Morphological Modeling of Inlets and Adjacent Shorelines on Engineering Timescales

Challenges and Model Improvements based on Recent Studies

Dobrochinski, J.P.H.; Benedet, L.; Signorin, M.; Pierro, T.

CB&I Coastal & Maritime Services, 2481 NW Boca Raton Blvd, Boca Raton, FL,

joao.dobrochinski@cbi.com

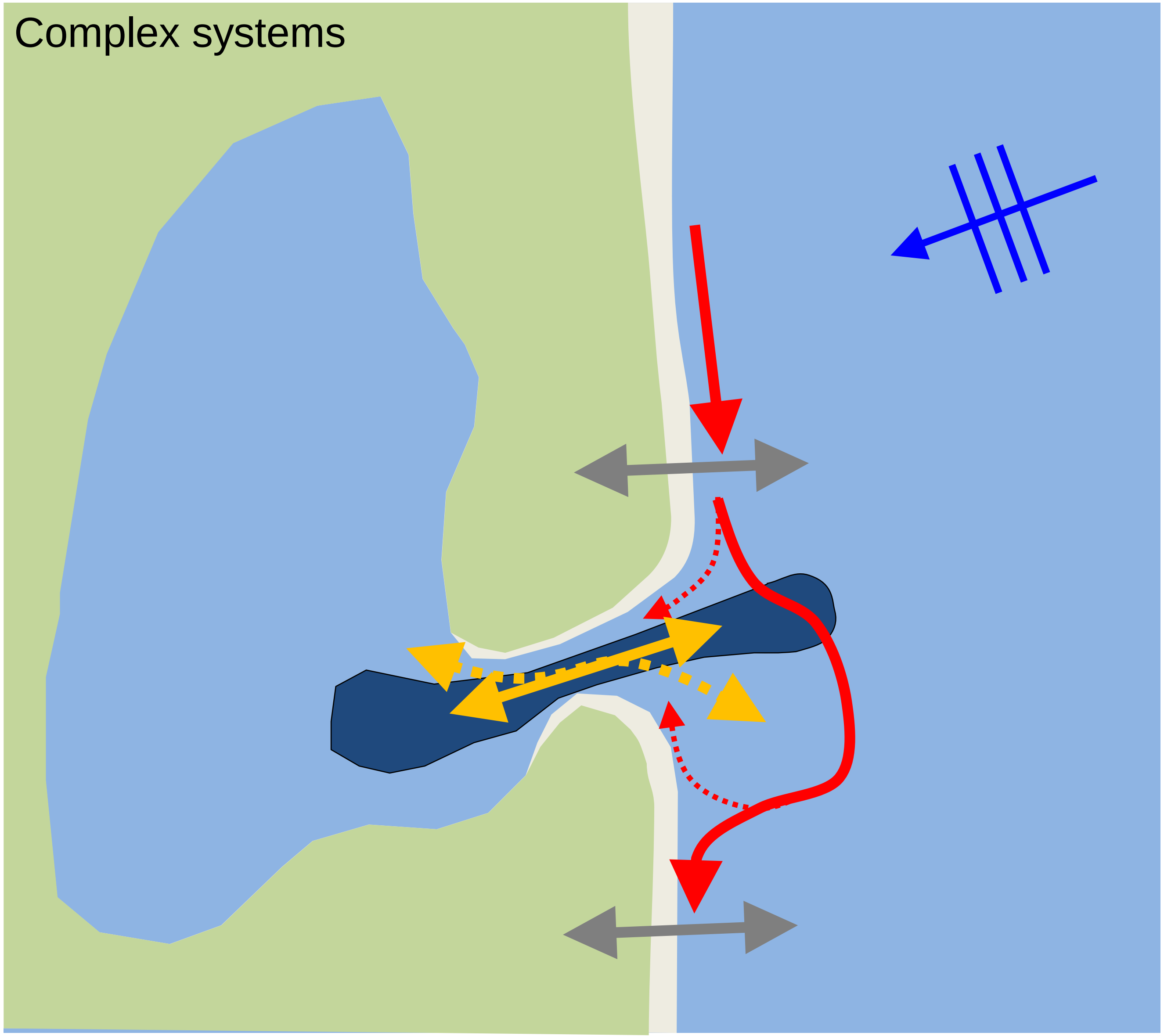
Outline

1. Inlet systems overview

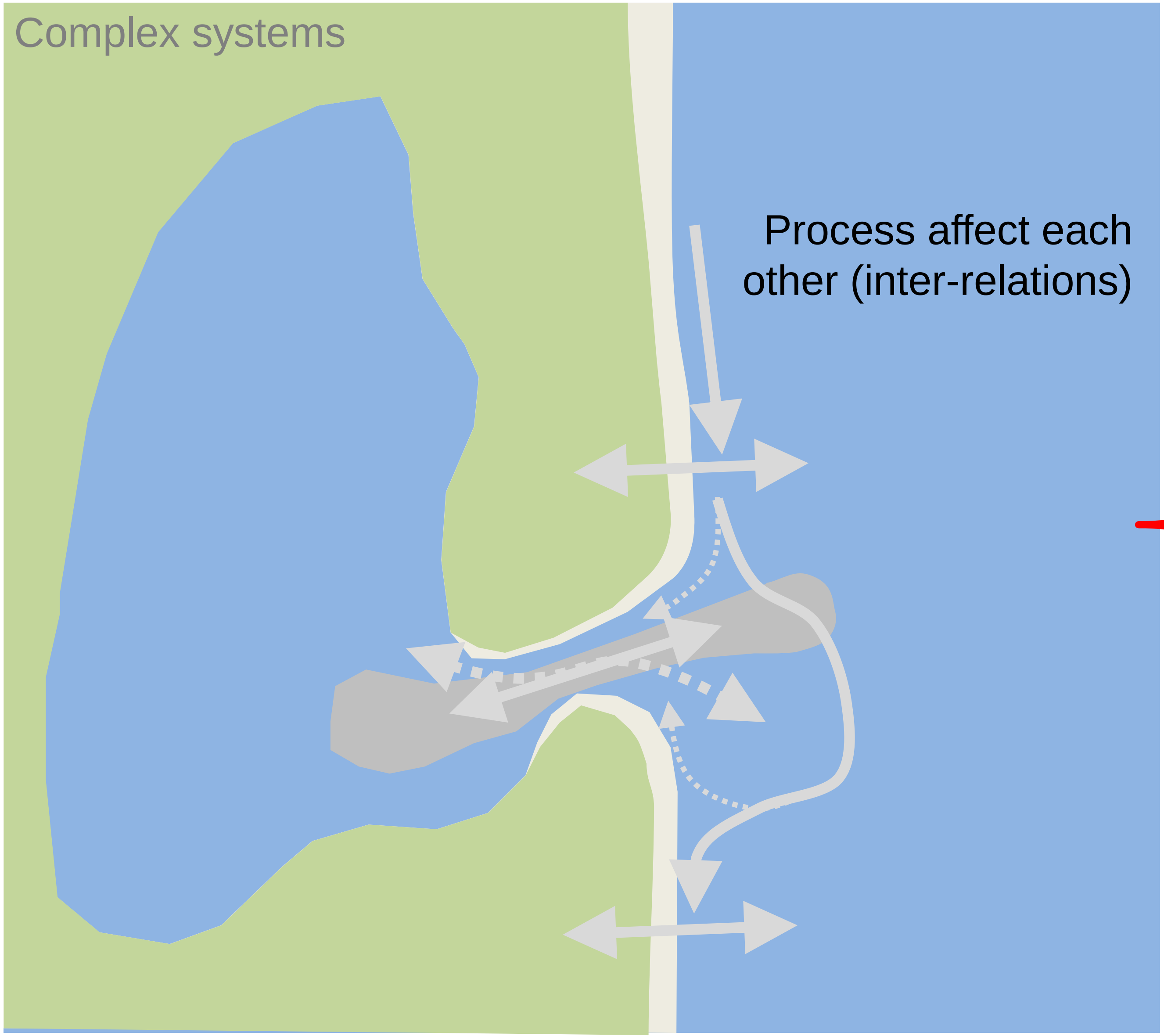
2. Project cases general description
   North Topsail Beach, NC
   Blind Pass (Lee County, FL)

3. Use of numerical models
   Hydrodynamic and wave calibration
   Morphology calibration
   Model application / production runs

4. Conclusions



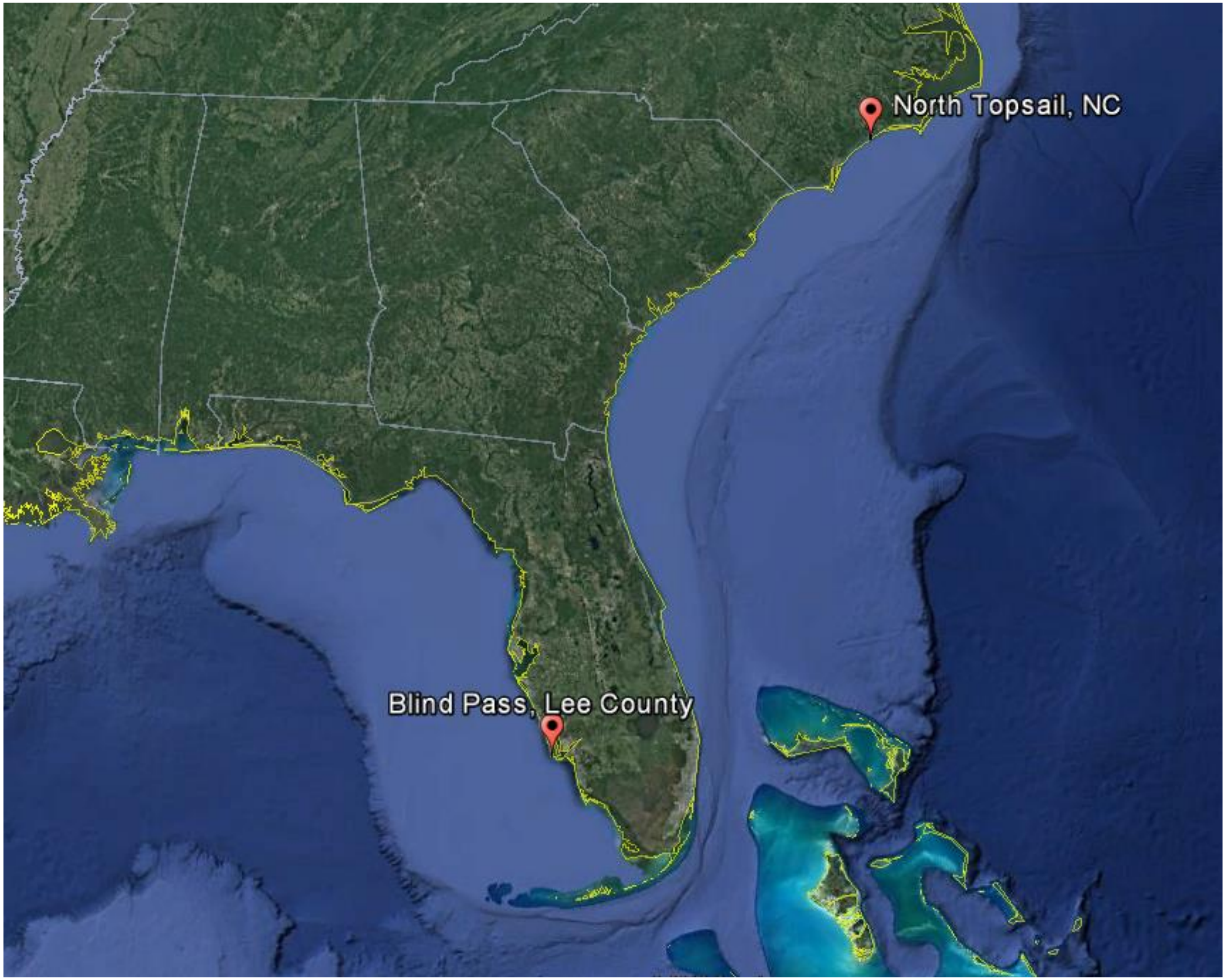
- Tidal currents
- Waves
- Alongshore current and sediment drift
- Sediment by-passing (complex sediment paths)
- Multiple grain sizes
- Channel and ebb shoal relocation
- Coastal erosion/accretion



- Tidal currents
- Waves
- Alongshore current and sediment drift
- Sediment by-passing (complex sediment paths)
- Multiple grain sizes
- Coastal erosion/accretion (influence of channel location/orientation and ebb shoal)

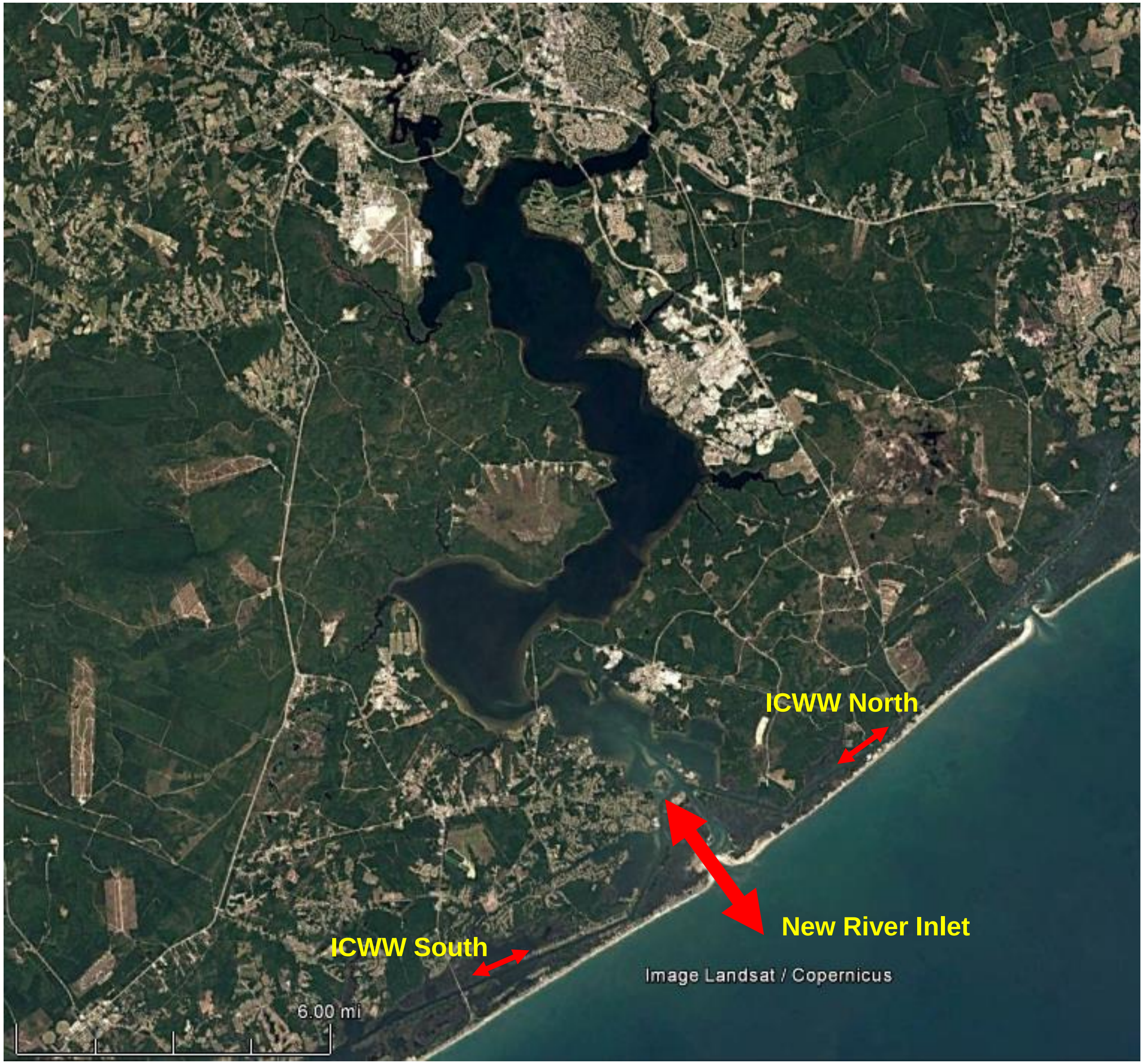
Project cases description

Study areas

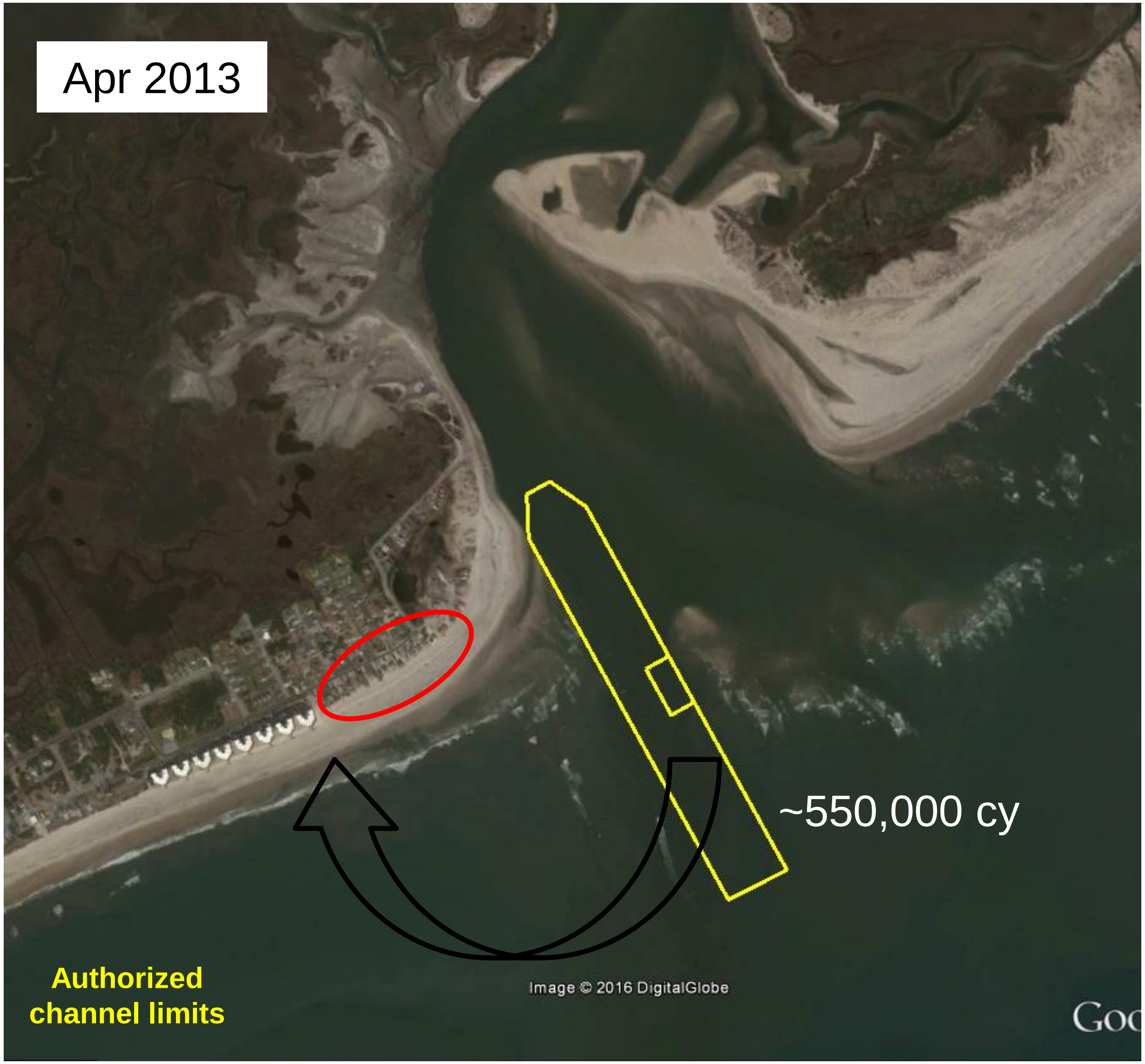


North Topsail, NC
(New River Inlet)

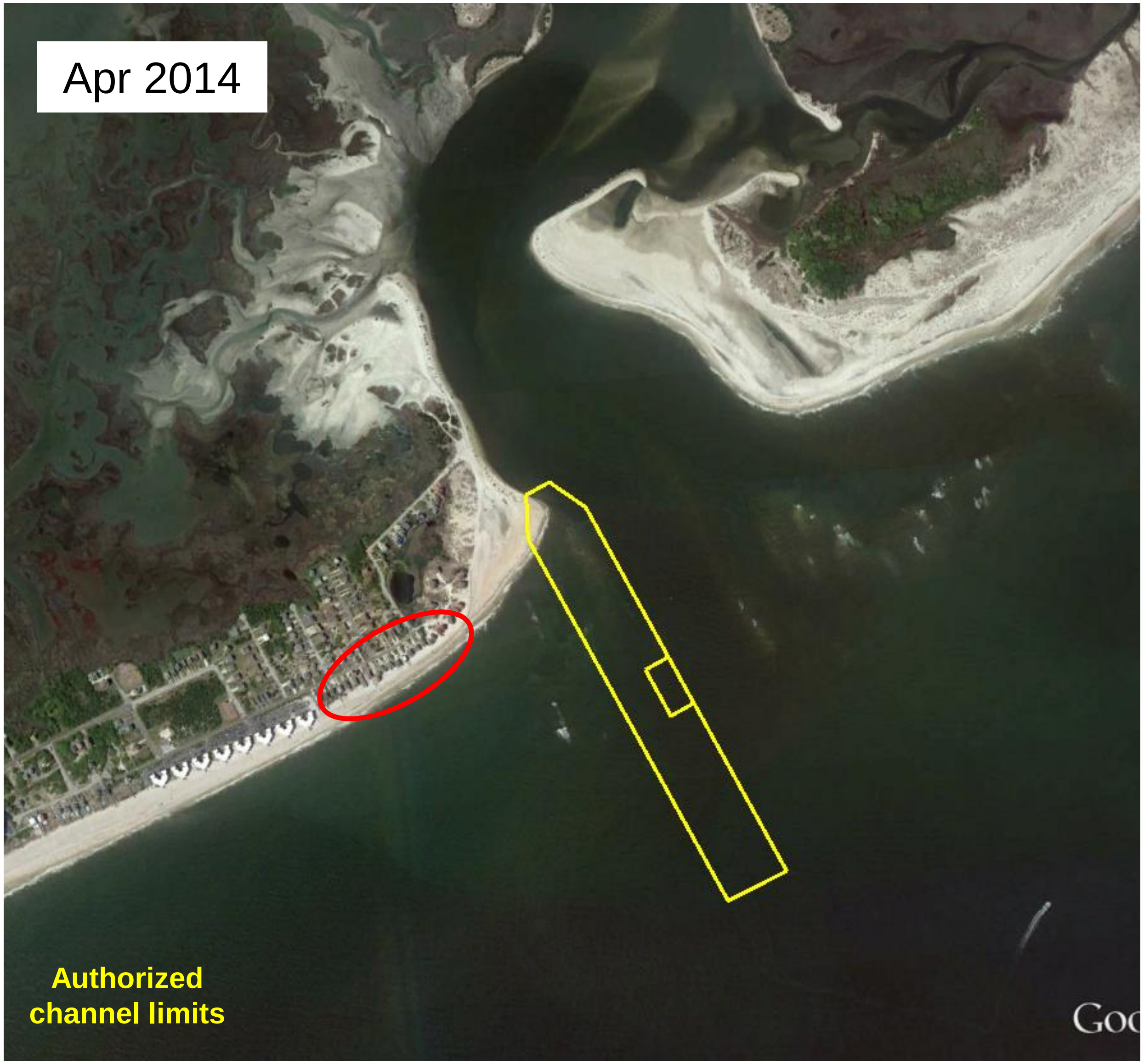
Study areas – North Topsail, NC



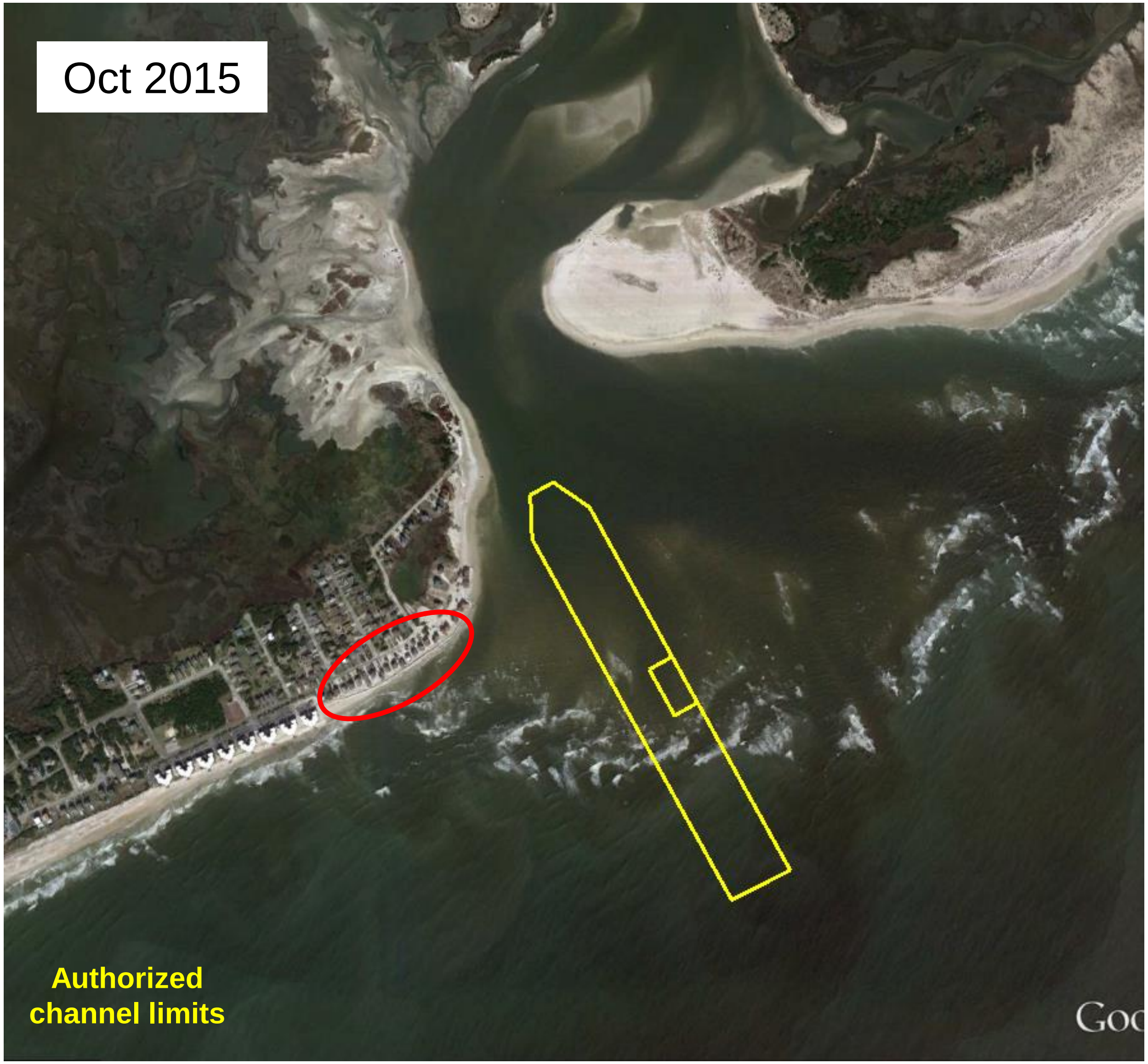
Study areas – North Topsail, NC



Study areas – North Topsail, NC



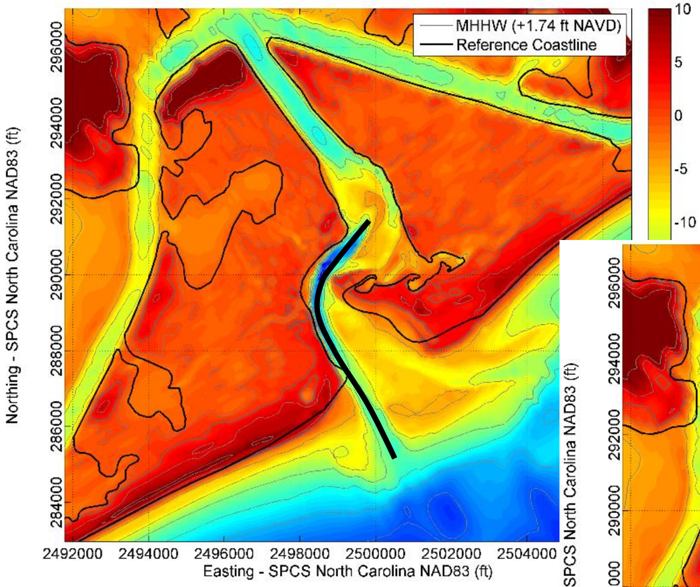
Study areas – North Topsail, NC



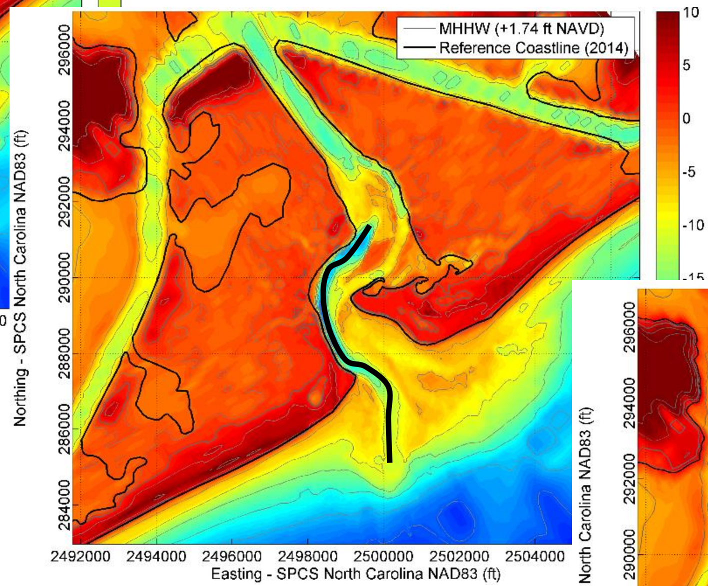
Study areas – North Topsail, NC

Measured Bathymetry

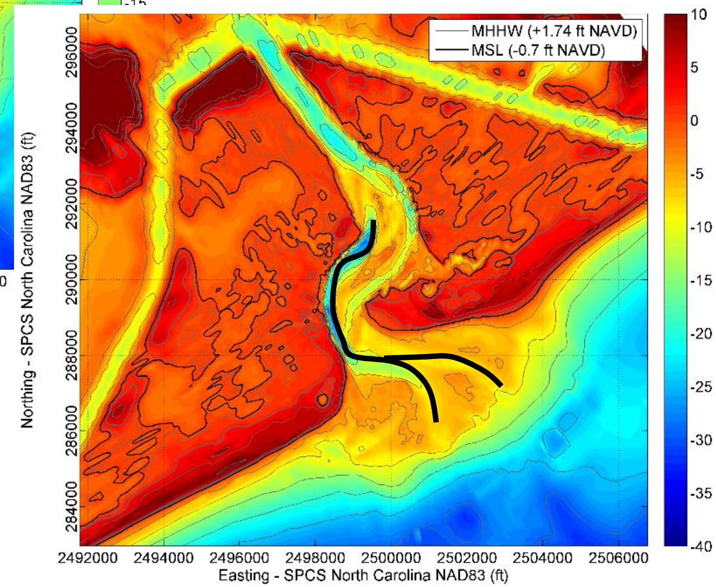
April 2013



April 2014

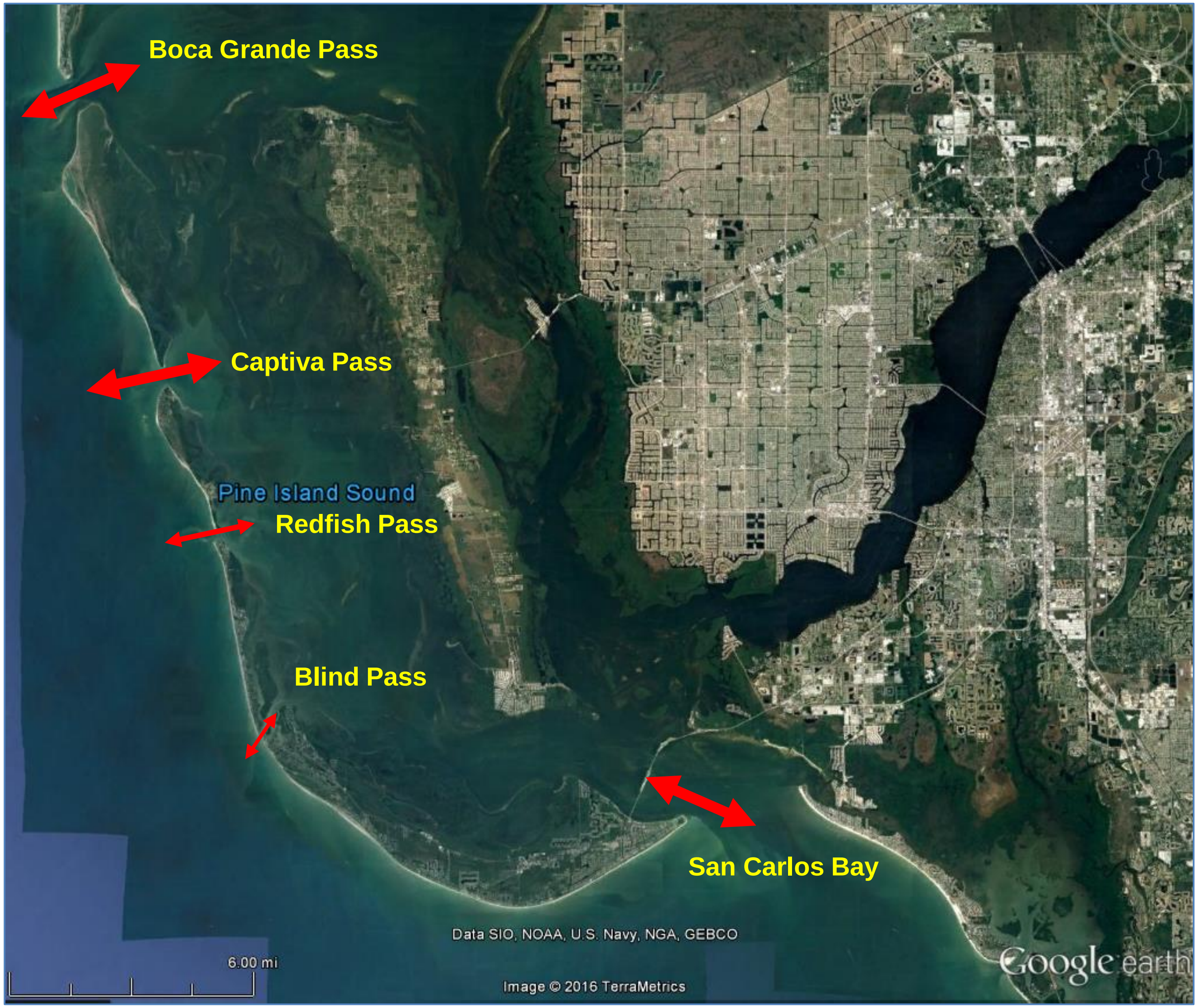


April 2015



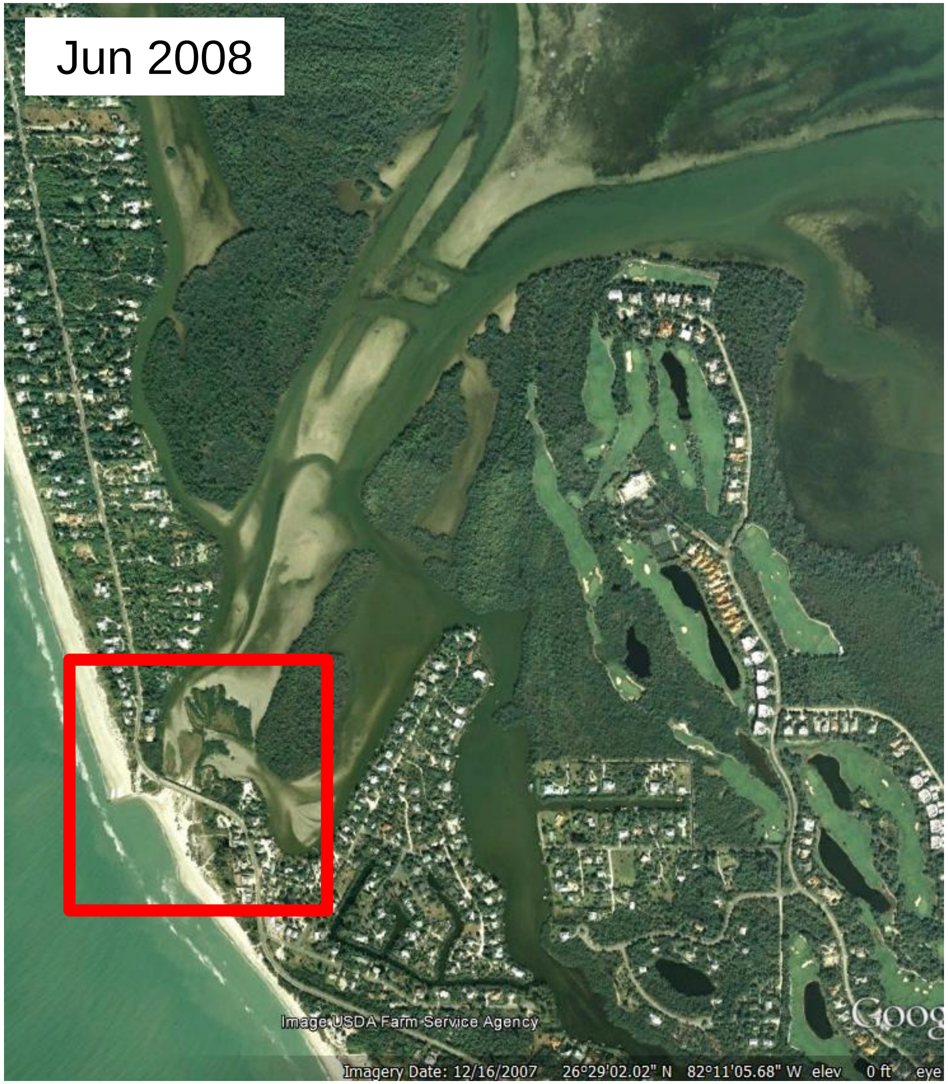
Blind Pass, FL
(Lee County)

Blind Pass, Lee County (FL)

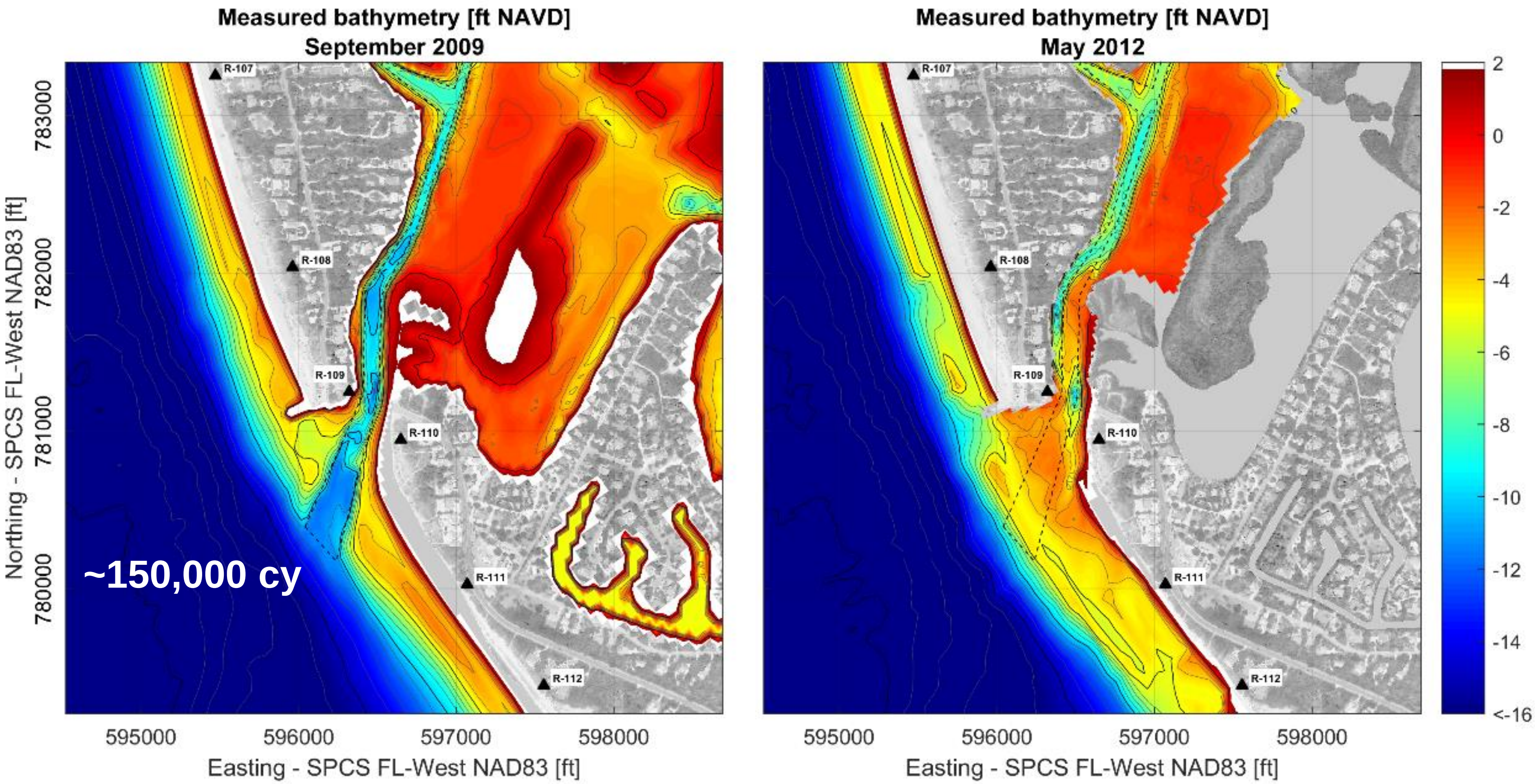


Blind Pass, Lee County (FL)

Source: Captiva Erosion Prevention District

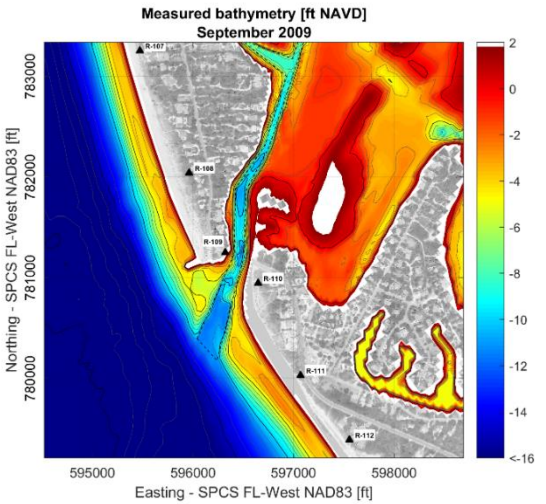


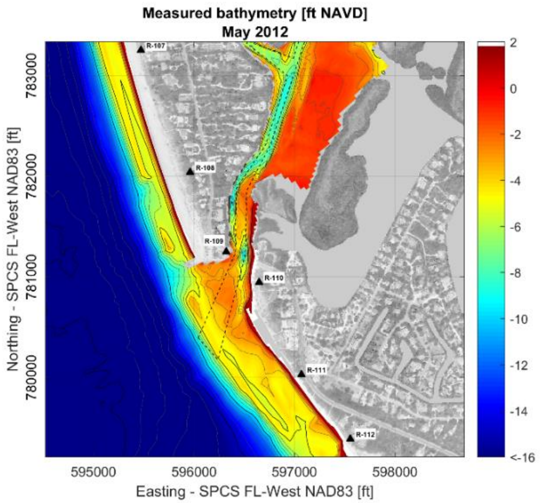
Blind Pass, Lee County (FL)

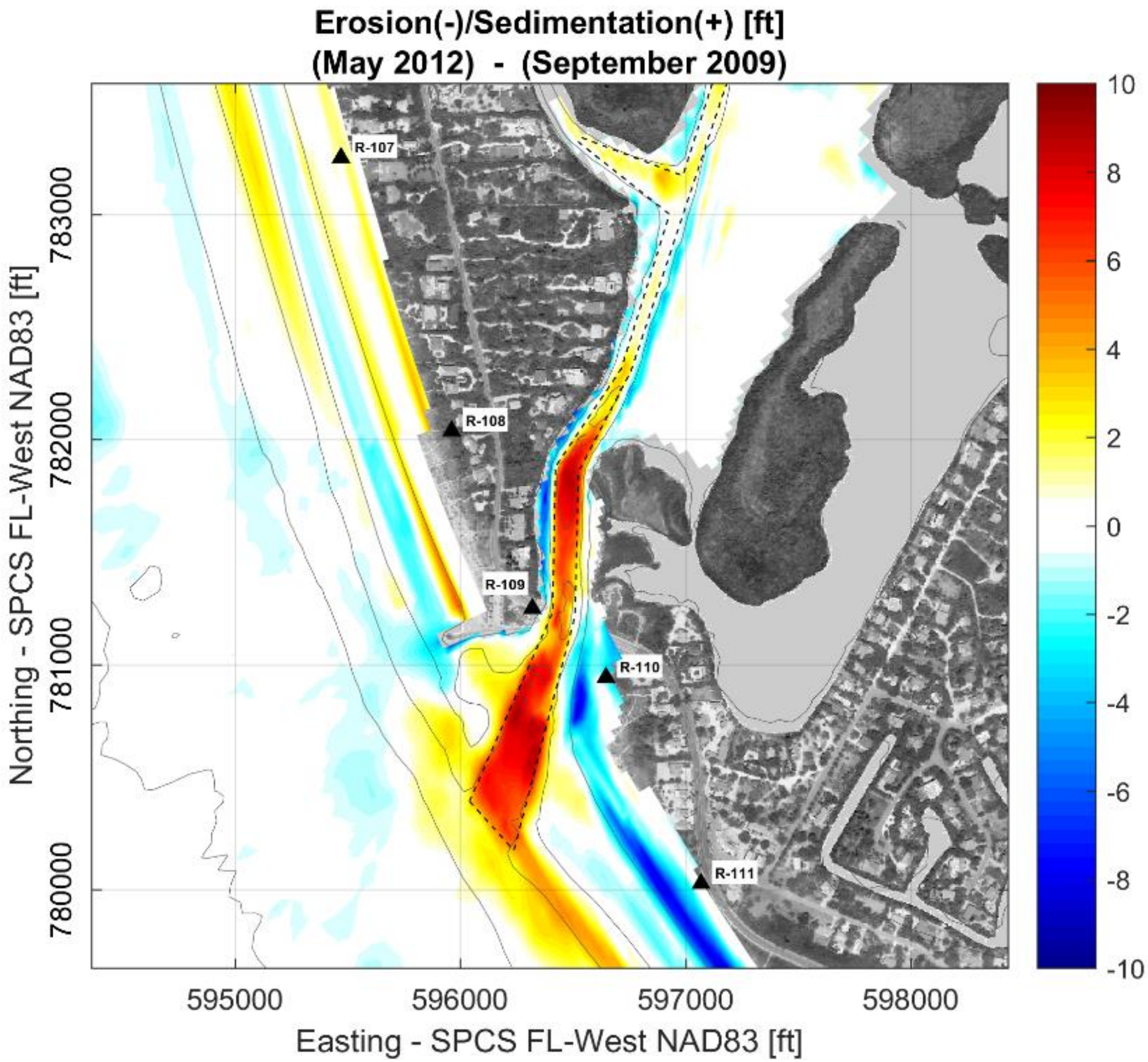


Study areas – Blind Pass, FL

Blind Pass, Lee County (FL)







- Extremely dynamic and responsive environments → challenging problems

- How to improve the situation, optimize project lifetime and expenses?
  alternate dredging layout, beach nourishment, hard structures, etc. (?)

Support for decision making :

a) Historical analysis of morphology changes

b) Engineering analysis and sediment budgets

c) Field surveys and measurements

d) Numerical modeling

e) Environmental resource mapping & impact assessments

INPUTS

General input
Bathymetry, bed roughness, turbulence coefficients (viscosity)

Boundary conditions
Water levels, discharges / velocities, wind stress

Delft3D-WAVE
(Wind wave generation and propagation)

State of the Art Morphology Modeling

Delft3D-FLOW
(3D currents, water levels)

Morphology update

APPLICATIONS

Transport of Constituents
(salinity, temperature, tracer, etc.)

Particle tracking
(oil spill, debris transport, etc.)

Sediment transport
(non-cohesive and cohesive)

Coastal Engineering Applications:

1) Hydrodynamic and wave model calibration

2) Morphology model calibration

3) Application - production runs

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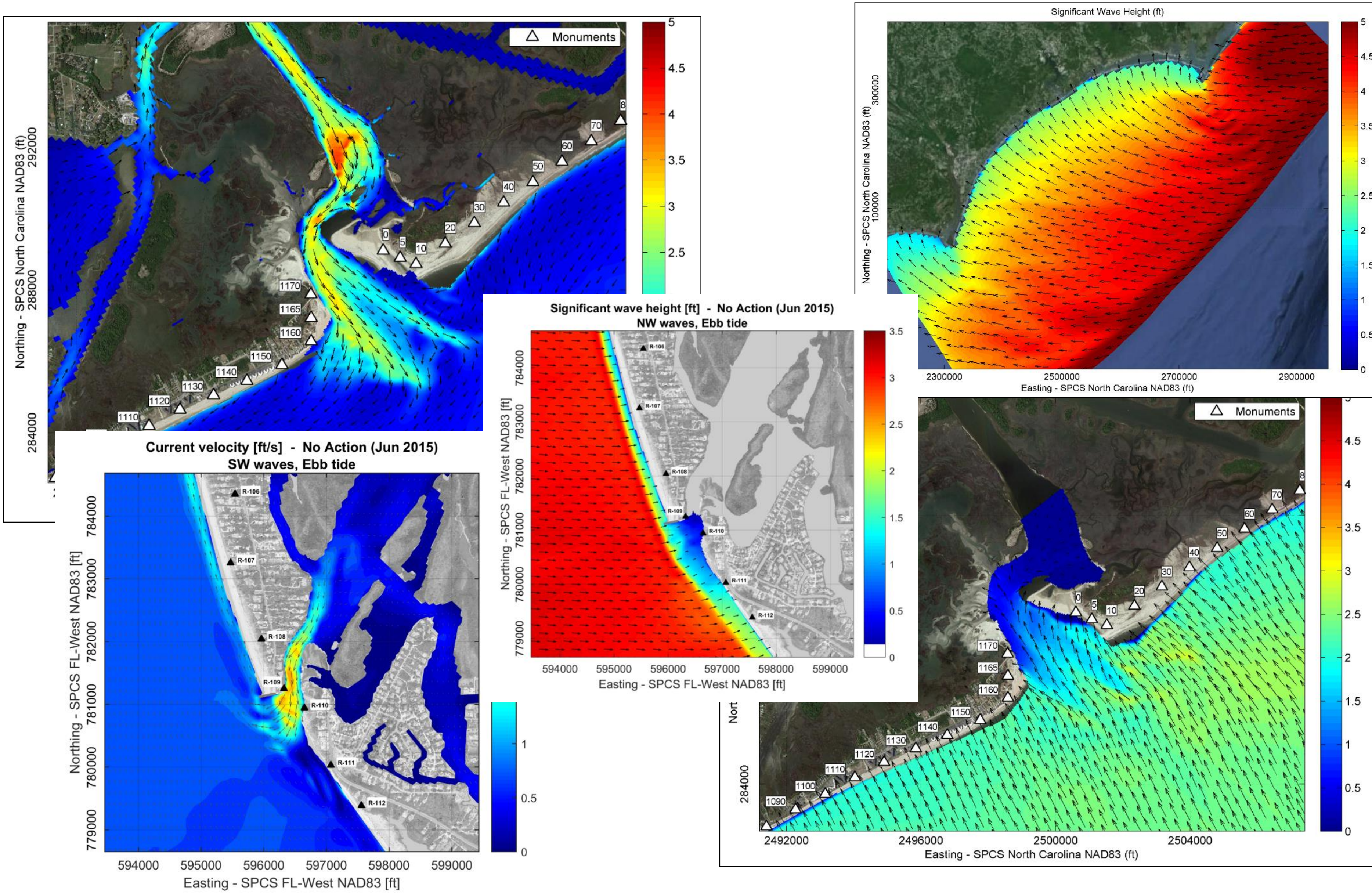
Flow and wave model



Coastal Engineering Applications:

1) Hydrodynamic and wave model calibration

2) Morphology model calibration

3) Application - production runs

First challenge

Computation time:

20 “model days” → ~1 computer day

5*365 “model days” → ~90 computer days! (longer term morphology)

- Wave, wind and tide input schematization required
- Selection of representative conditions
  - reproduce gross and net sediment transport
  - Mix wave conditions, avoid long repetitions, include the calm wave periods
  - Individual storms are/were relevant during calibration period (?)

- Definition of calibration target (measured datasets for model verification)
  - Sediment budget
  - Alongshore volume change (erosion/sedimentation curves)
  - Morphology changes in the inlet

- Morphology model (main) variables
  - Sediment transport formula (*e.g.* Van Rijn 1997, TRANSPOR 2004)
  - Cross shore sediment transport coefficients (i.e. SusW/BedW)
  - Bed roughness: bed forms and roughness predictor
  - Number and structure of vertical model layers: 3D flow structure and near-bed velocities
  - Horizontal eddy viscosity (flow) and diffusivity (transport) coefficients
  - Sediment mapping (3D measured data unavailable) and non-erodible layers
  - Transverse bed slope effect on transport (AlfaBn)

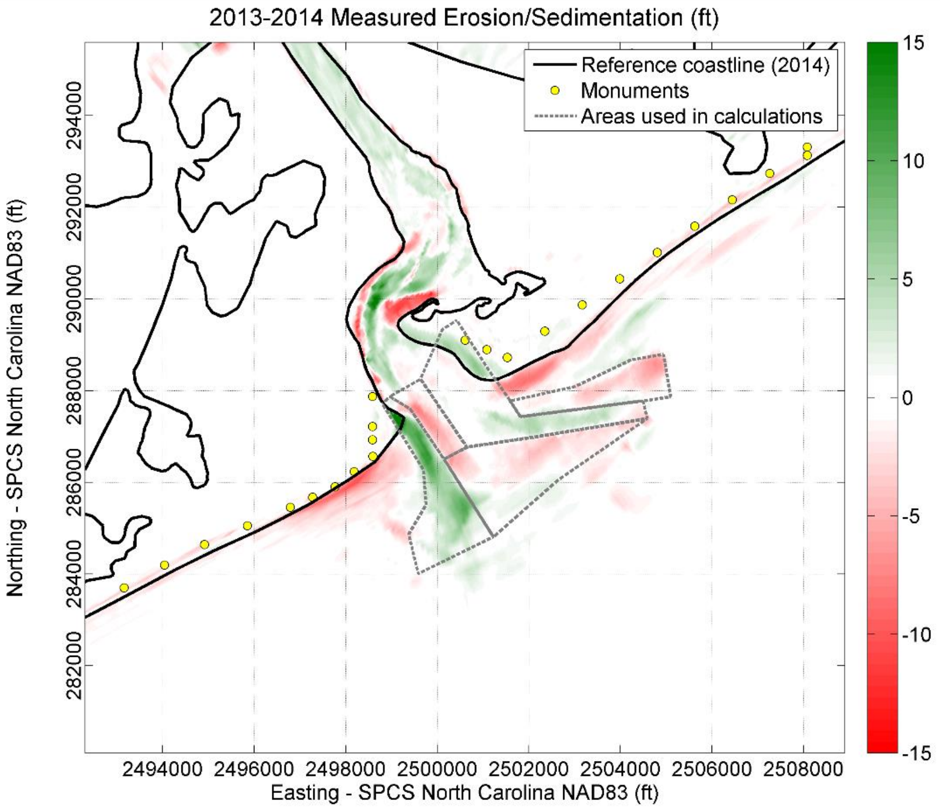
TOTAL: >100 model runs

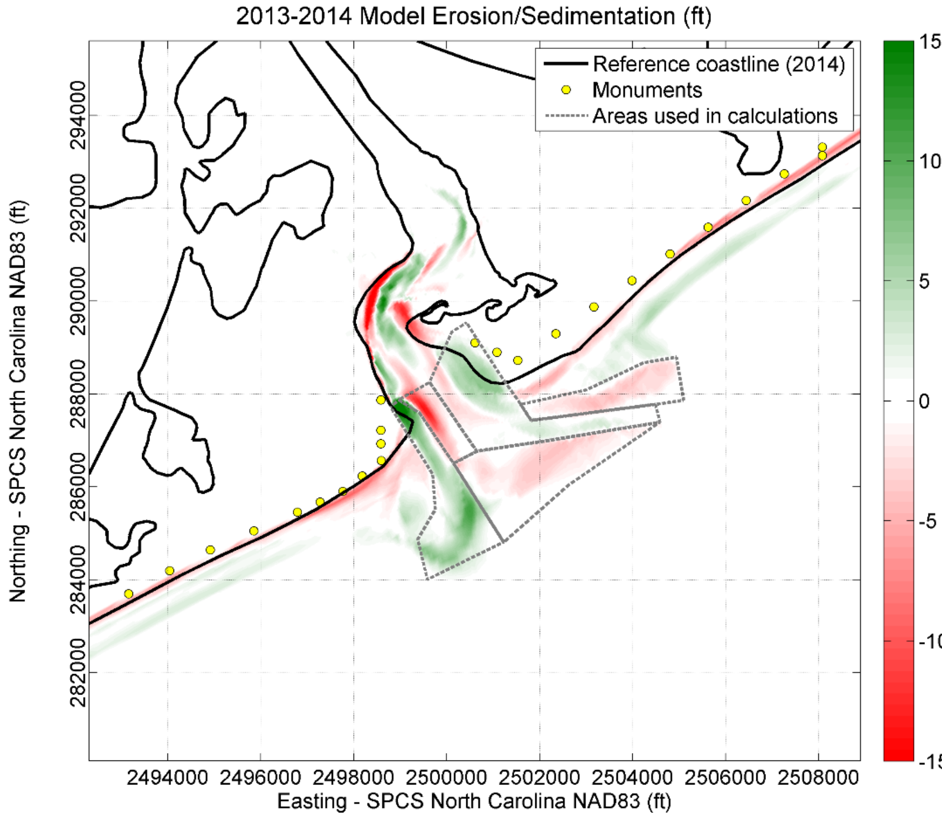
How good is 'good enough'?

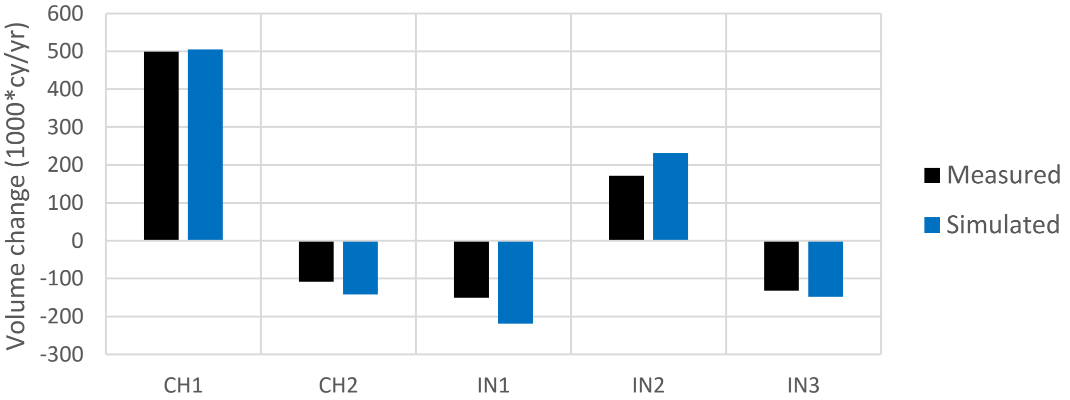
Examples of morphology calibration results

North Topsail and Blind Pass Projects

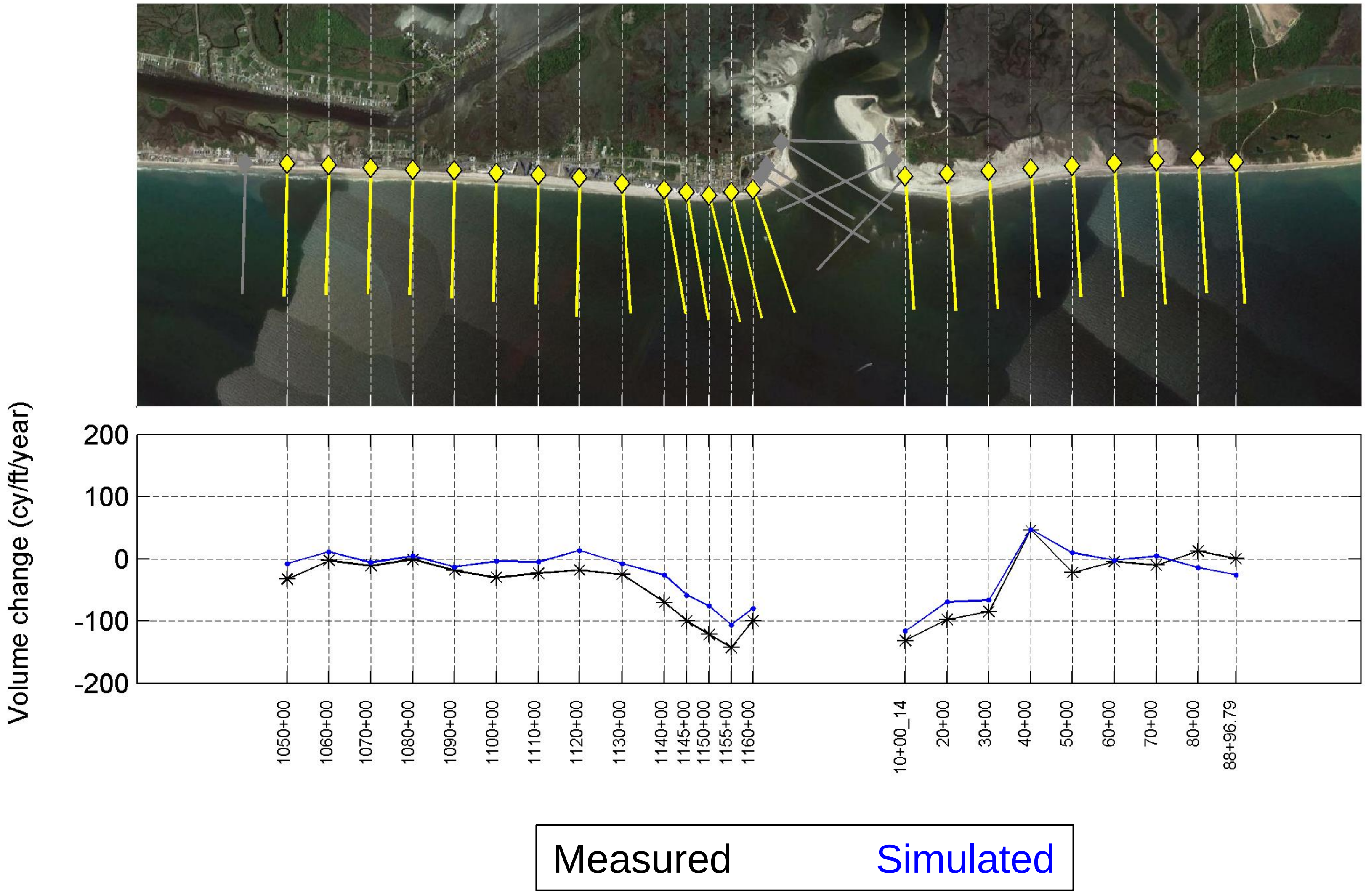
Calibration results - North Topsail







Calibration results - North Topsail



Coastal Engineering Applications:

1) Hydrodynamic and wave model calibration

2) Morphology model calibration

3) Application - production runs

Calibrated model setup:

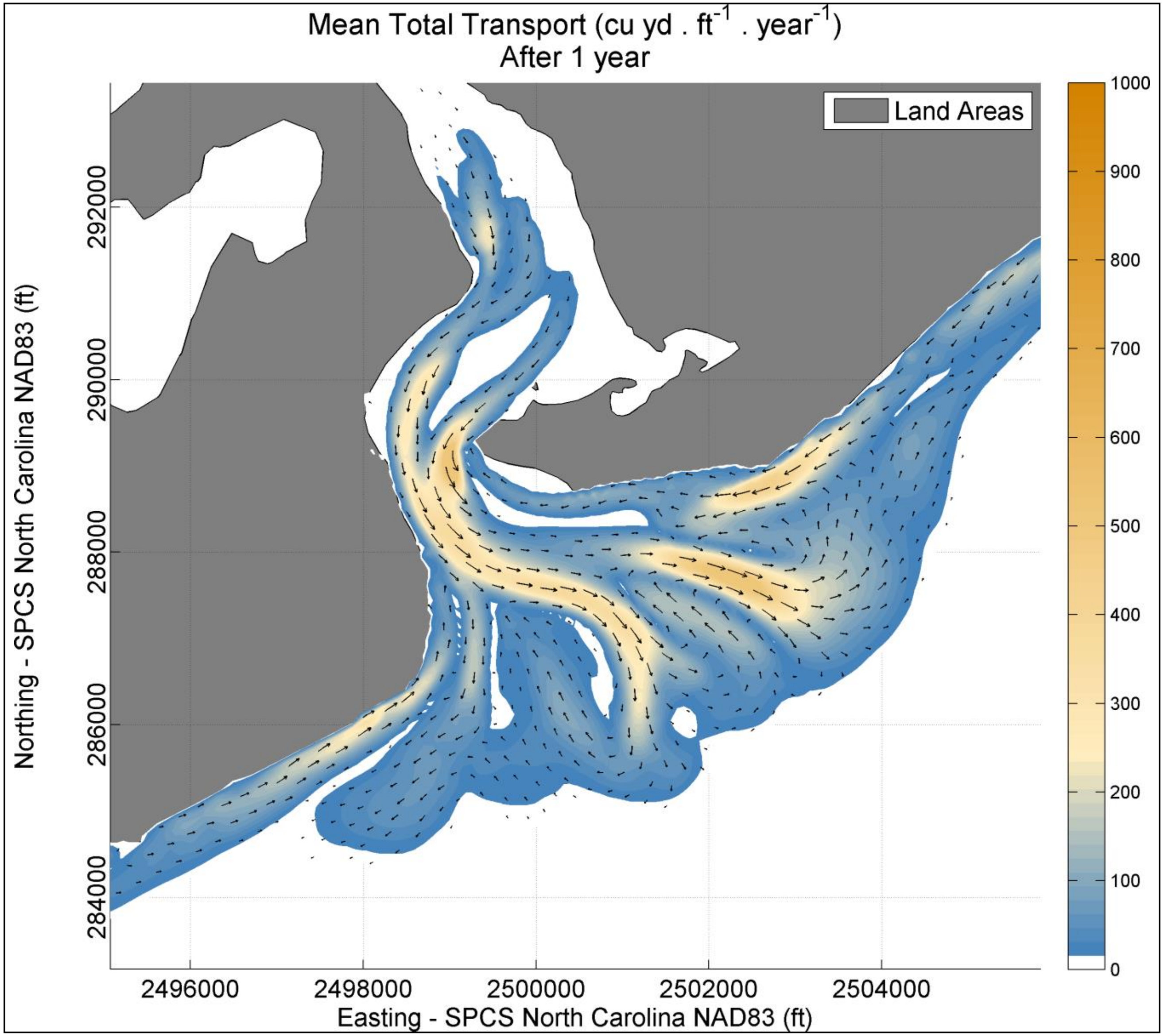
- Parameters
- Forcing scheme

Base case simulation (usually "*No Action*" scenario)

Several alternatives tested

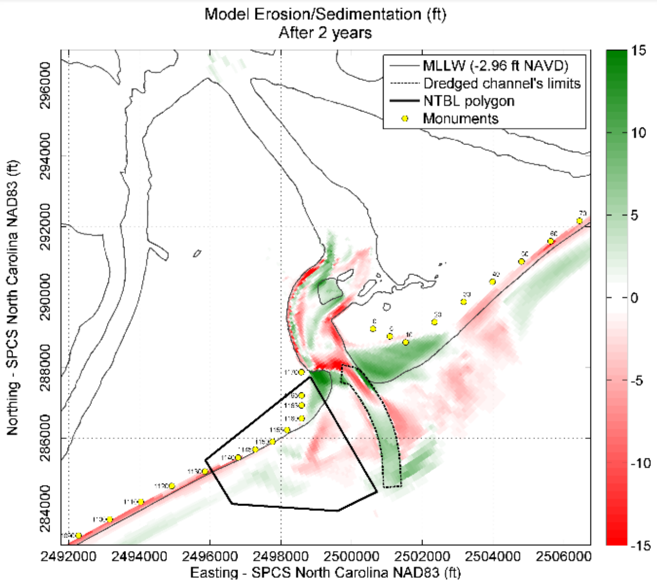
- 1 – 5 year morphology simulations
- Storm simulations

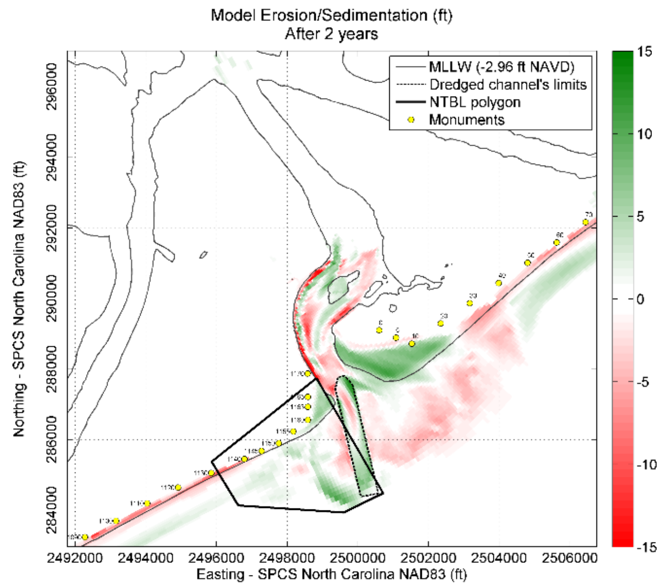
Analysis of absolute and relative results (benefits / impacts)



Mean Total Transport (cu yd . ft^{-1} . year^{-1})
After 1 year
Land Areas
Northing - SPCS North Carolina NAD83 (ft)
284000
286000
288000
290000
292000
Easting - SPCS North Carolina NAD83 (ft)
2496000
2498000
2500000
2502000
2504000
0
100
200
300
400
500
600
700
800
900
1000

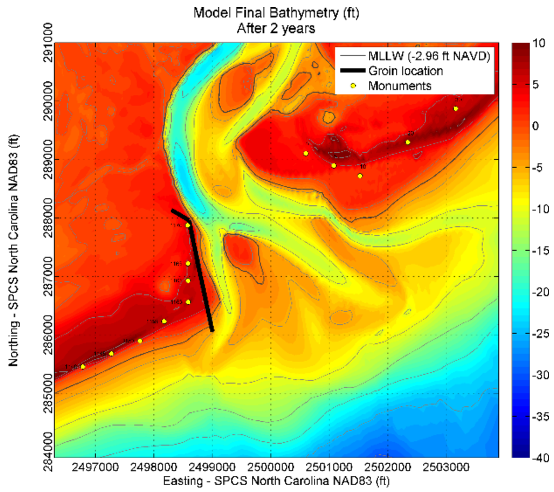
Application/production runs

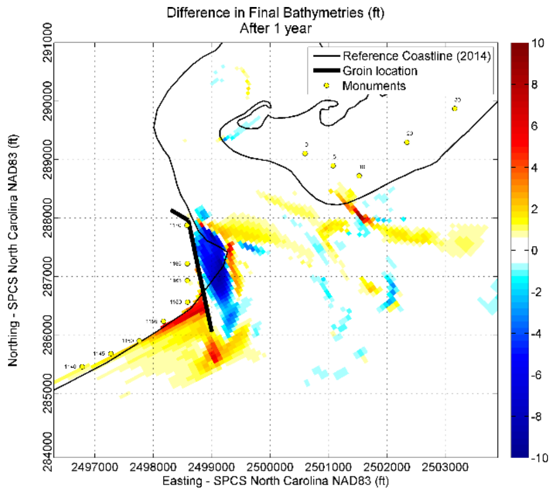




Channel layouts

Coastal structures and beach nourishment





Blind Pass: under development

Tidal inlets + adjacent shorelines: extremely complex systems

State-of-the-art morphological models (*e.g.* Delft3D) might supplement other analysis to:

- ✓ better understand beach/inlet changes
- ✓ assess the effects of engineering solutions

Morphology calibration is essential for a solid application of the model

- Calibration target ←→ goals of the project
- Final/calibrated model setup: combination of several choices
- No general recipe or shortcuts to get there (experience builds up over the years)

Good luck in your next morphology model application!