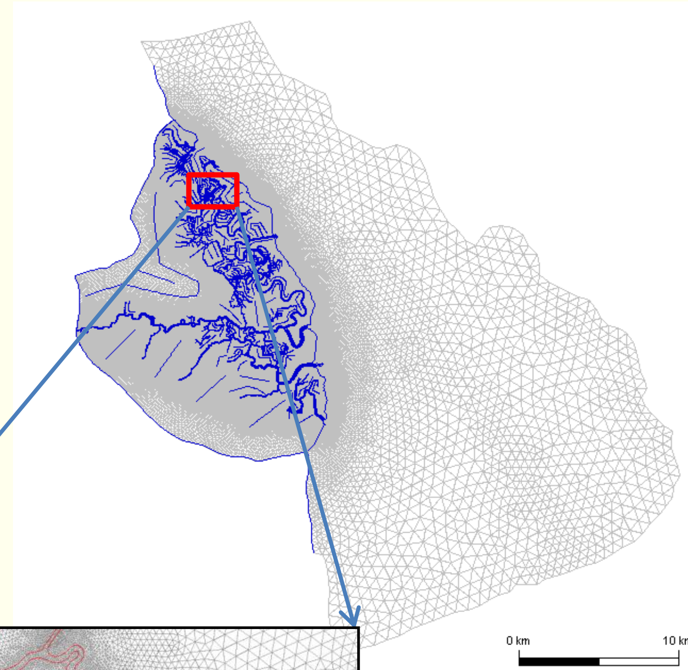
Grid Generation

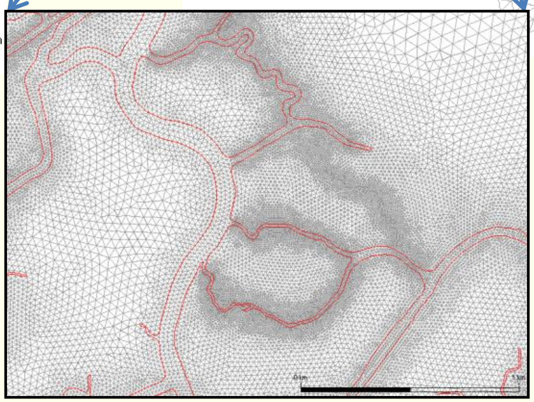
Triangulation



Bombay Hook – Model grid







695,390 elements

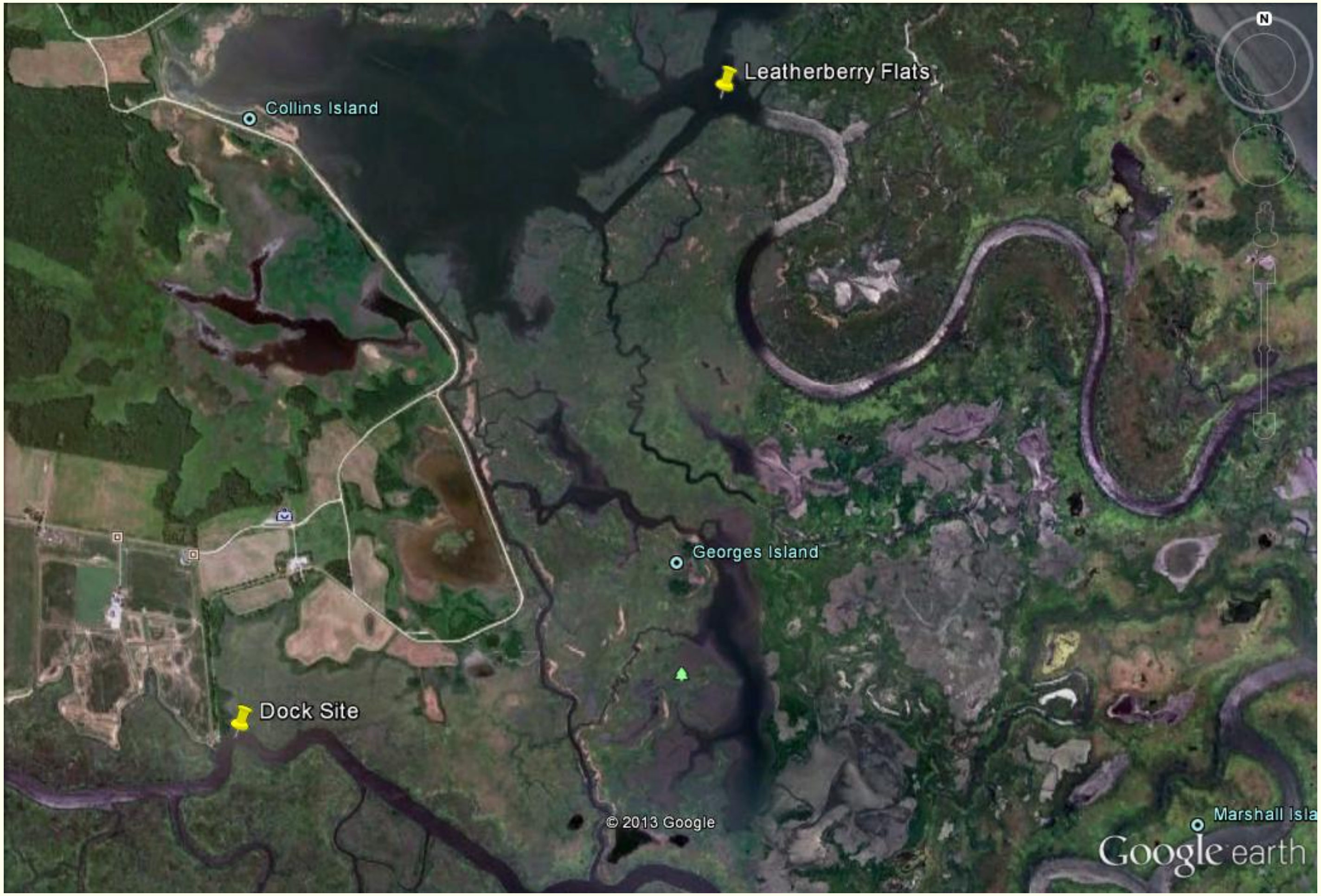
max L = 1000 m

min L = 3.0 m

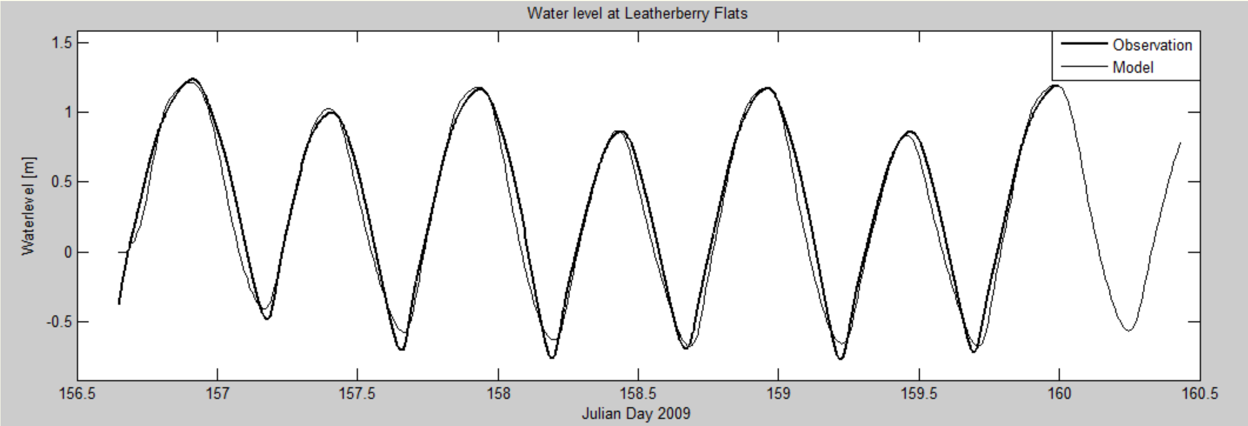
Bathymetry

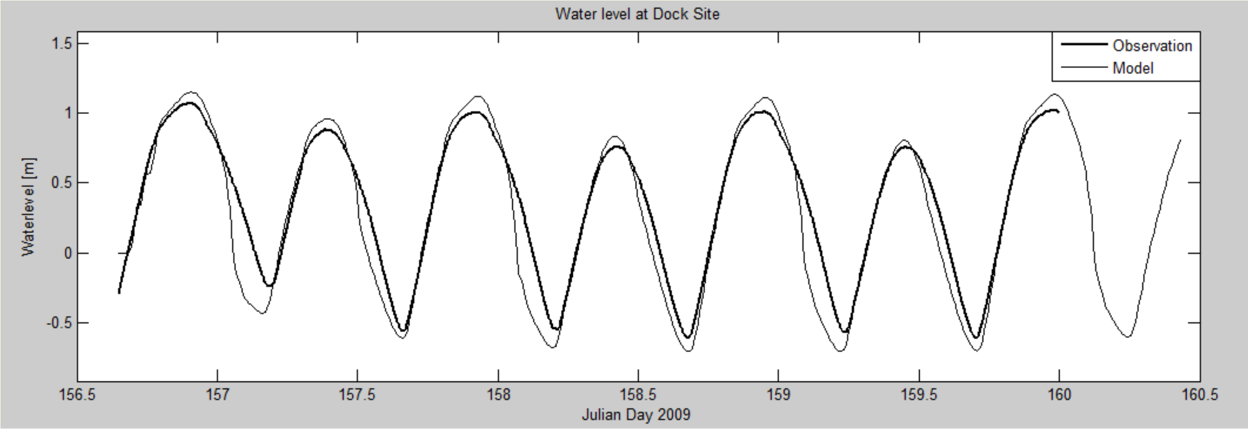
Model Grid

Reference Stations

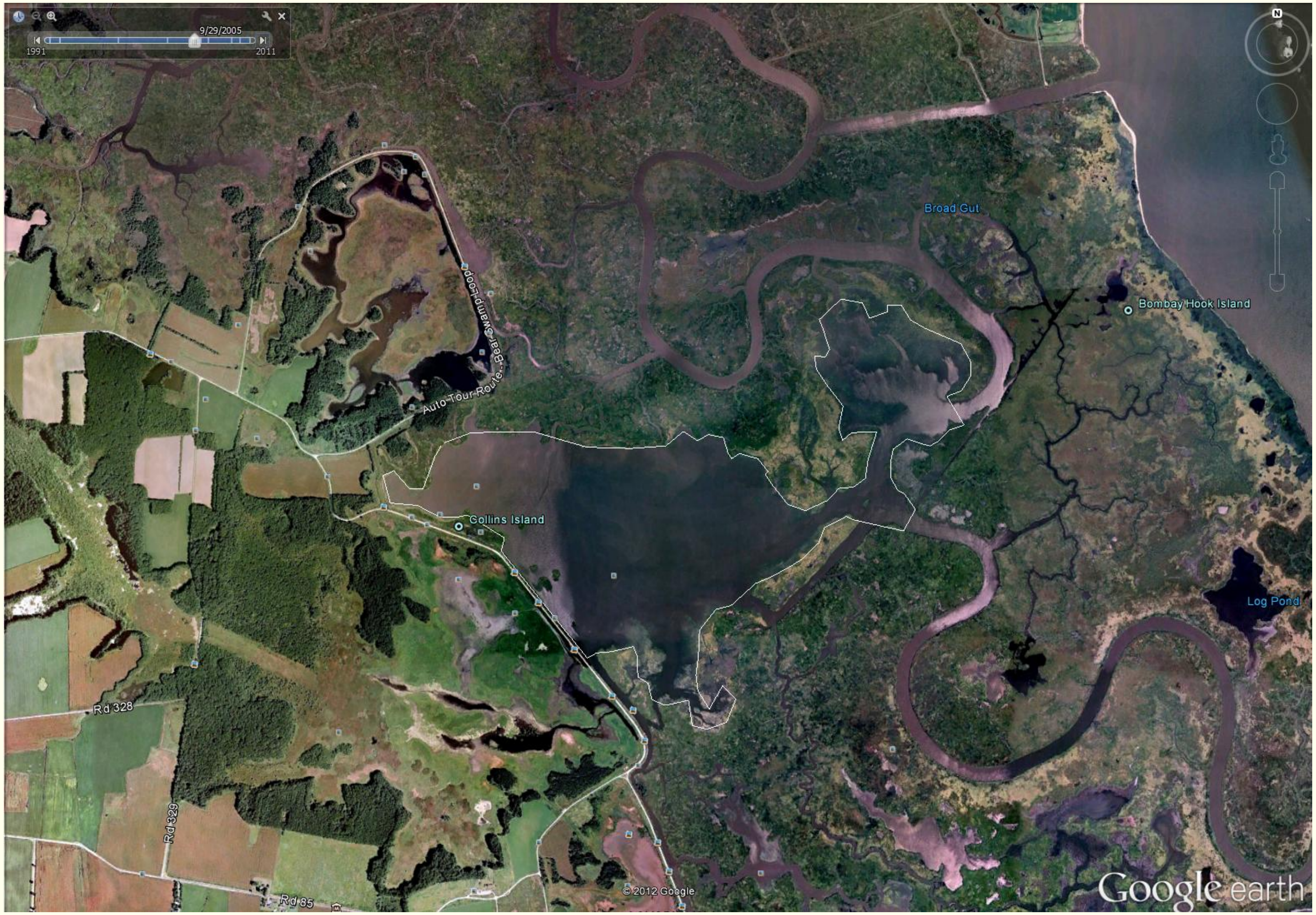


Water Levels



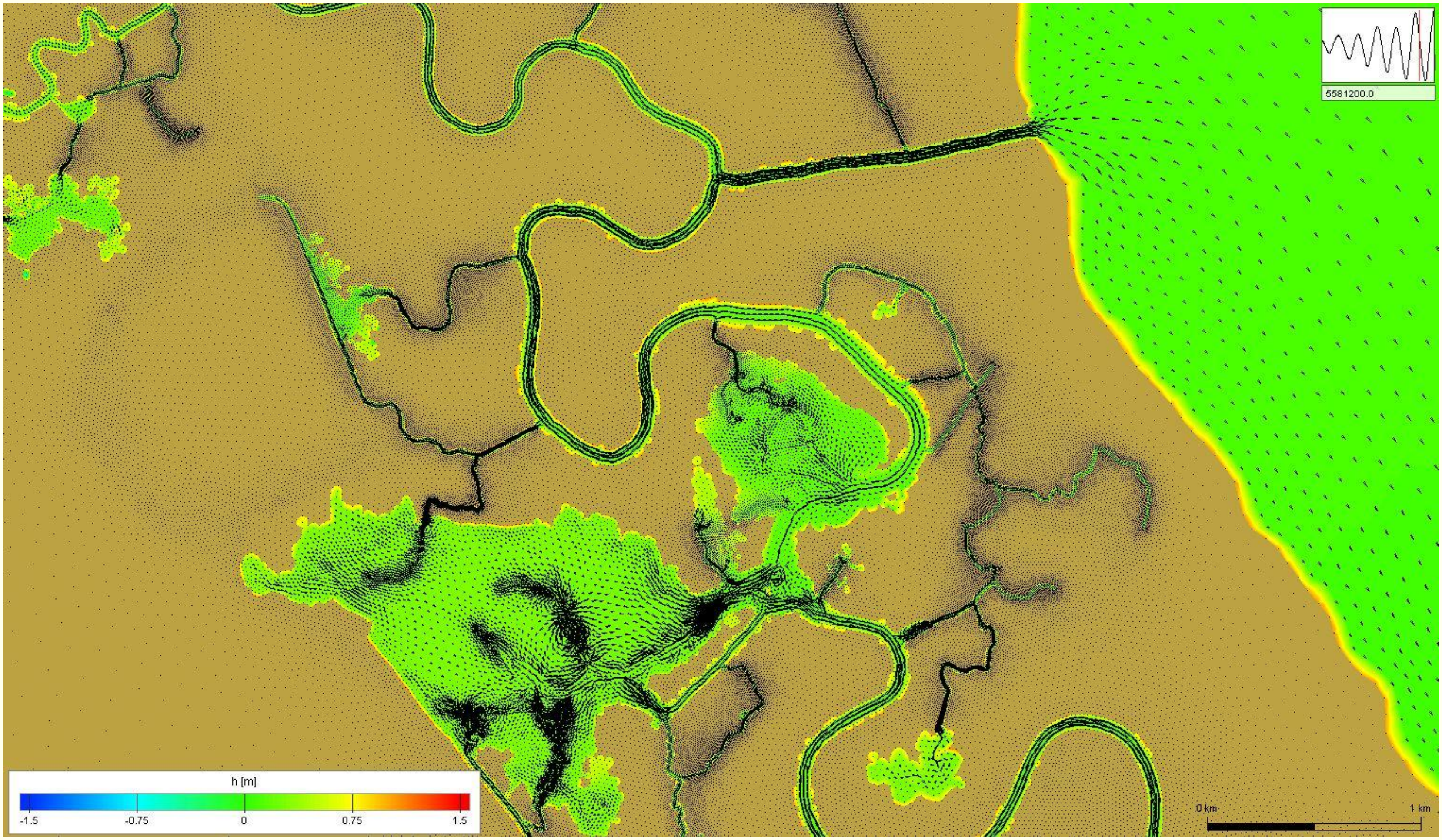


Mud flats 2005



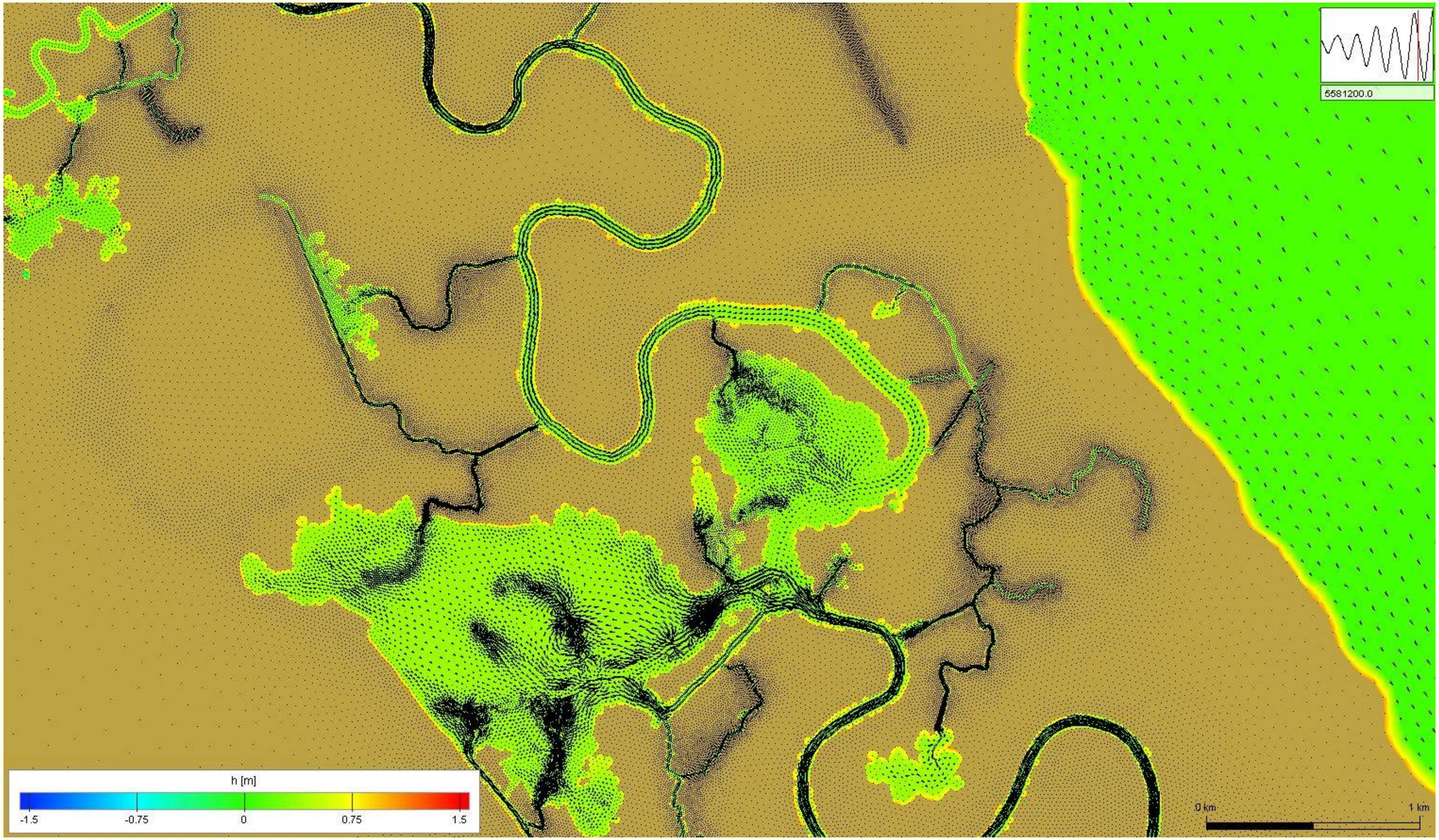
Mud flats 2010

Hydrodynamics
change of channel geometry – with channel



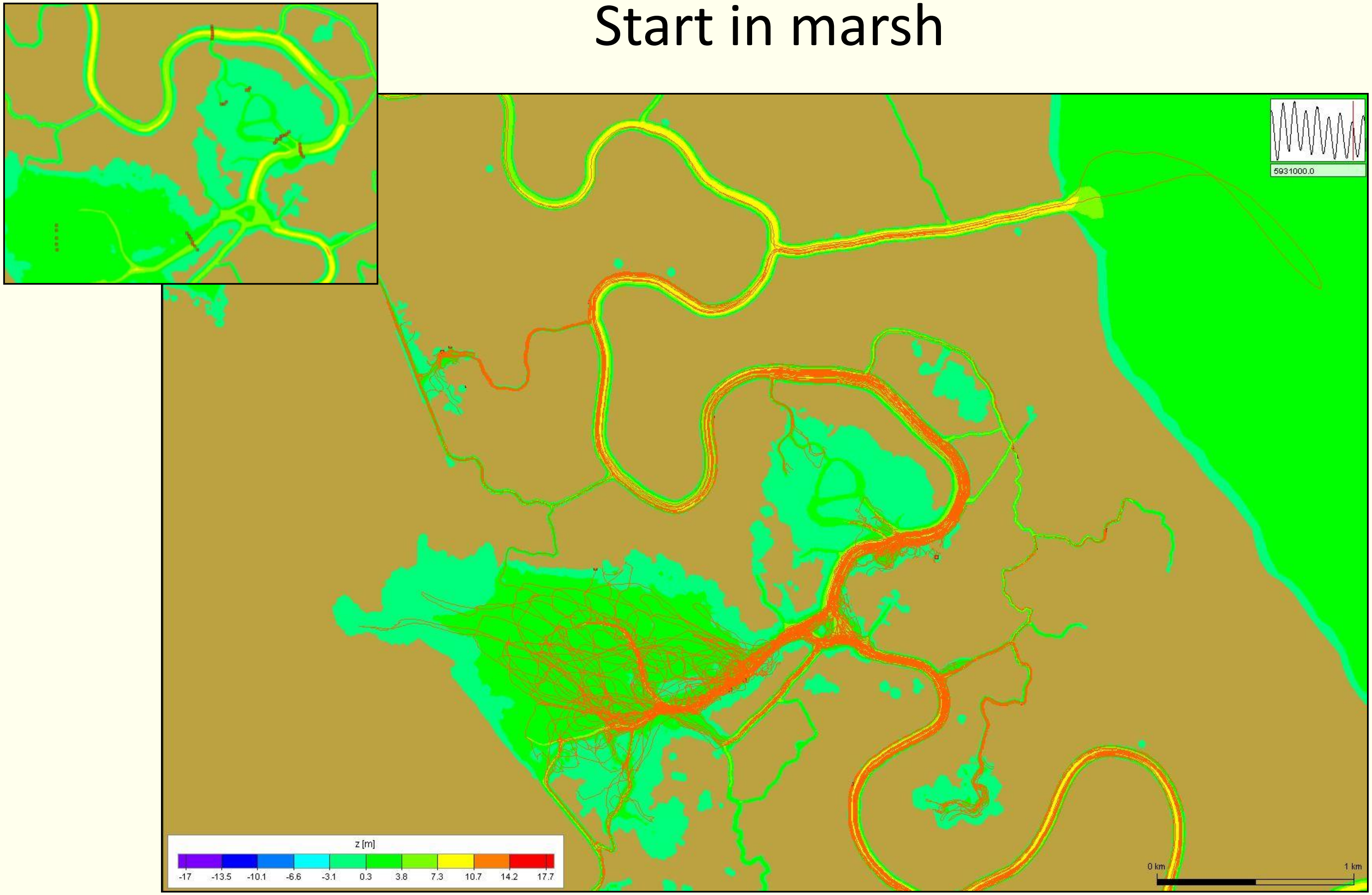
Hydrodynamics

change of channel geometry – no channel



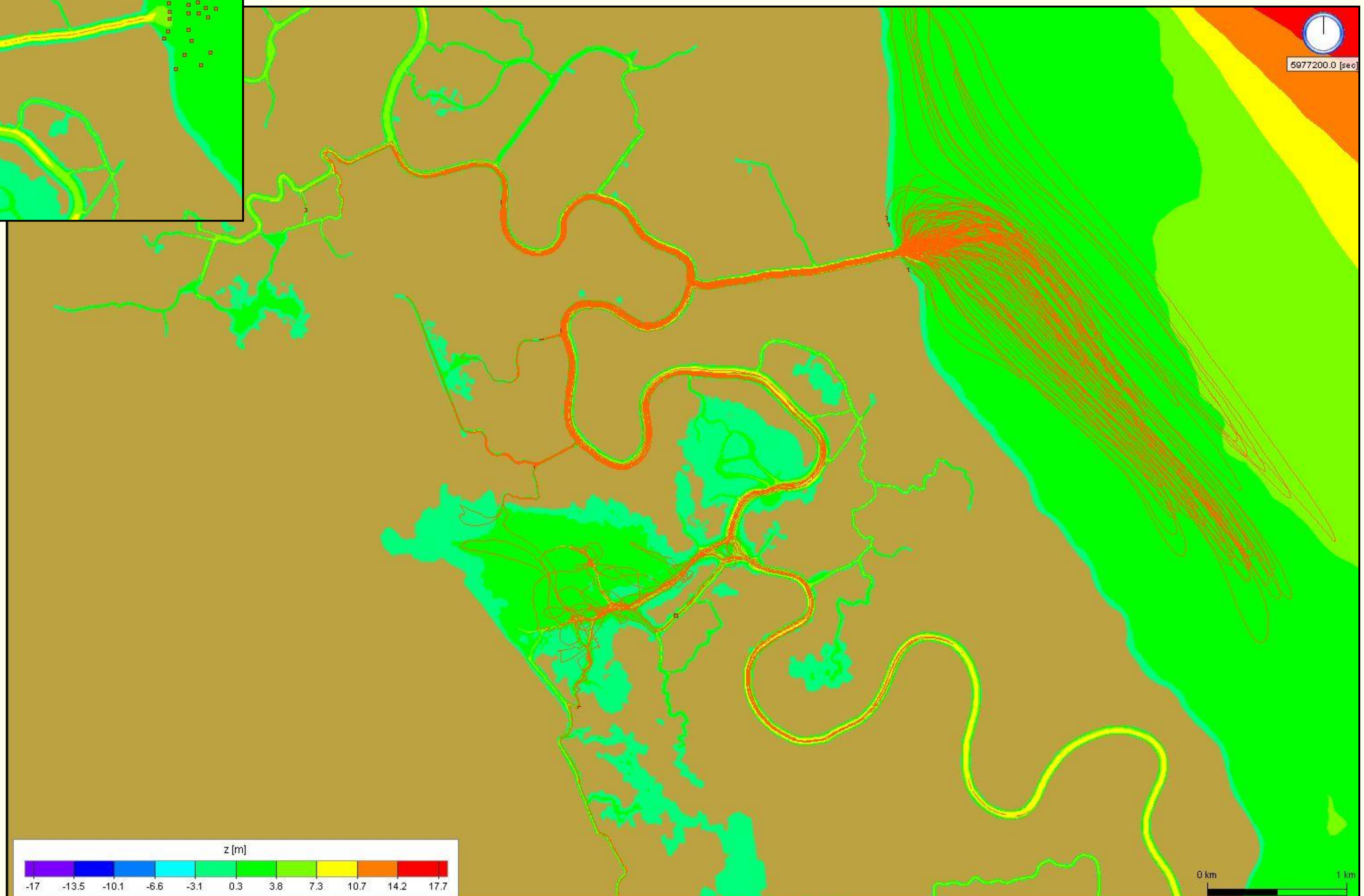
Tracer experiment

Start in marsh



Tracer experiment

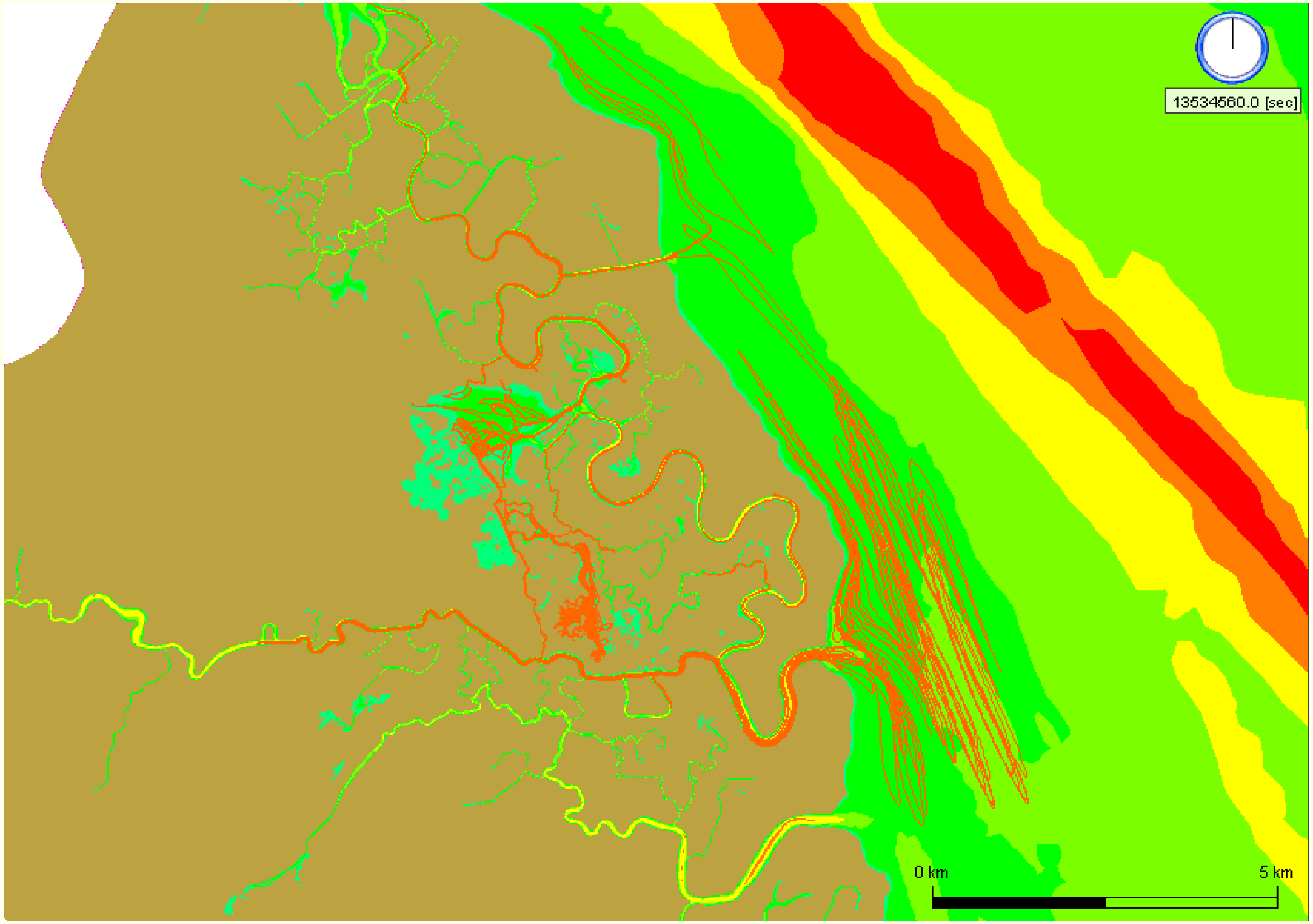
Start in bay



Tracer Experiment Block
overview

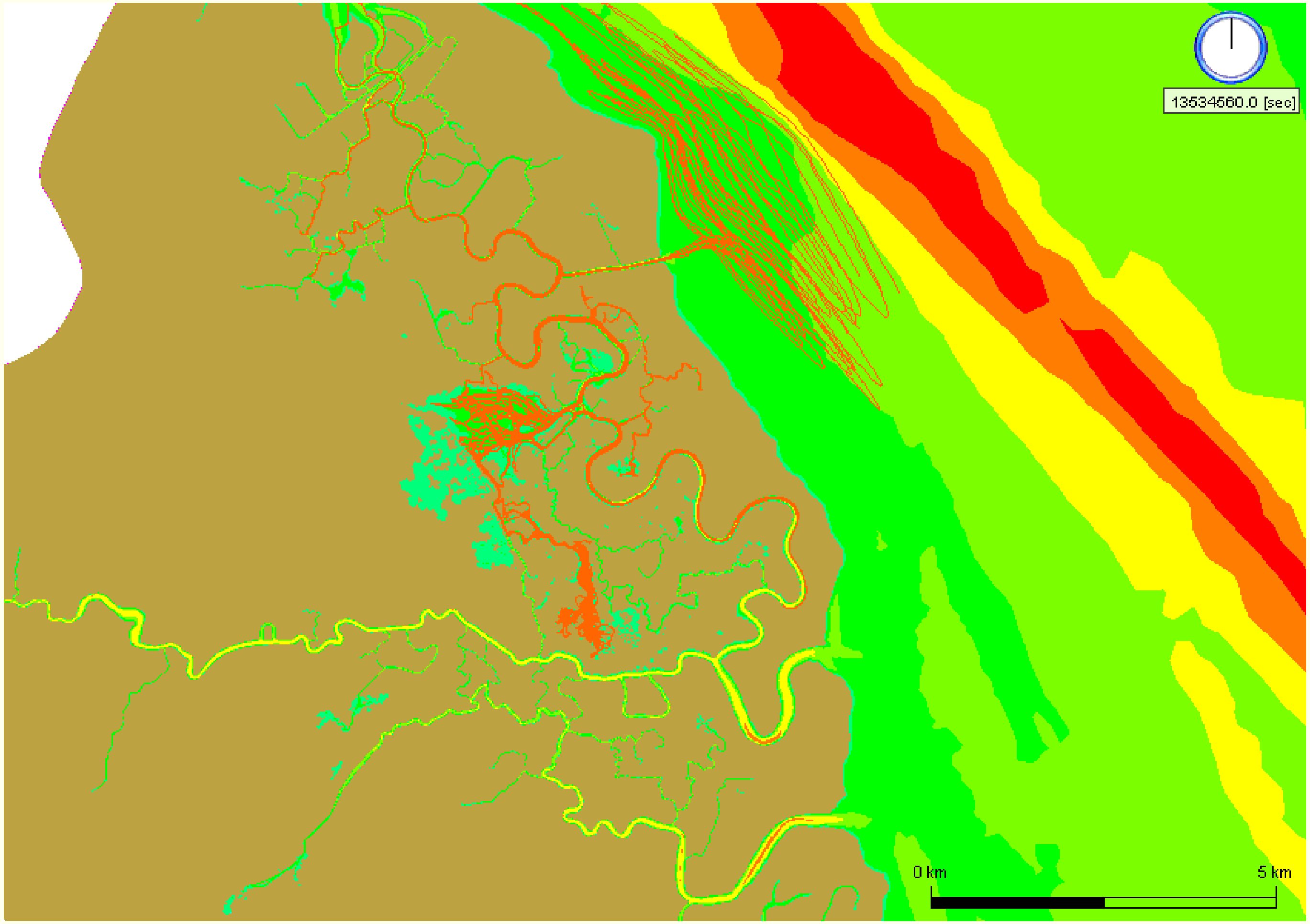
Tracer Experiment Block

original geometry



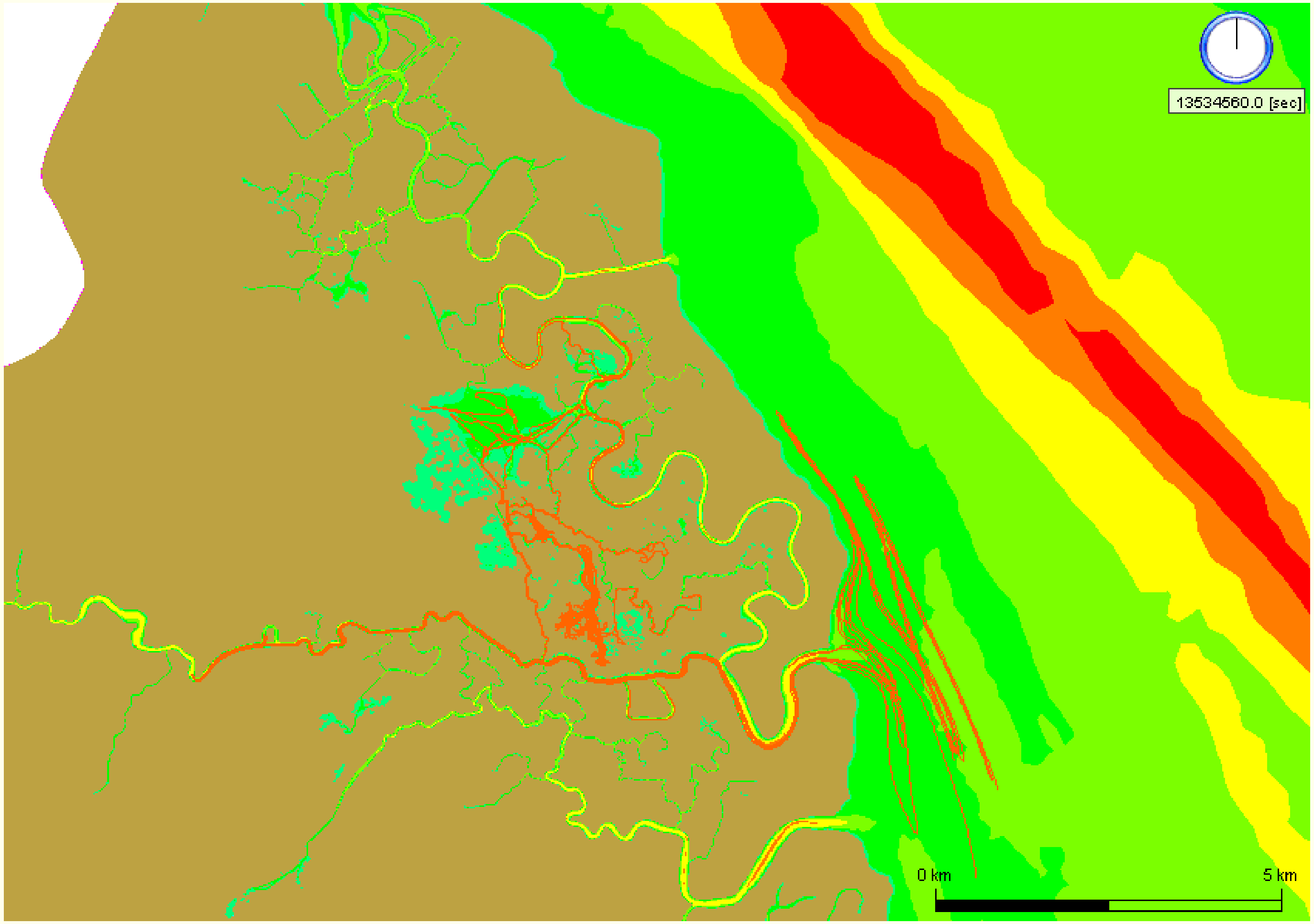
Tracer Experiment Block

Block 1



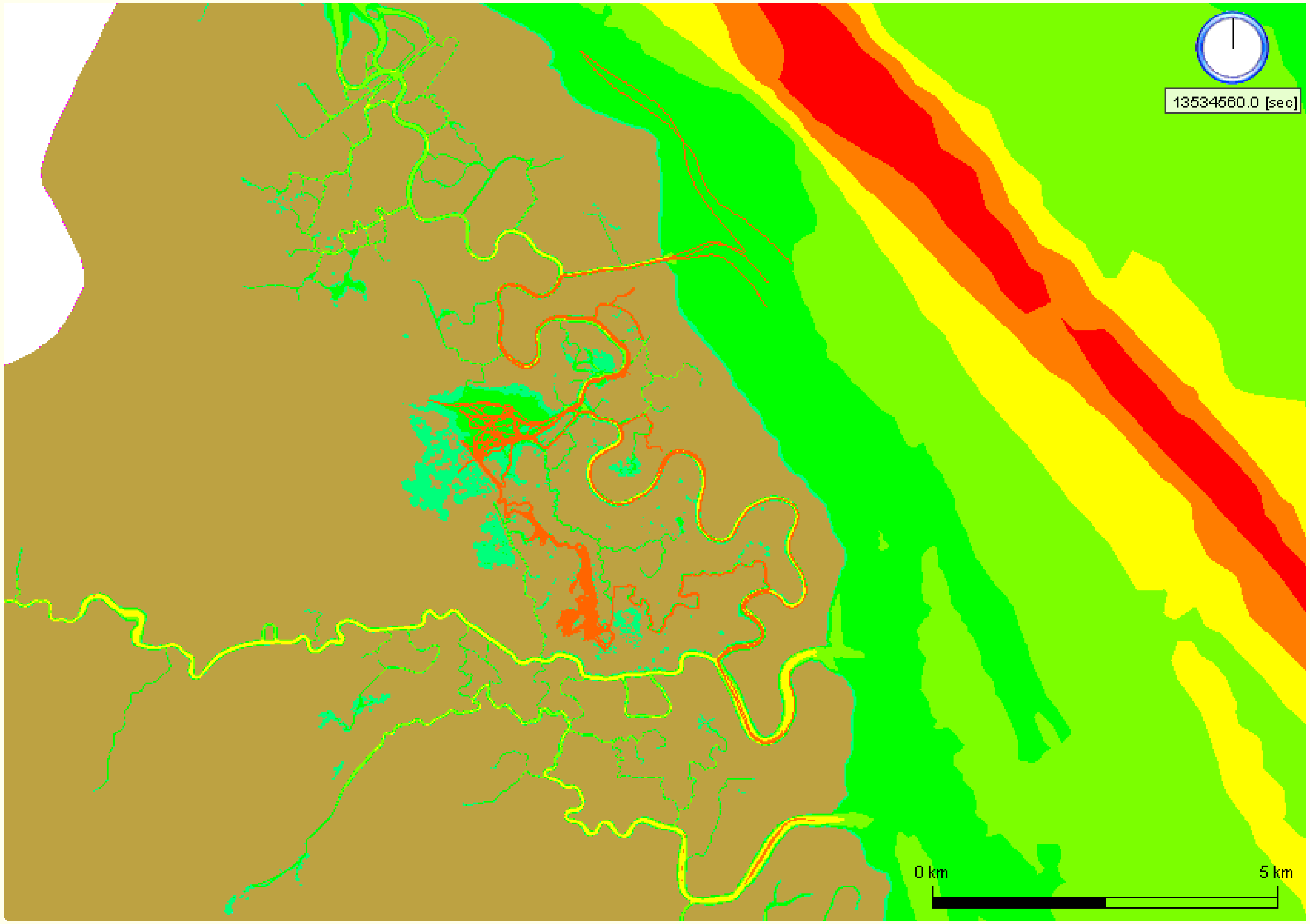
Tracer Experiment Block

Block 2

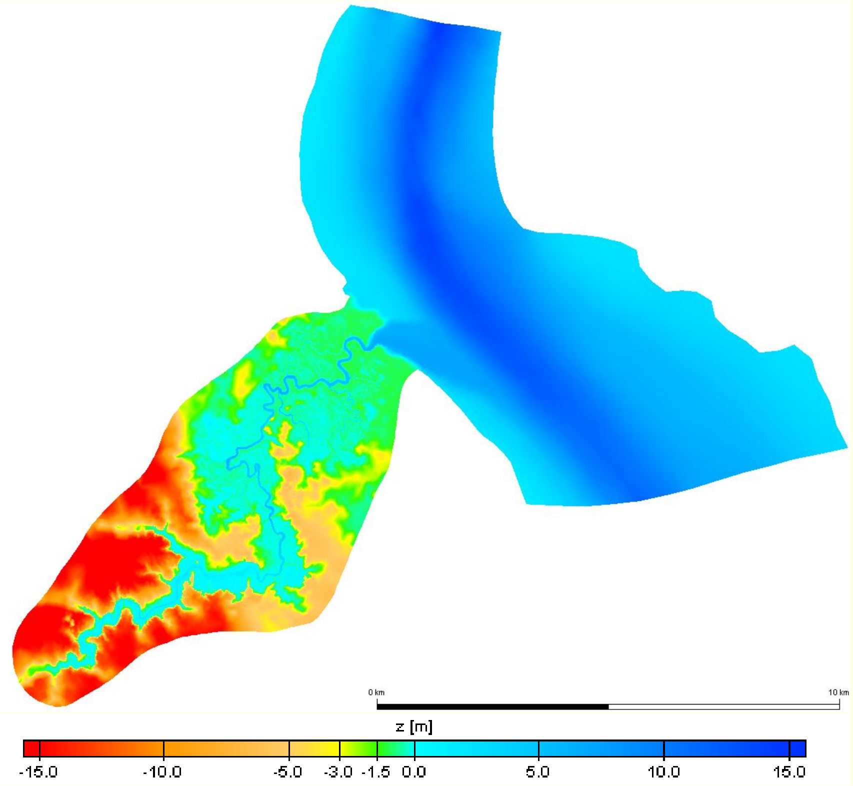


Tracer Experiment Block

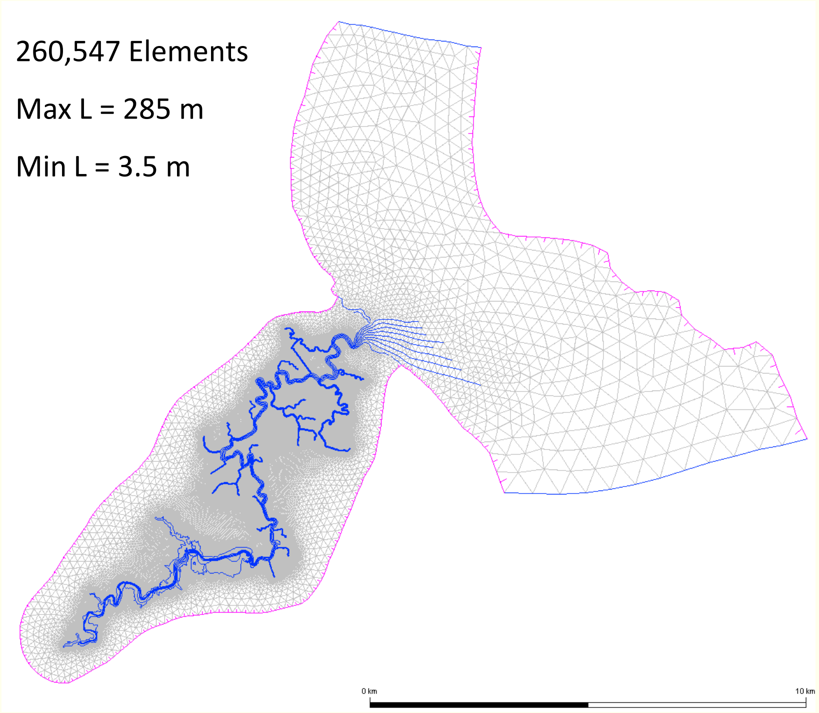
Block 1 & 2



Blackbird Creek Model Grid



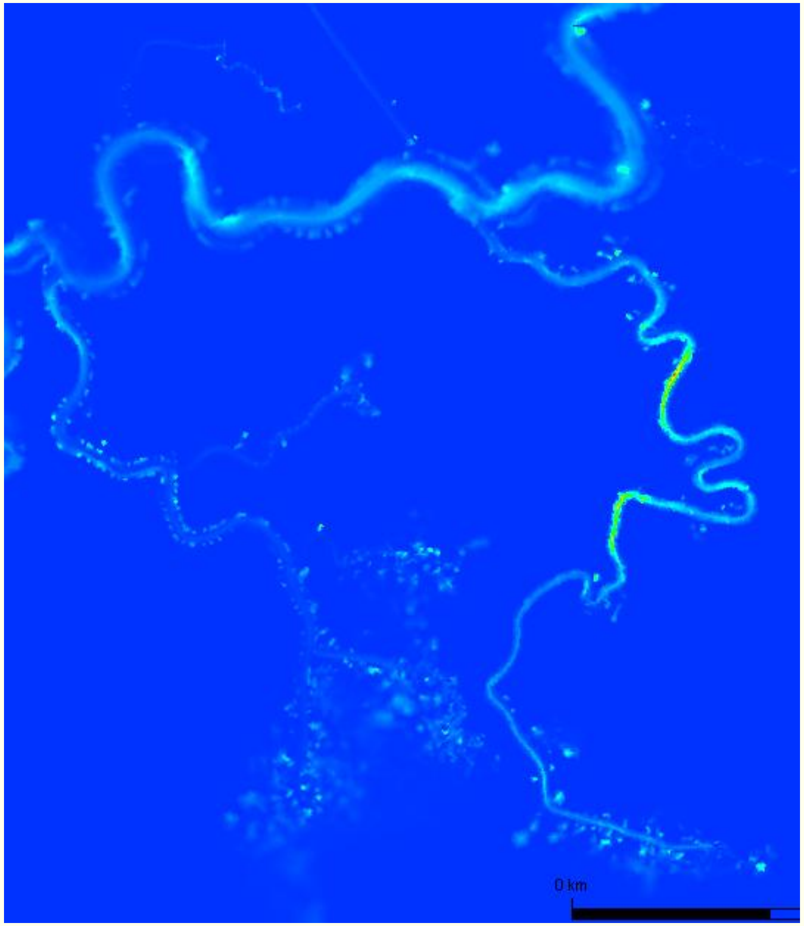
Bathymetry



Model Grid

Initial sediment distribution
Blackbird Creek

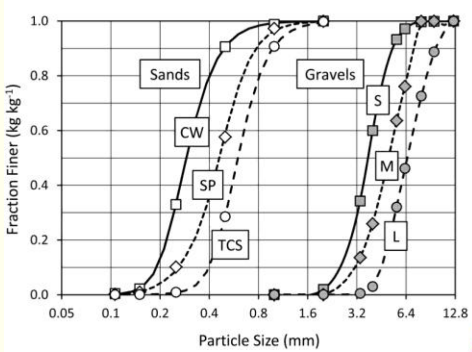
- Procedure
  - Simulate hydrodynamics only
  - Extract shear stress
  - Determine D_{50} with inverse Shields equation
- Results
  - Coarser sediment in channels
  - Extreme coarse in areas where assumptions of initial bathymetry are wrong
  - Further adjustment of initial bathymetry

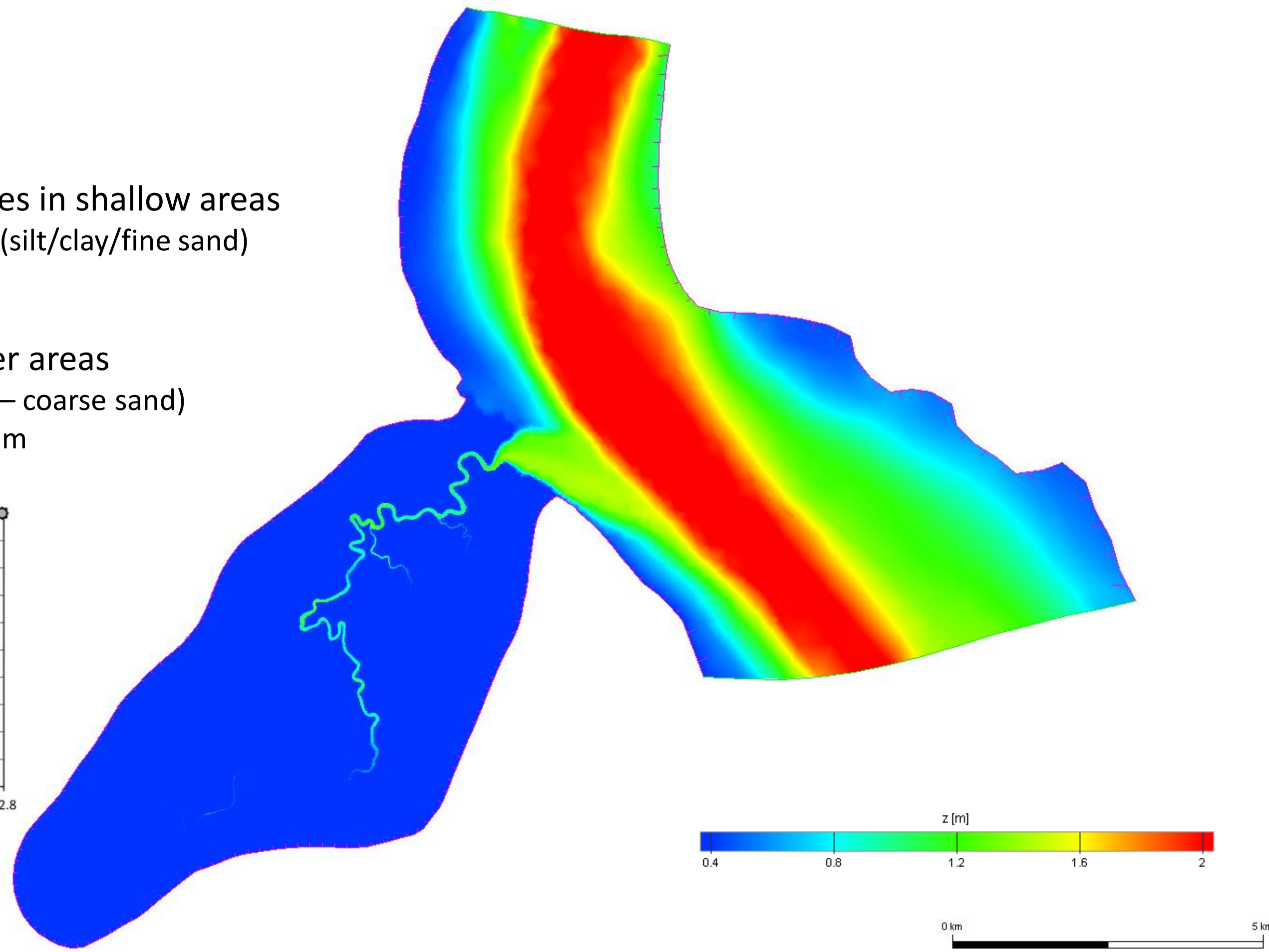


Sediment composition

$$\alpha = \frac{d_{90} - d_{10}}{d_{50}}$$

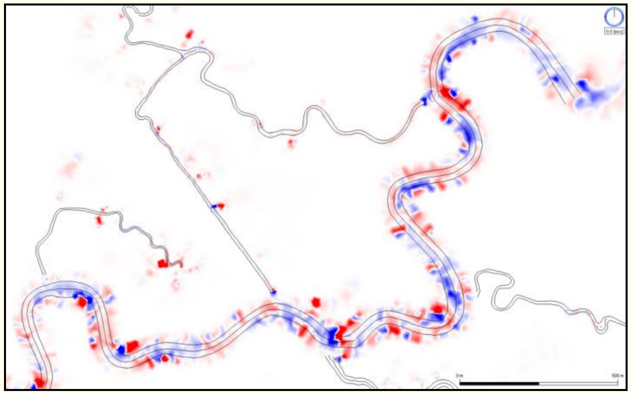
- Low variability of grain sizes in shallow areas
  - >> mainly fine sediments (silt/clay/fine sand)
  - >> a = 0.4 in depths < 2m
- Higher variability in deeper areas
  - >> mix of sediments (silt – coarse sand)
  - >> a = 0.4 -2 in depths > 2m



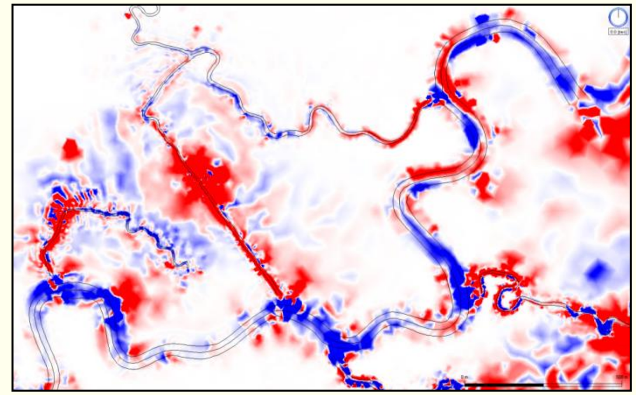


Sediment Transport

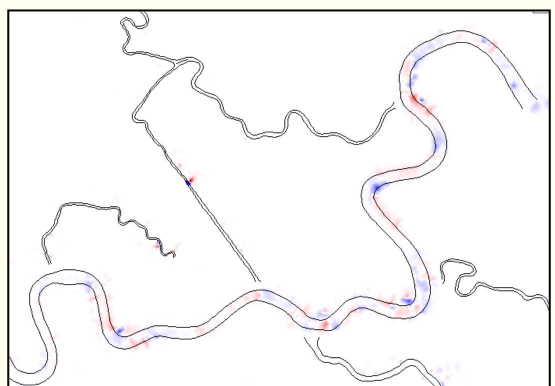
Erosion and Deposition after 3 days



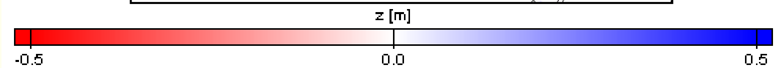
With vegetation



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

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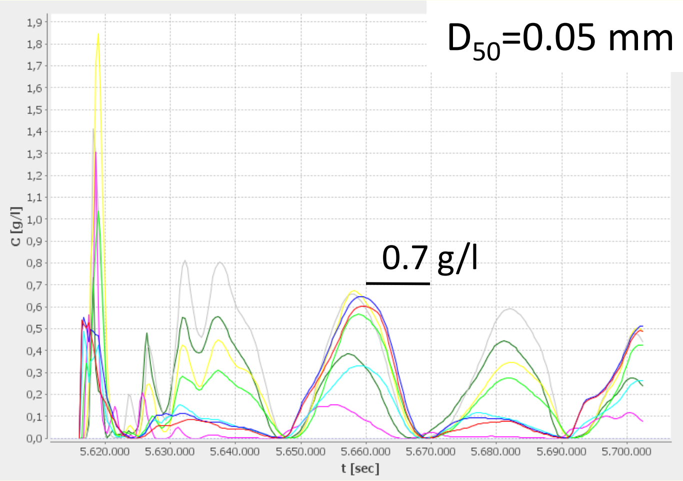
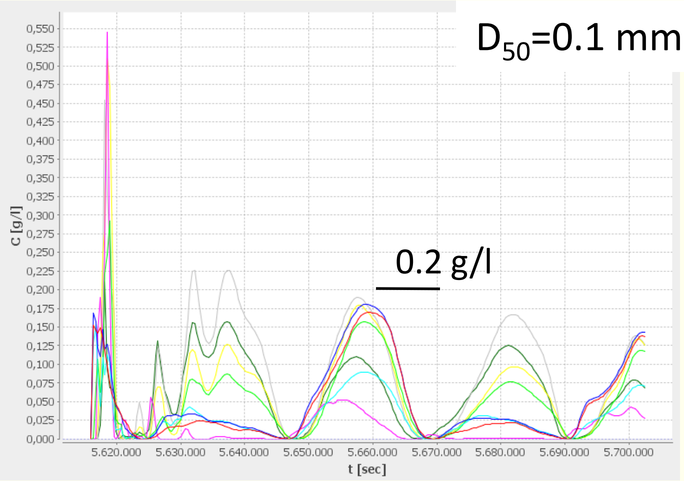
Questions?

Suspended Sediment





- 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 erodable 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