Morphological Modeling of Inlets and Adjacent Shorelines on Engineering Timescales

Challenges and Model Improvements based on Recent Studies

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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
Inlets systems

Complex systems

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

- 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)

Process affect each other (inter-relations)
Project cases description
Study areas

- North Topsail, NC
- Blind Pass, Lee County

A World of Solutions
North Topsail, NC
(New River Inlet)
Study areas – North Topsail, NC

Apr 2013

~550,000 cy

Authorized channel limits

Image © 2016 DigitalGlobe
Study areas – North Topsail, NC

Authorized channel limits

Apr 2014
Blind Pass, FL
(Lee County)
Blind Pass, Lee County (FL)

- Boca Grande Pass
- Captiva Pass
- Redfish Pass
- Blind Pass
- San Carlos Bay

Data: NOAA, U.S. Navy, NGA, GEBCO
Image © 2016 TerraMetrics
Study areas – Blind Pass, FL

Blind Pass, Lee County (FL)

May 2002

Source: Captiva Erosion Prevention District

Jun 2008
Study areas – Blind Pass, FL

Blind Pass, Lee County (FL)

Measured bathymetry [ft NAVD]
September 2009

Measured bathymetry [ft NAVD]
May 2012

~150,000 cy
• 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
**Delft3D Overview**

**Inputs**
- General input: Bathymetry, bed roughness, turbulence coefficients (viscosity)

**Applications**
- Transport of Constituents: (salinity, temperature, tracer, etc.)
- Particle tracking: (oil spill, debris transport, etc.)
- Sediment transport: (non-cohesive and cohesive)

**State of the Art Morphology Modeling**

**Delft3D-FLOW**
(3D currents, water levels)

**Boundary conditions**
- Water levels, discharges / velocities, wind stress

**Delft3D-WAVE**
(Wind wave generation and propagation)

**Morphology update**
Coastal Engineering Applications:

1) Hydrodynamic and wave model calibration

2) Morphology model calibration

3) Application - production runs
Coastal Engineering Applications:

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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” $\rightarrow$ ~1 computer day

5*365 “model days” $\rightarrow$ ~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 (?)
Morphology model calibration

- **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

2013-2014 Measured Erosion/Sedimentation (ft)

Nothing - SPCS North Carolina NAD83 (ft)

2013-2014 Model Erosion/Sedimentation (ft)

Nothing - SPCS North Carolina NAD83 (ft)

Volume change (1000 $^3$/yr)

CH1  CH2  IN1  IN2  IN3

-300  -200  -100   0    100   200  300  400  500  600

Measured

Simulated
Calibration results - North Topsail

Measured vs. Simulated
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 \cdot ft^{-1} \cdot year^{-1})
After 1 year
Application/production runs

Channel layouts

Coastal structures and beach nourishment

Blind Pass: under development
Conclusions

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!