Hydrodynamic and Morphologic Modeling at Sebastian Inlet, FL: Engineering and Management Applications

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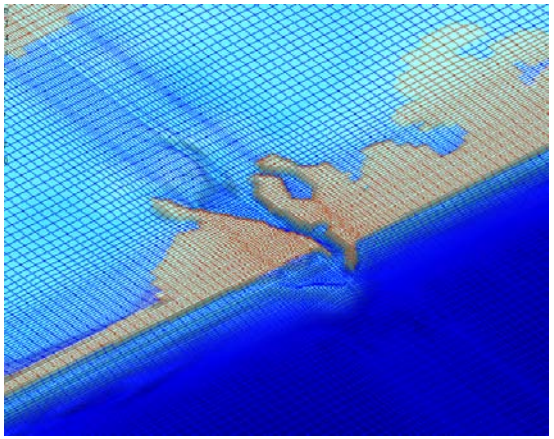


Overview

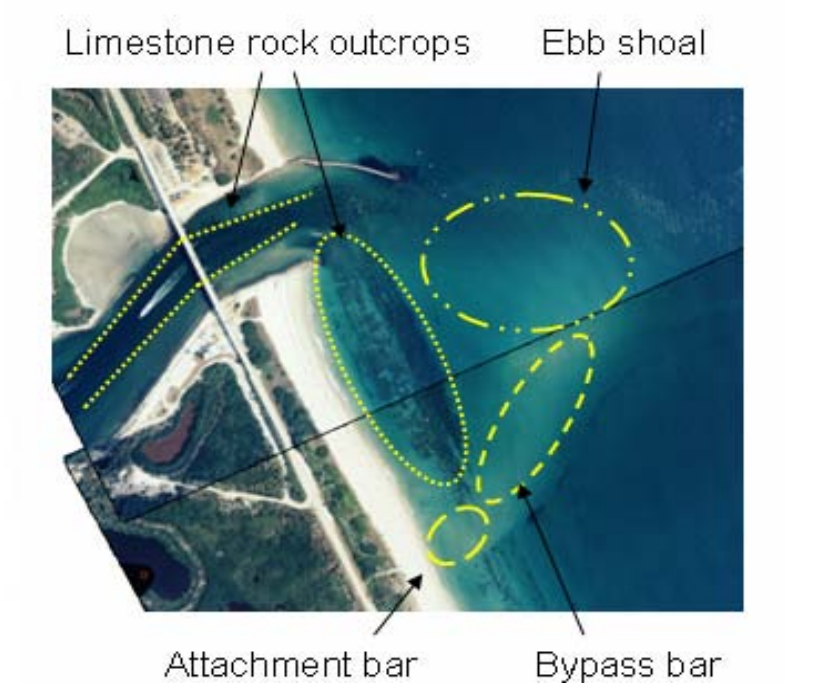
- Re-cap on Sebastian Inlet:
  - Geomorphologic & physical settings
  - Sand resources management
  - Surfing breaks
- Motivations and objectives
- The modeling platform (CMS)
- Hydrodynamic and morphological model
- BOUSS2D wave model
- Summary & ongoing work

Looking South, toward attachment bar (R2), summer 2007

Ebb shoal “Monster Hole” on a clean day, summer 2008

Sebastian Inlet: re-cap

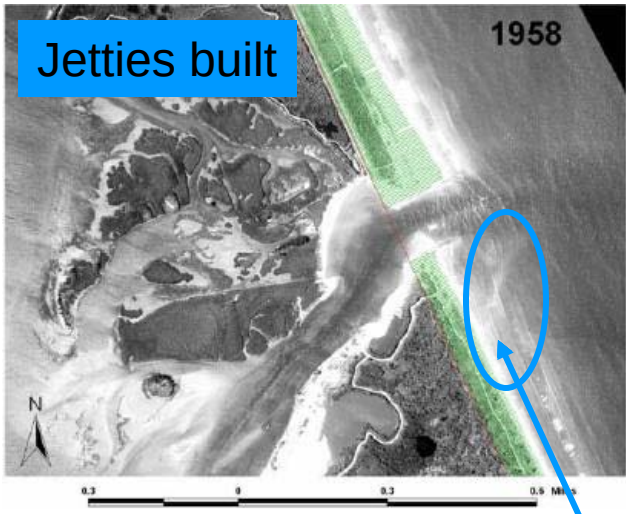
- Maintained & monitored by SITD
- Stabilized by 2 offset jetties (1970's)
- Excavated sand trap
- Downdrift erosion
- Ebb shoal system
- Hard bottom coquina rock



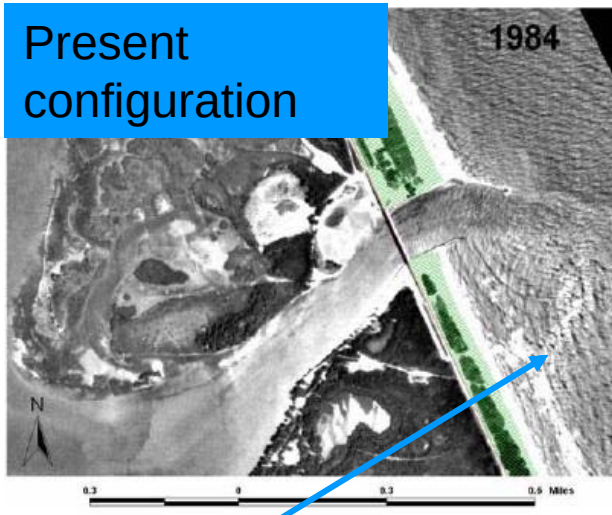
From Inlet Reservoir Model (Zarillo et al., 2003)

Shoreline evolution & ebb-shoal formation

Inlet closed – no jetties yet

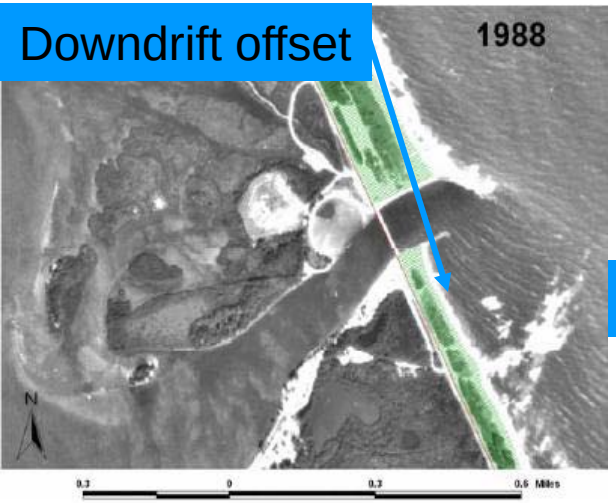


Jetties built

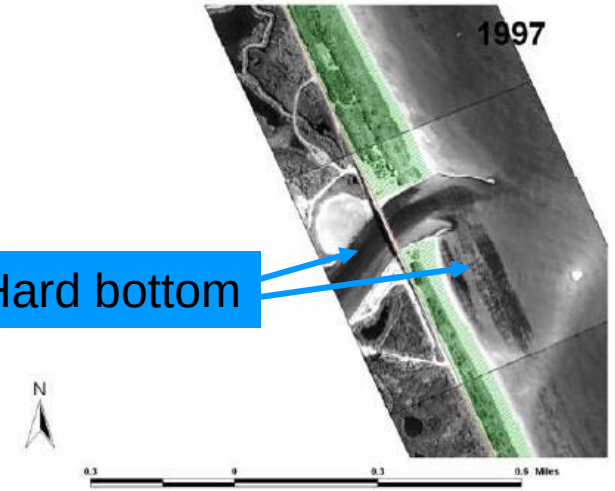


Present configuration

Ebb shoal/Attachment bar



Downdrift offset

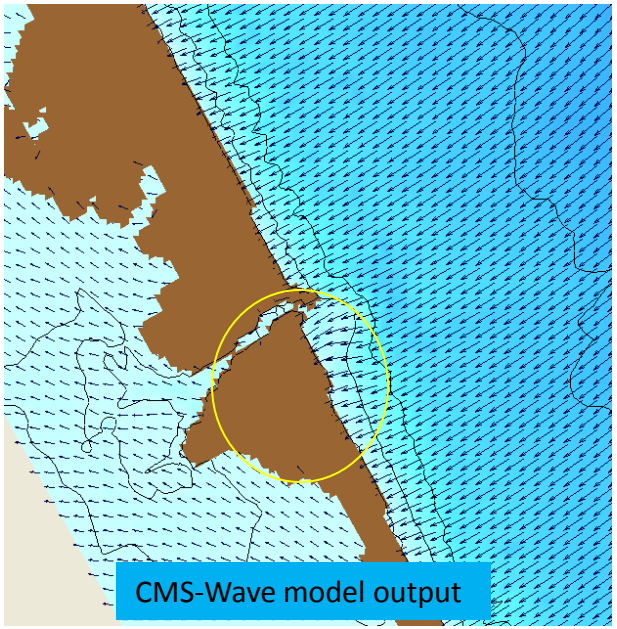


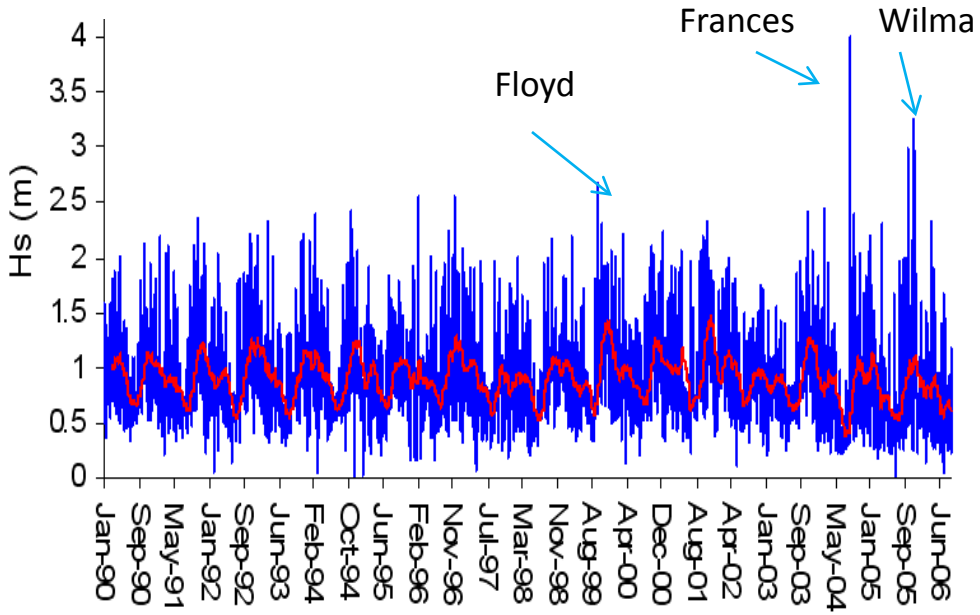
Hard bottom

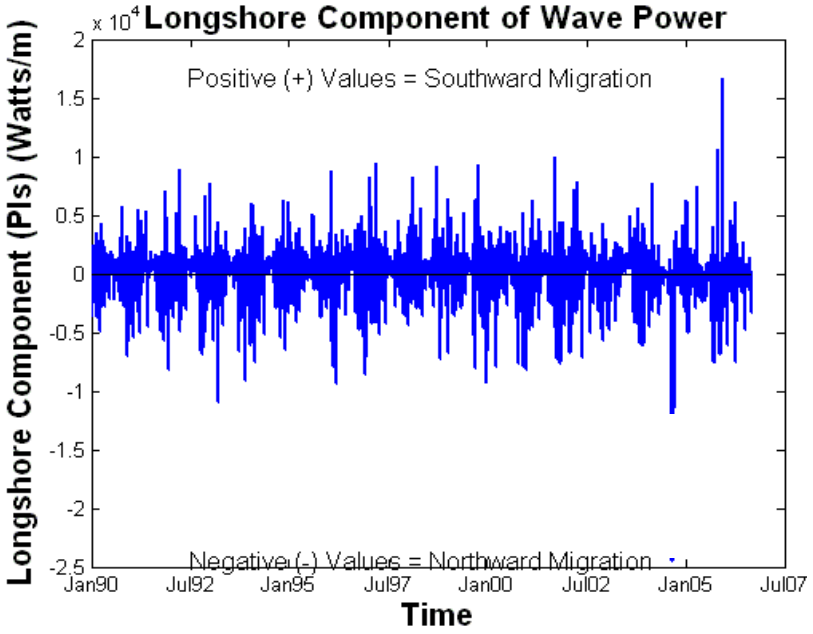
Ebb shoal/Attachment bar (further south)

Physical setting

- Moderate wave climate (Avg. Hs = 0.6 m), strong seasonal signal
- Nor'easter vs. tropical storms: net southward littoral drift (120,000 to 250,000 cy/yr)
- Reversals in longshore drift (storms vs. longer cycles)
- Importance of ebb-shoal (micro-scale wave climate)

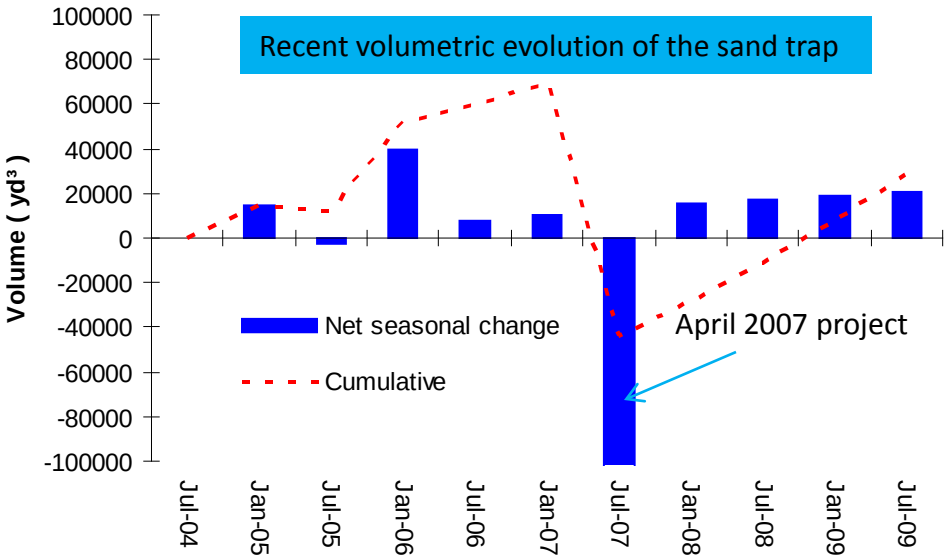






Sand resources management

- Beach fill > 1,000,000 cy since 90's (various sources)
- State of Sebastian Inlet Report: morphologic and volumetric evolution
- Not enough sand in trap: + 70,000 cy since last dredged April 2007
- Geotechnical survey identified potentia 400,000 cy in outer ebb shoal
- Multi-faceted: boating, fishing, surfing, reef protection, flood protection

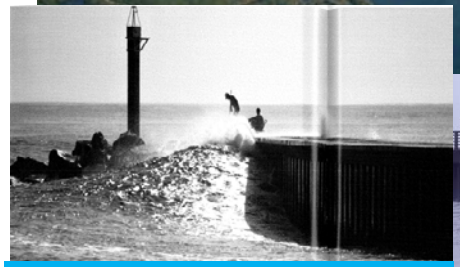


Surfing breaks

- A variety of surfing breaks:
  - North side: jetty-type (1st Peak), beach breaks (2nd Peak and 3rd Peaks …)
  - Ebb shoal: Monster Hole
  - South side: Attachment bar and nearshore reefs during long period swells
- History dates back to early 1960's with pioneers like Dick Catri, Gary Propper …
- Surfing breaks in constant evolution as result of the engineering activities (better back then?)
- Surfrider Foundation, "Sebastian Inlet chapter"

Monster Hole, Hurricane Florence, Sep. 15th 2006

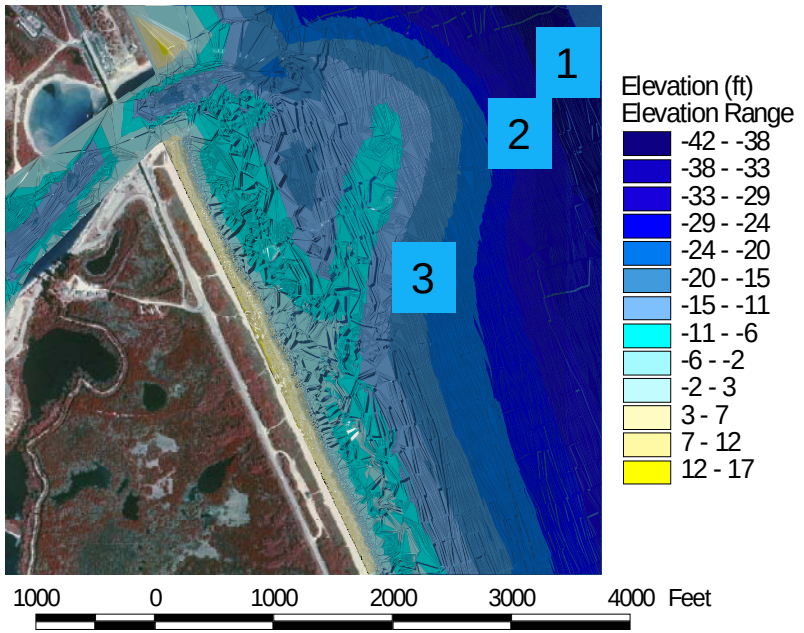
January 1949



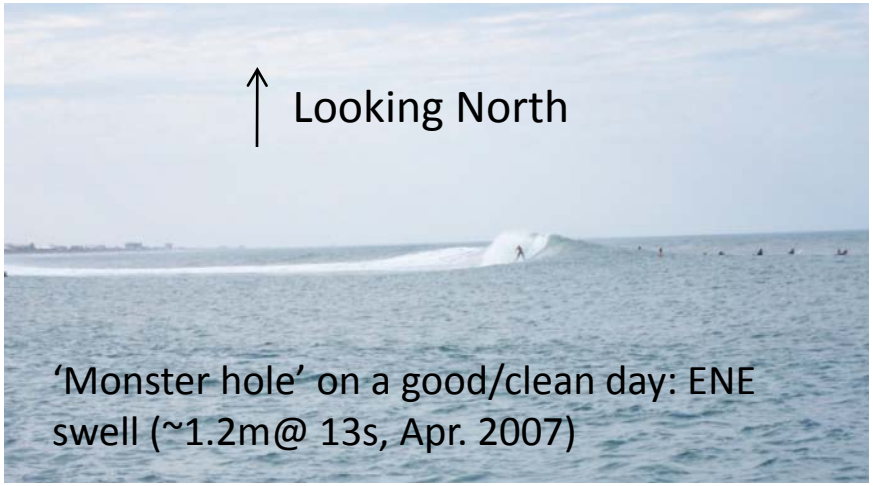
1st Peak in the 70's

1st Peak, Hurricane Hanna, Sep. 5th 2008

Sebastian Inlet ebb shoal surfing break: "Monster Hole"

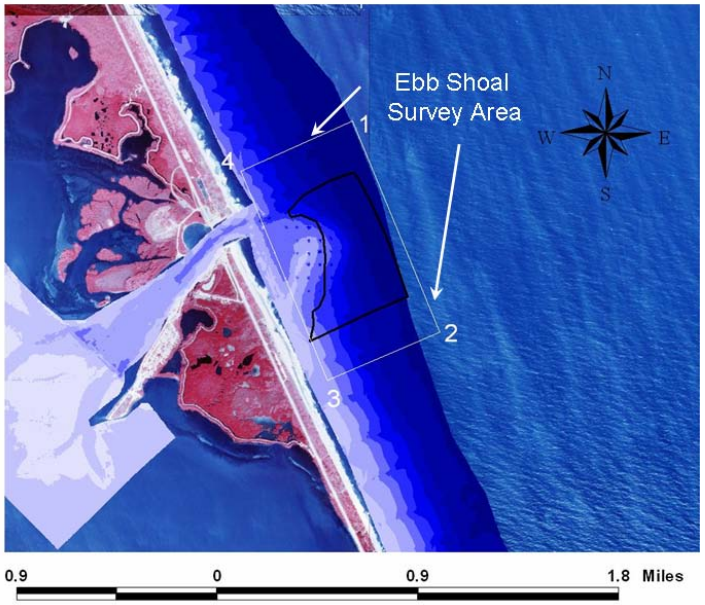


- Entrance bar type
- Left hander, > 300m on epic days
- Best at 1 to 3m, Tp > 13sec, ENE/NE
- Bathymetric components:
  - Ramp
  - Focus
  - Wedge



Motivations

- Reproduce and understand sand transport, beach fill performance, hard bottom interactions
- Determine the effects of the proposed engineering modifications on the hydrodynamics and sand transport
- Effect of dredge cut:
  - Natural sand bypassing
  - Surfing Break
- Entrance bar surfing breaks Vs. engineering activities (Mundaka, Spain; Whangamata, NZ)
- Sustainable management and protect surfing amenities



Objectives

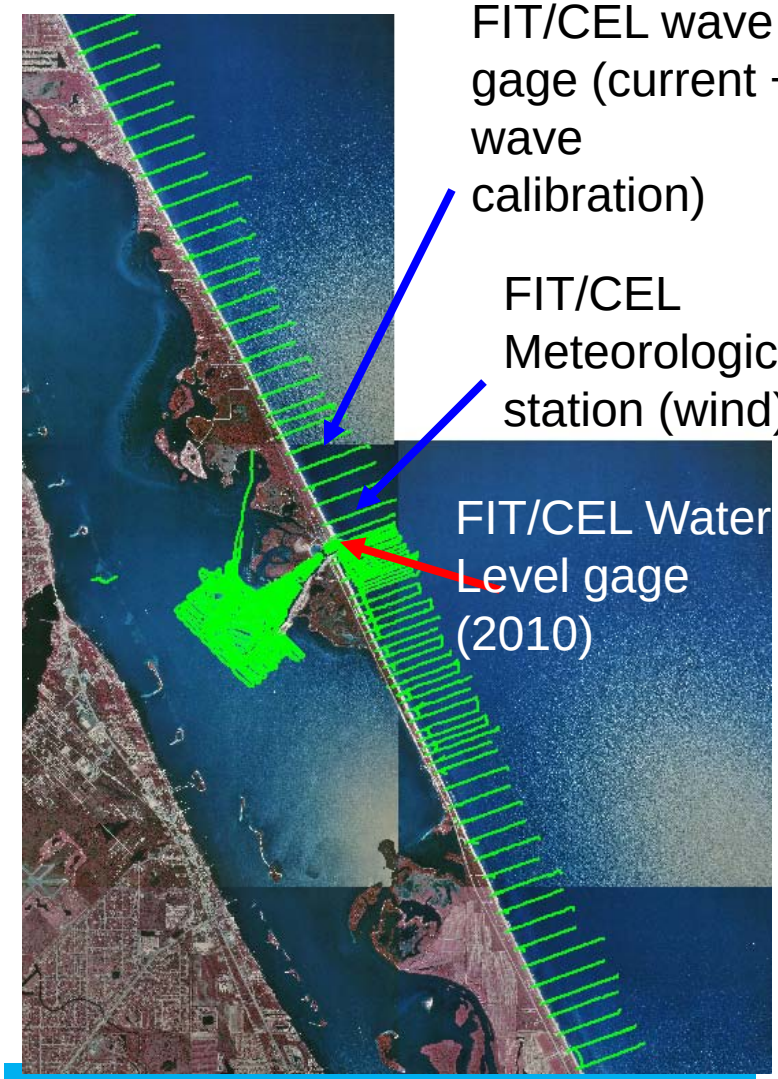
- Apply a set of numerical models from the Coastal Modeling System to understand sediment transport and the induced morphologic changes over various time scales at Sebastian Inlet

- <u>Morphological modeling:</u>
  - Coupled hydrodynamic/wave model (CMS-Flow & CMS-Wave)
  - Long term runs with update in bathymetry every 6 months
  - Effect of hypothetical modifications

- <u>Wave modeling on the ebb shoal:</u>
  - Wave propagation
  - Wave breaking

Data available

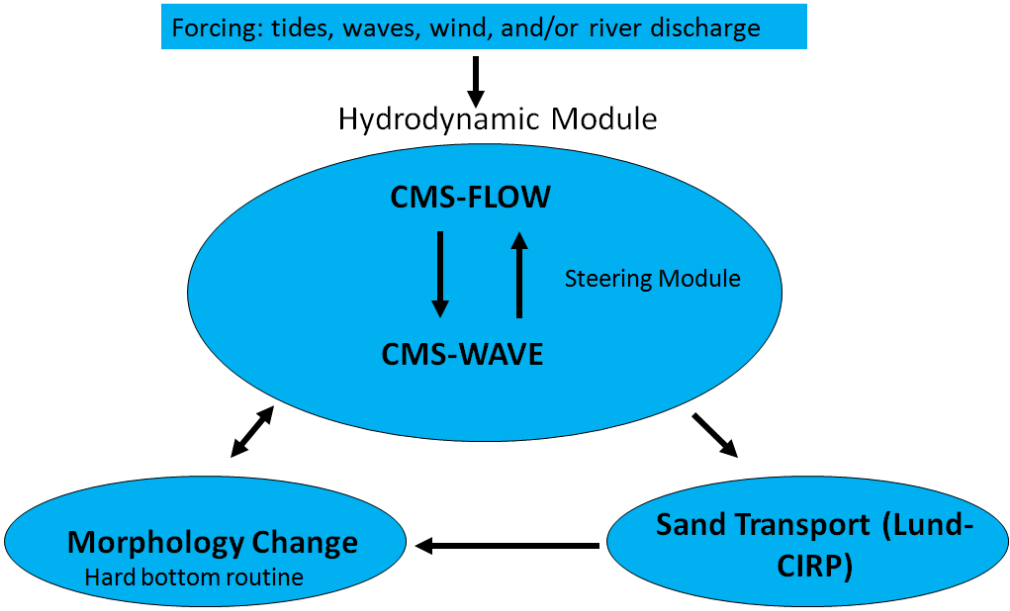
- High resolution bottom topography from semiannual surveys (SITD) from summer 1990 to summer 2009 (Florida State Plane East NAD27– NGVD29):
  - Model grid generation
  - Calibration and validation of morphology change calculations
- Aerial Images (1943 to 2009):
  - Digitize Shoreline and nearshore reef/hard bottom features
- Waves and Water Levels:
  - Measured (FIT/CEL)
  - Hindcast (CMS-WAVE using WW3 inputs)
- Meteorological station (FIT/CEL): wind speed and direction
- Hard bottom (RoxAnn) coverage (FIT)



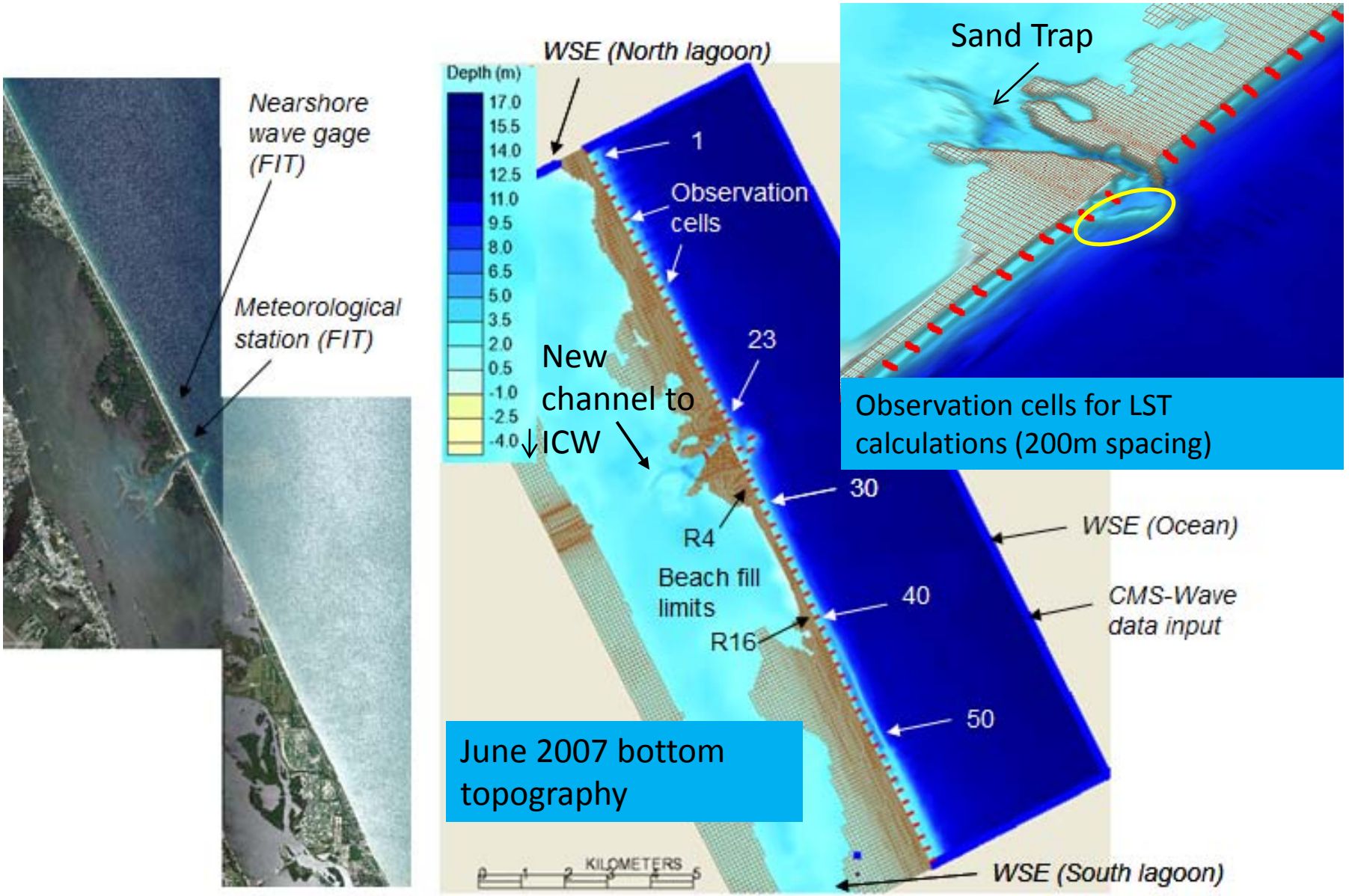
Extent of 2007 winter hydrographic survey and equipment location

The Coastal Modeling System (CMS)

- Coastal Hydraulics Laboratory (CHL), USACE
- Full integration of wind, wave, circulation, sediment transport, and morphologic change in numerical simulations
- Interfaced through Surface Water Modeling System (SMS)
- Coupling of circulation and wave models through steering module
- Models used: CMS-Flow, CMS-Wave,BOUSS2D

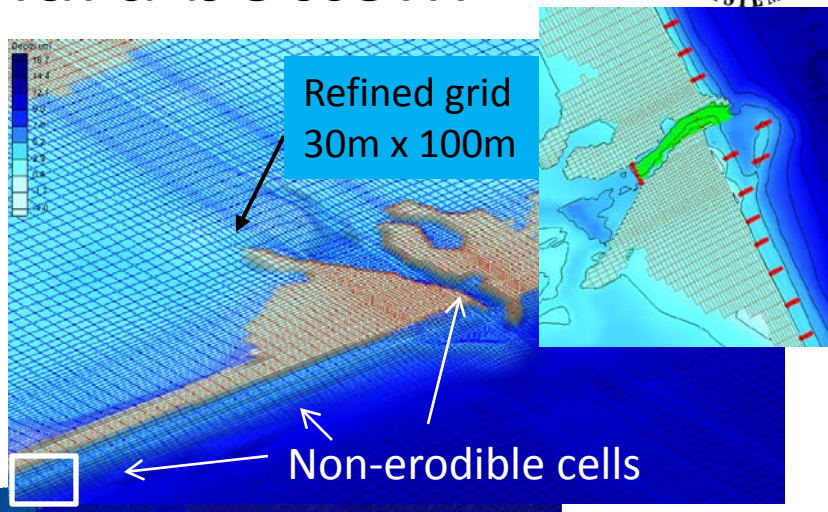


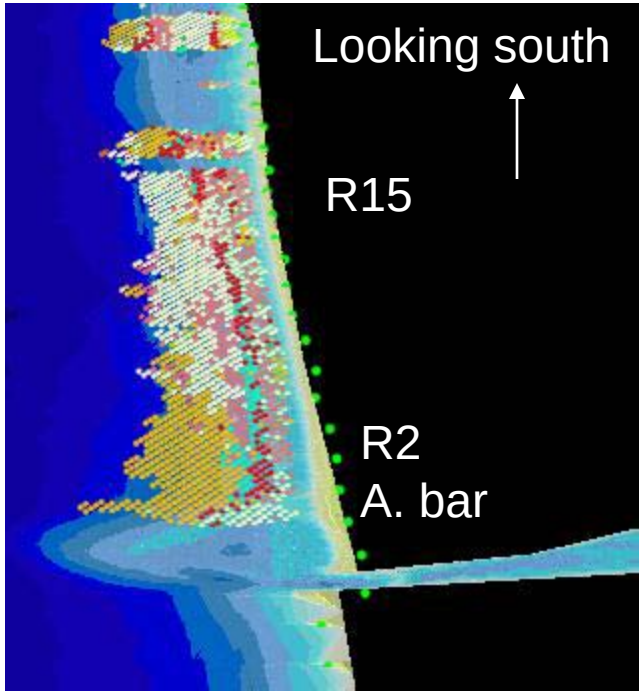
Morphological model domain

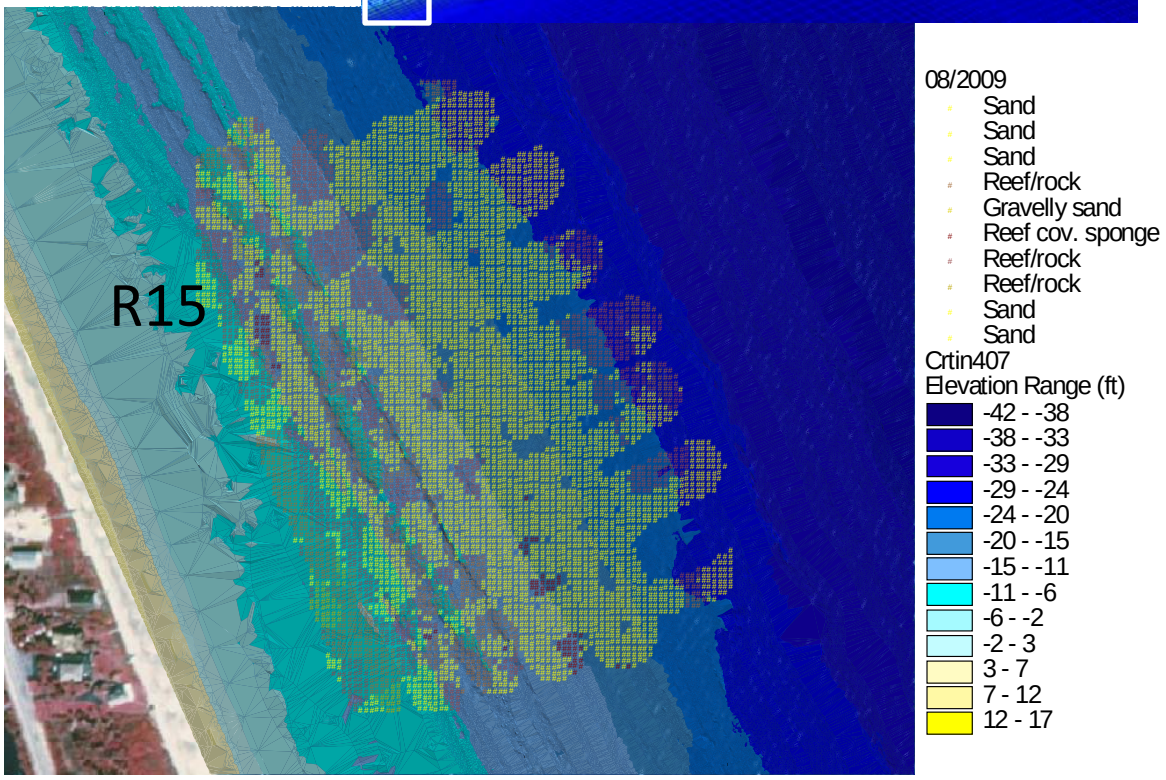


Representation of hard bottom

- Recent field data (RoxAnn)
- Coverage includes R2 to R30 (3 surveys between June and September 2009)
- Import shapefile into SMS and tag cells as non-erodible

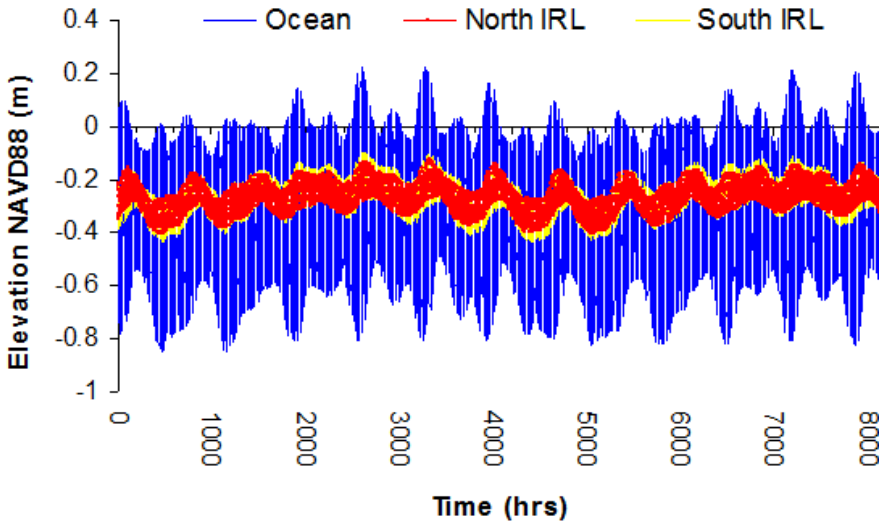




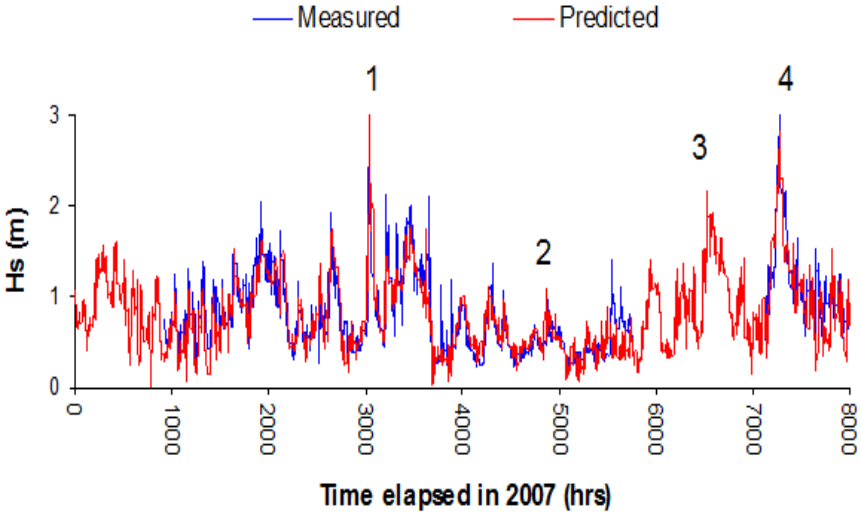


Boundary conditions: 2007 runs

Water surface elevation (WSE) time series input (2007)



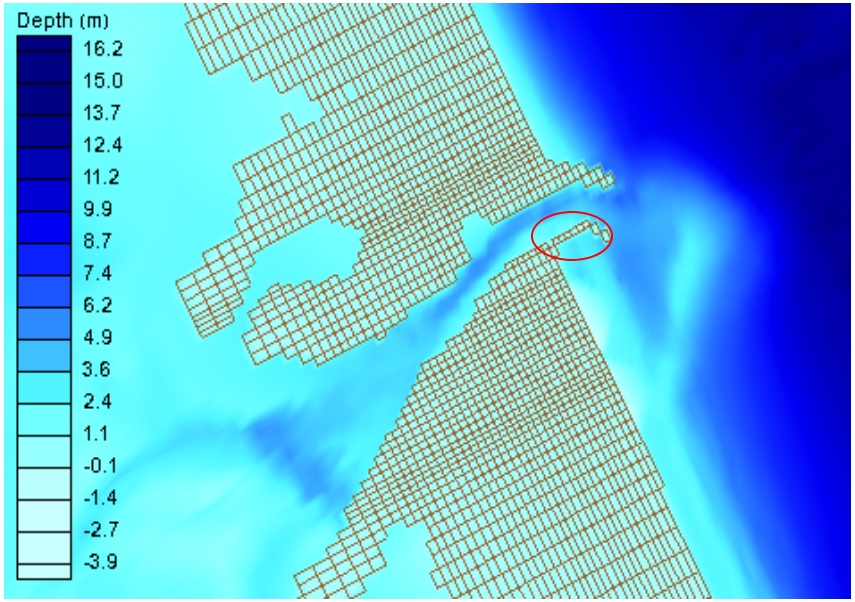
Significant wave height (Hs) time series input (2007)



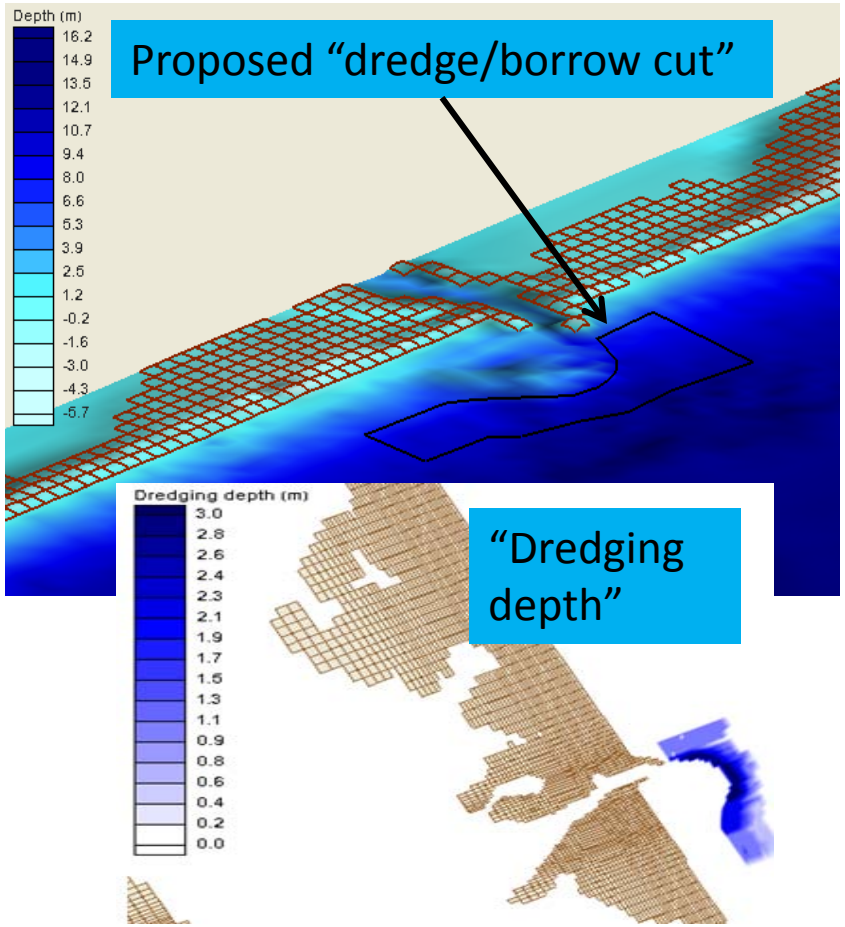
1. *Sub-tropical storm Andrea*
2. *Hurricane Dean*
3. *"Wind chop" event*
4. *Hurricane Noel*

Proposed engineering modifications

1. South jetty extension
(Approx. 100m, parallel to North jetty)

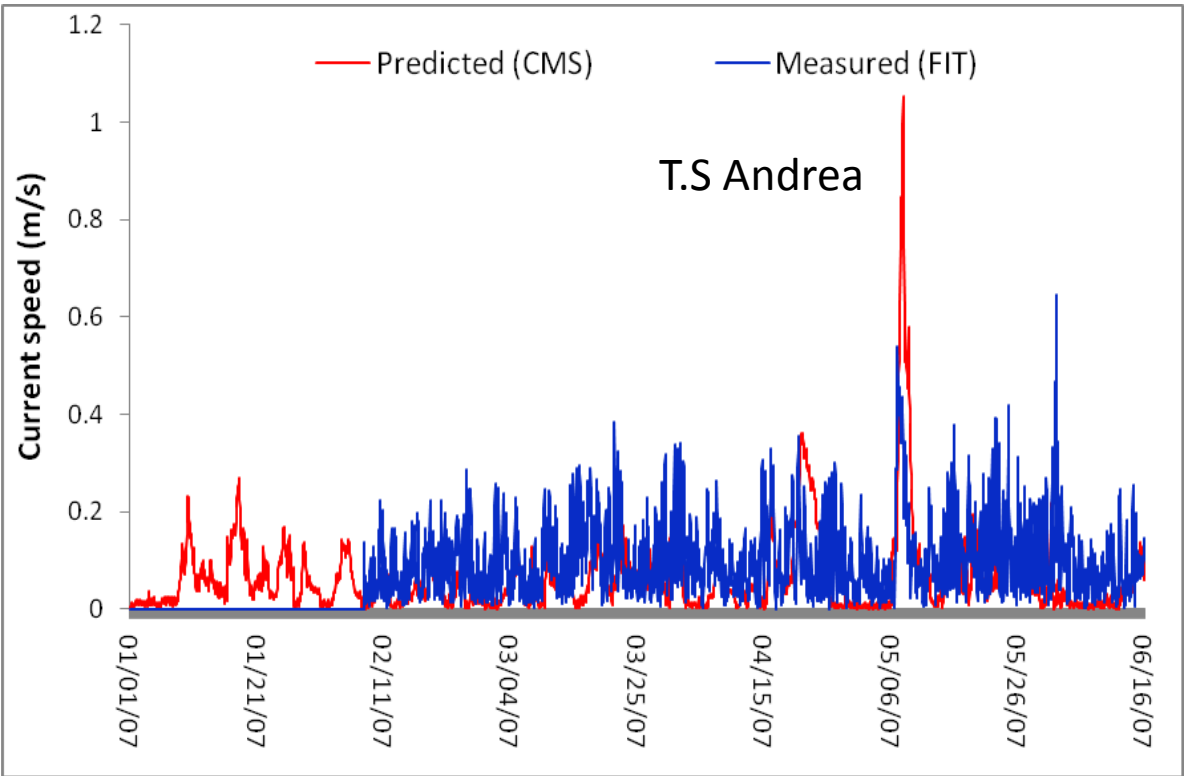


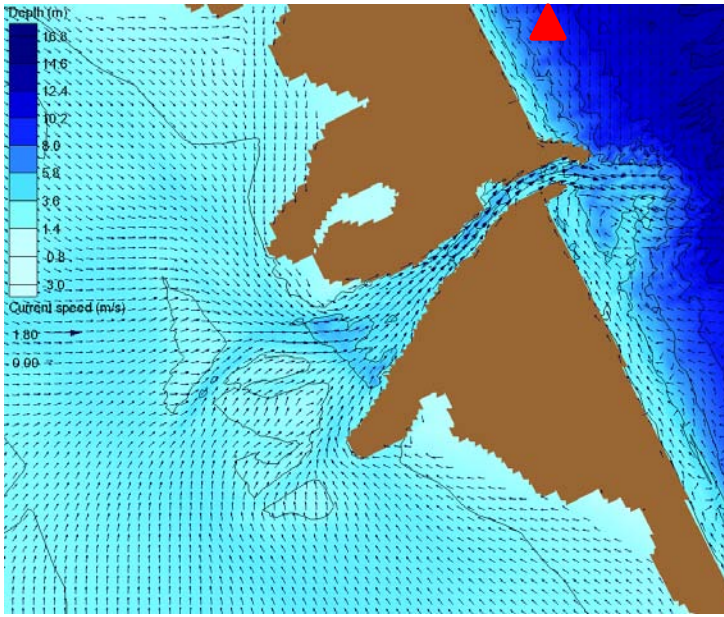
2. Ebb-shoal dredging
(Approx. 300,000 cy)

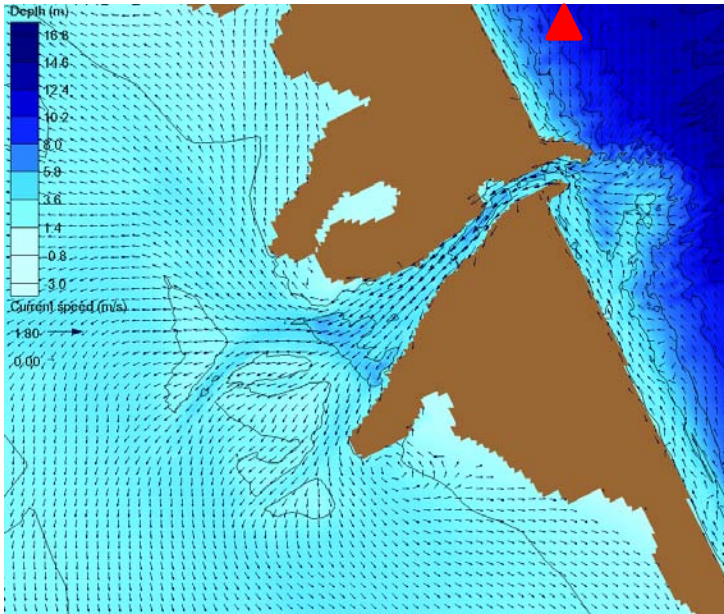


Model calibration

- Hydrodynamics (current, water levels) -FIT gages
- Waves – FIT gages
- Morphology change & Volumes (SITD)

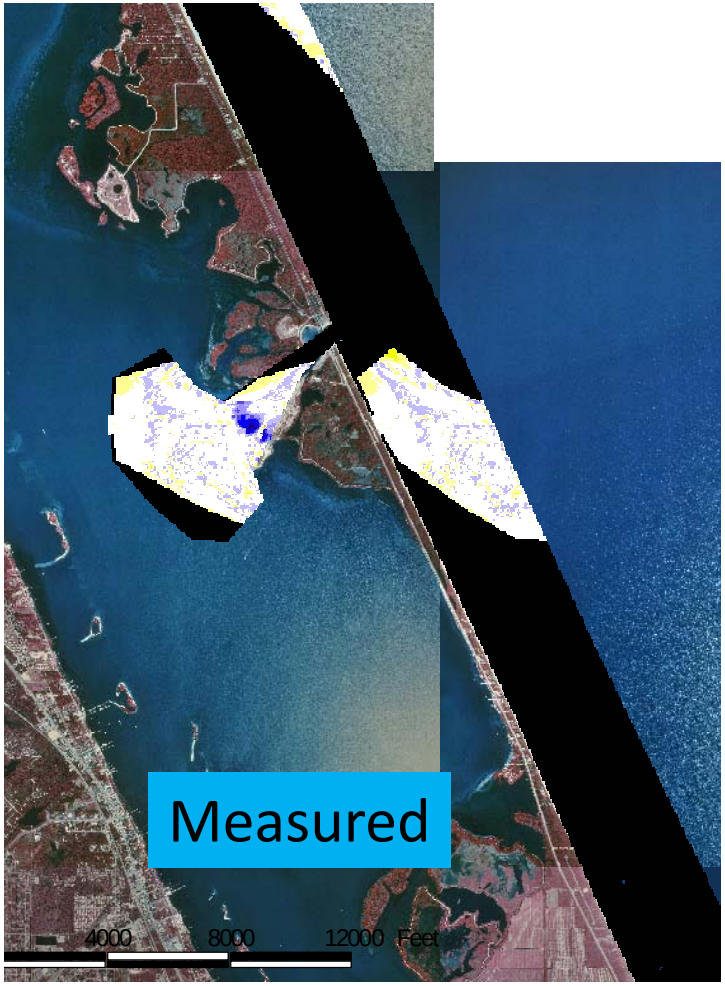


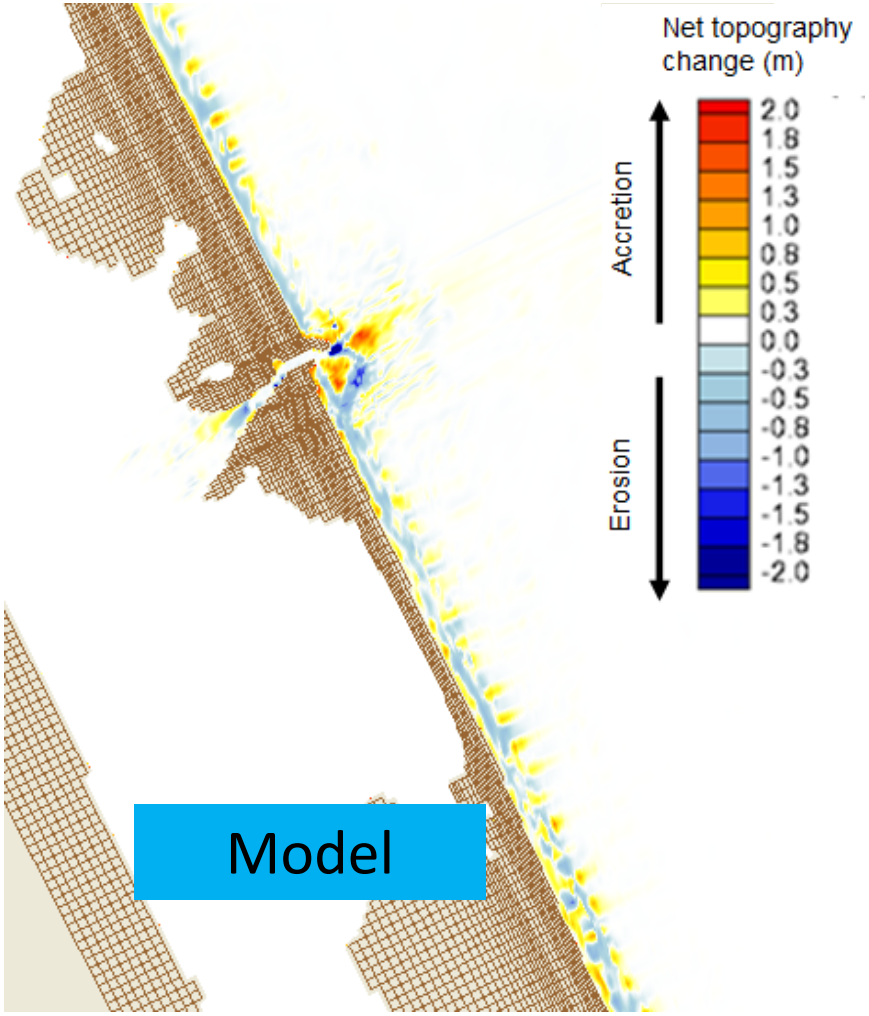




Long -Term bottom topography changes

January to June 2007

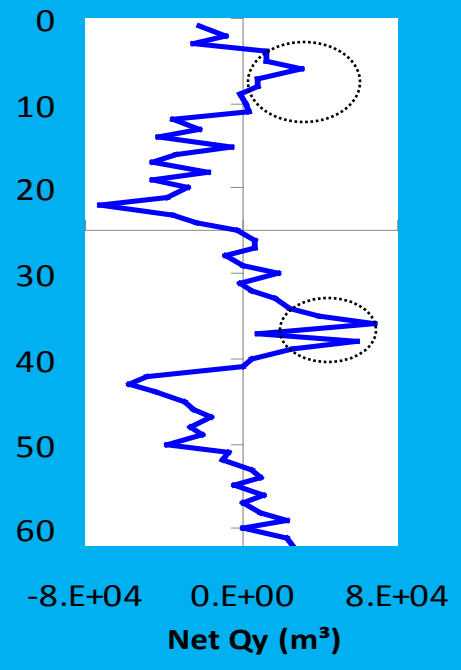


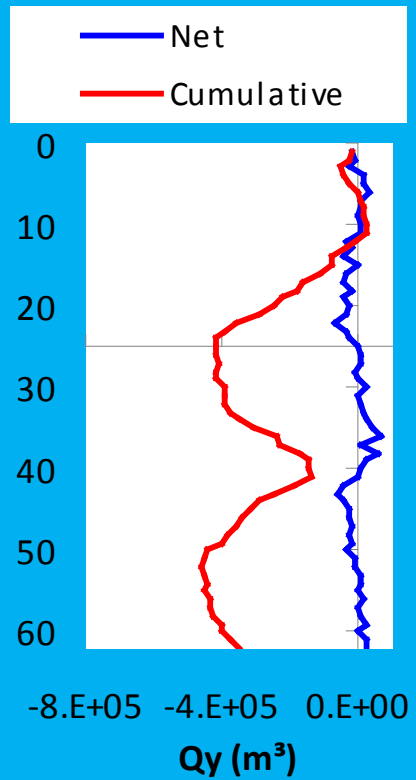


Littoral sand transport

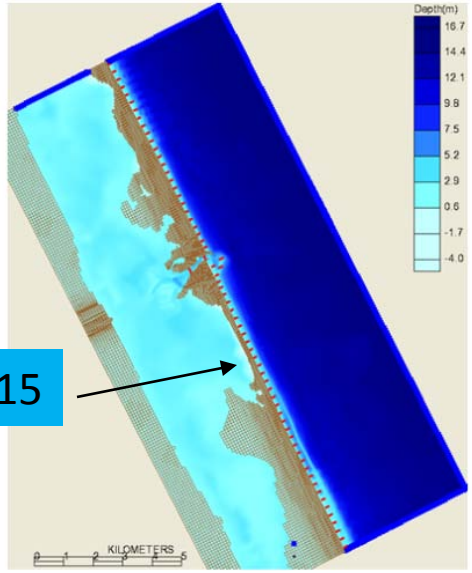
January to June 2007

Reversals



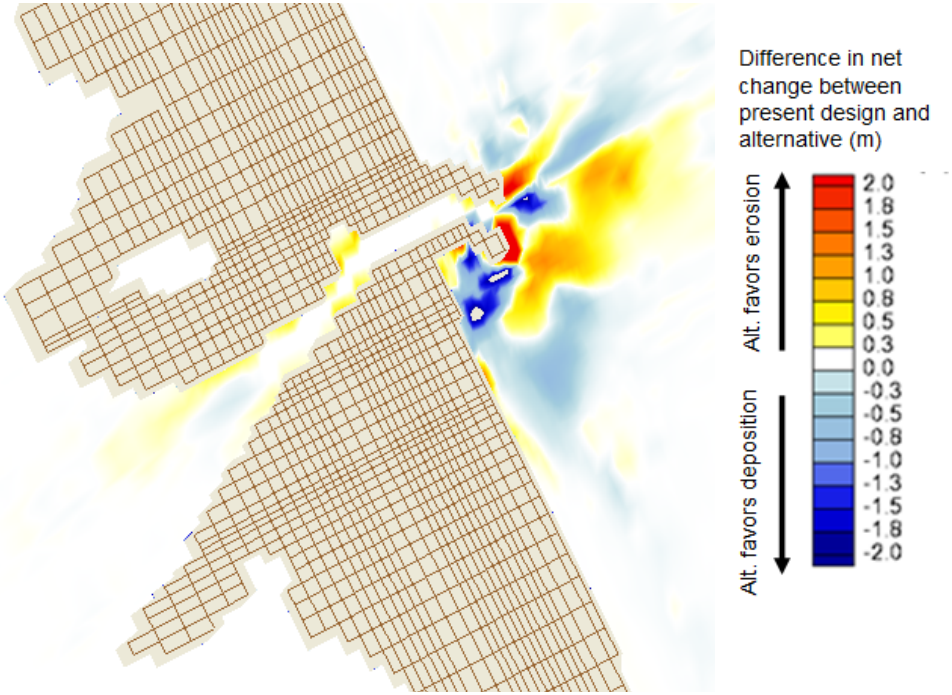


Q_y

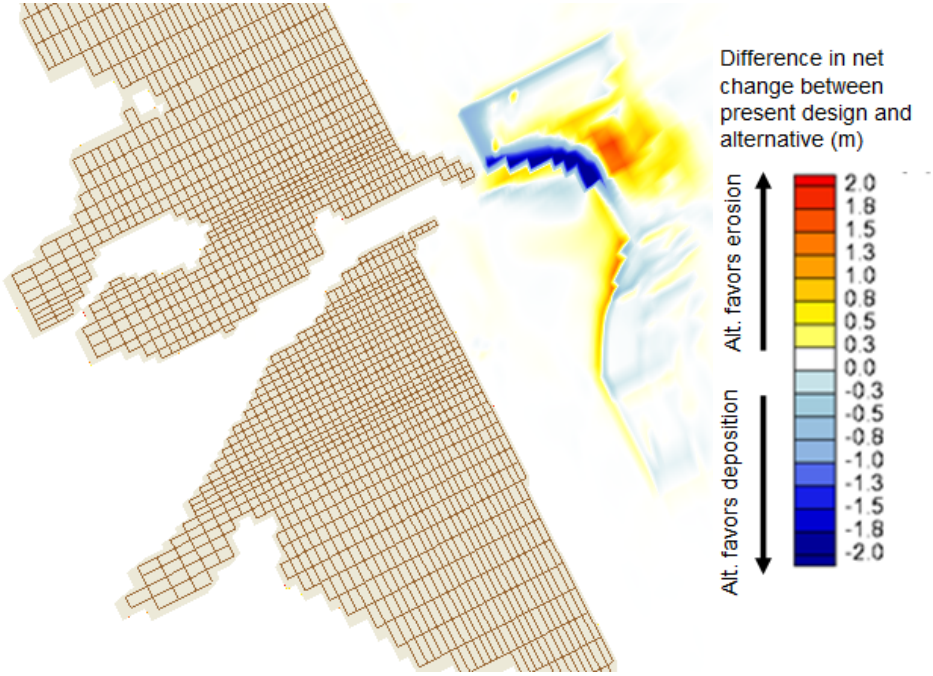


R15

Differences in net topography change due to proposed modifications (January to June 2007)

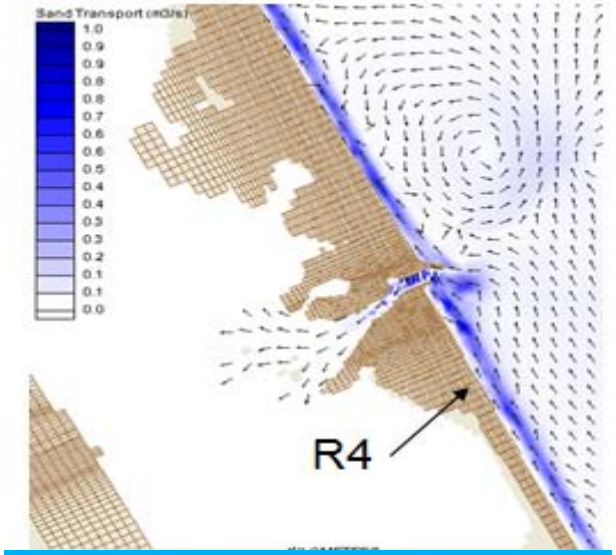


South jetty extension case

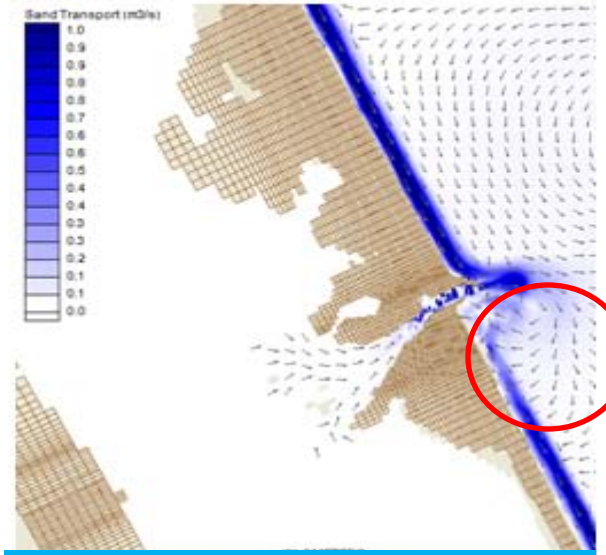


Dredging case

Snapshots: sand transport patterns

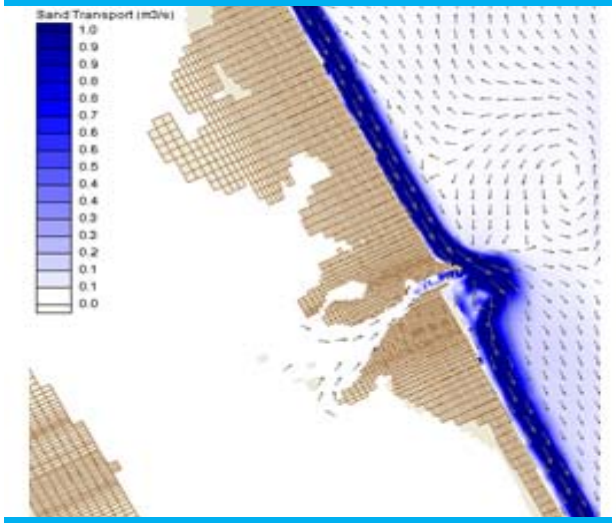


Hurricane Dean

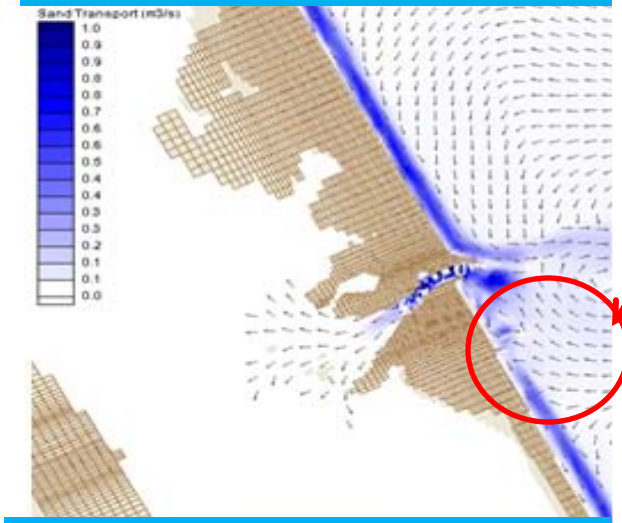


S.T.S. Andrea

reversals in littoral transport



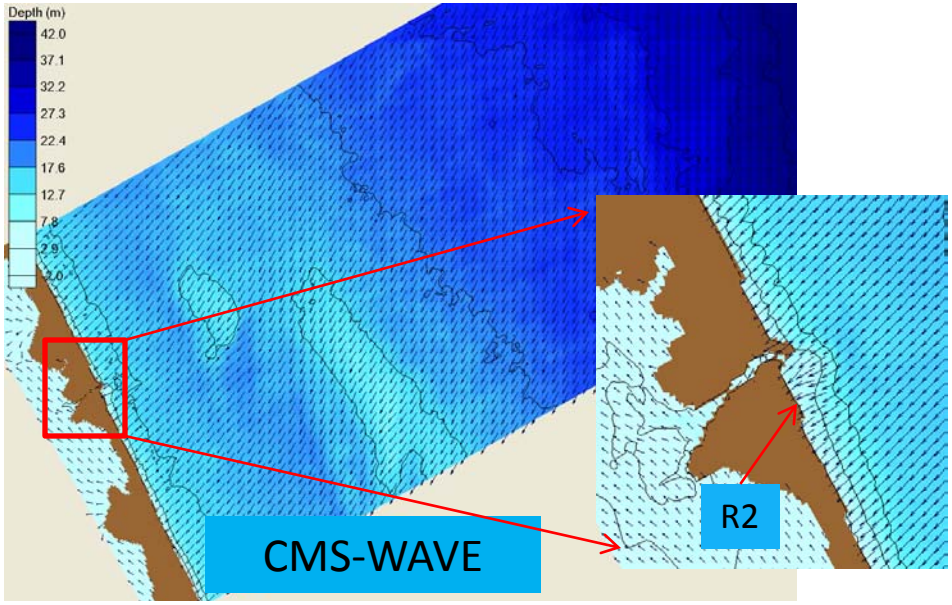
Hurricane Noel

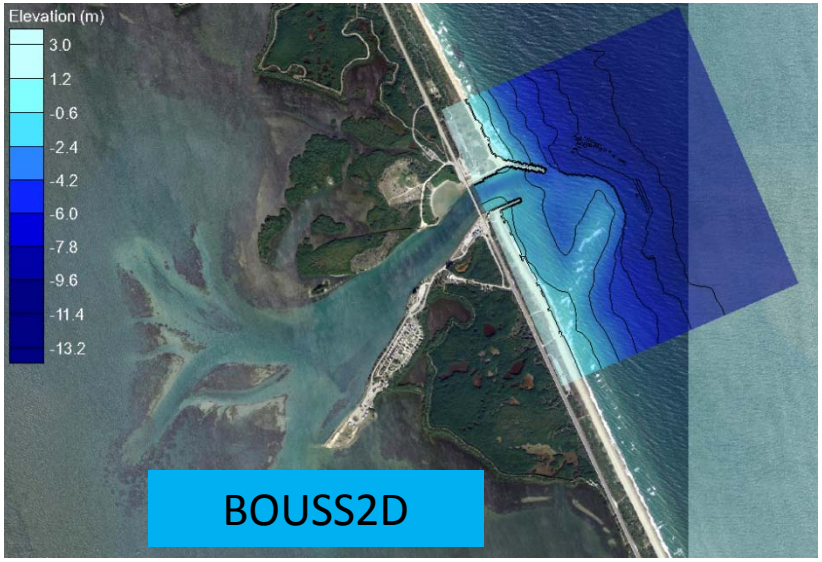


Wind chop

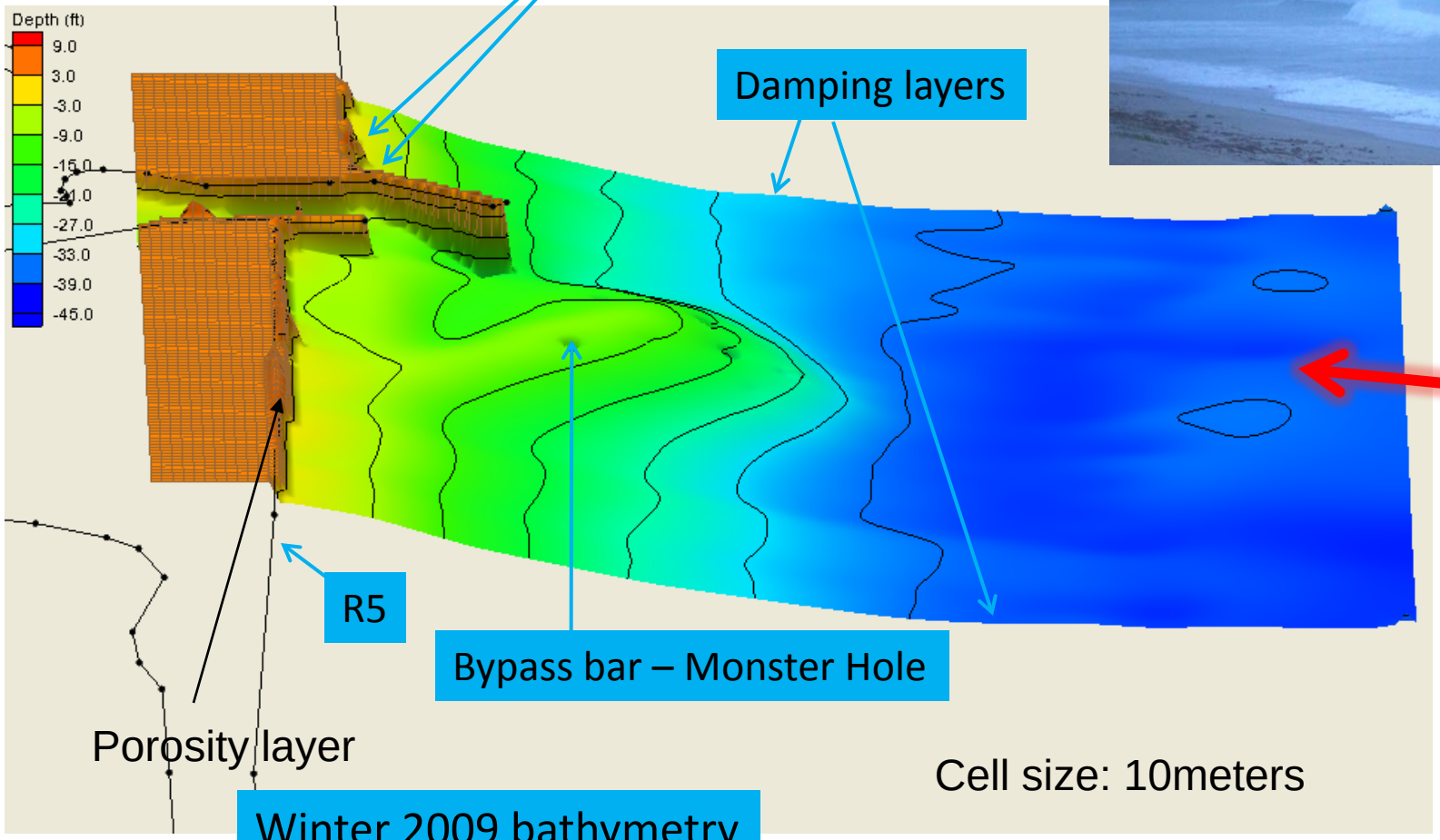
BOUSS2D: model description and limitations

- Phase resolving, finite difference method
- Shoaling, refraction, diffraction, reflection and transmission, non-linear wave interactions, wave breaking and dissipation…
- Periodic (regular), non periodic (irregular), uni-directional or multi-directional sea states
- Damping and Porosity layers
- <u>Limitations:</u>
  - spilling breaker type
  - Lack of field measurements around ebb shoal





Example set-up: Hurricane Bill



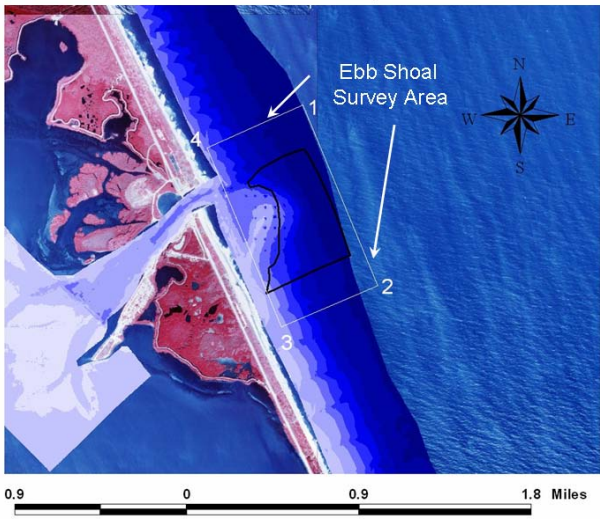
Wave maker

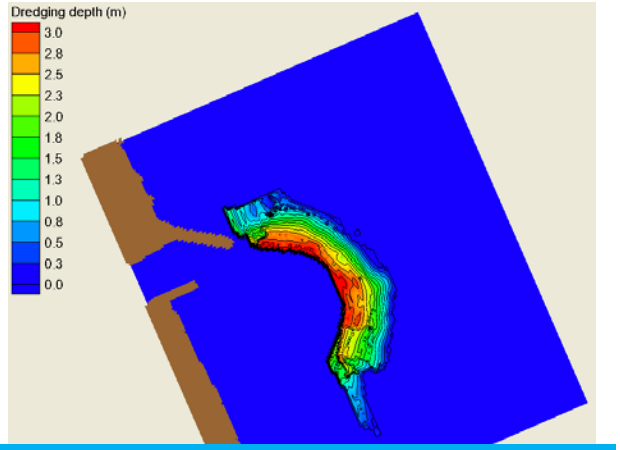
Hs = 2.5m
Tp = 17 sec
Dp = -15˚

Hurricane Bill: wave propagation

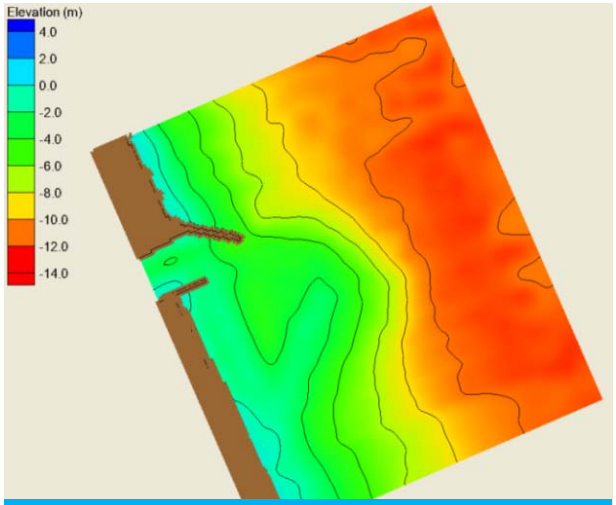
Hurricane Bill: wave breaking

BOUSS2D representation of ebb shoal dredging scenario

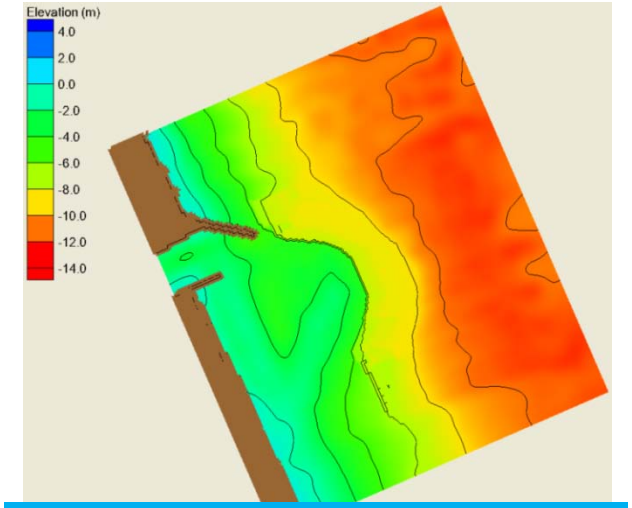




Model grid representation of the proposed dredge cut (~400,000cy)

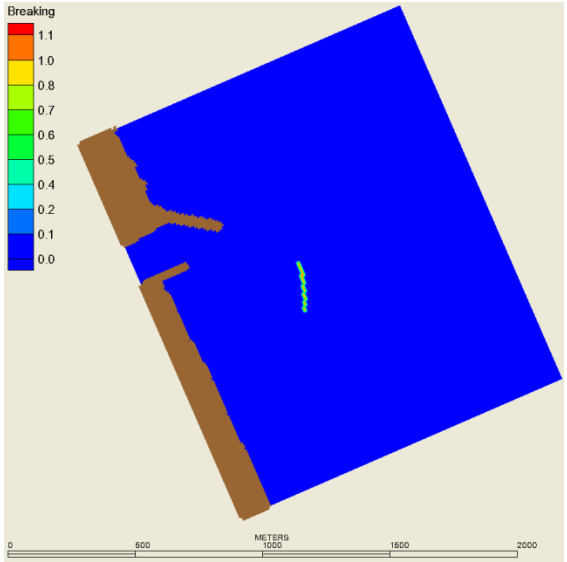


BOUSS2D run under existing bathymetry (winter 2008)



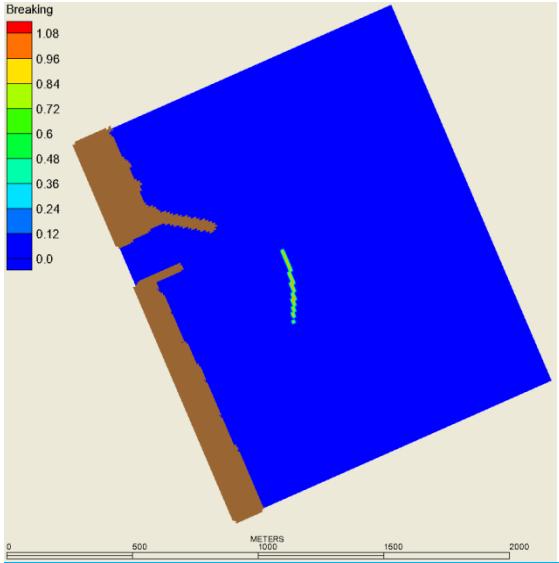
BOUSS2D model run under modified bathymetry (after dredge cut)

Effect of dredging on wave breaking

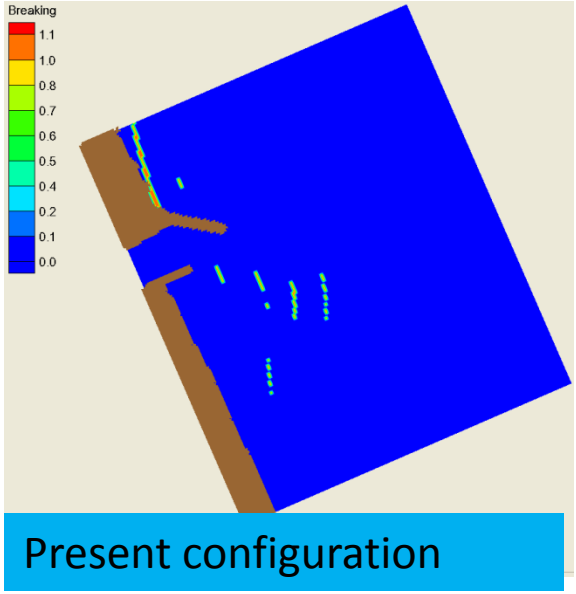


Present configuration

t_1

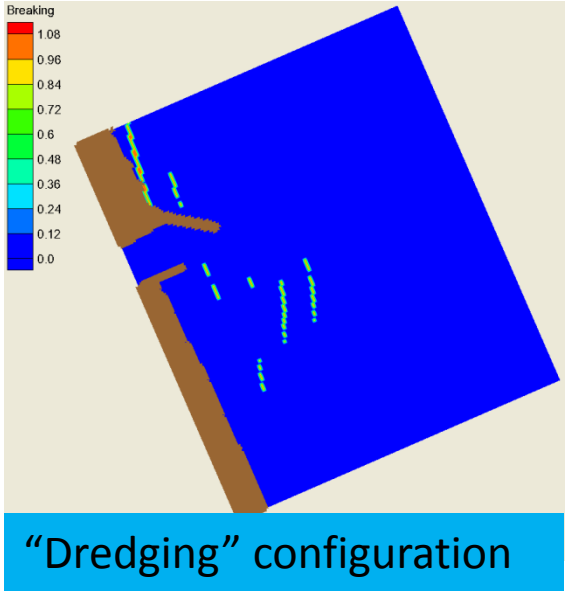


"Dredging" configuration



Present configuration

t_2



"Dredging" configuration

Summary

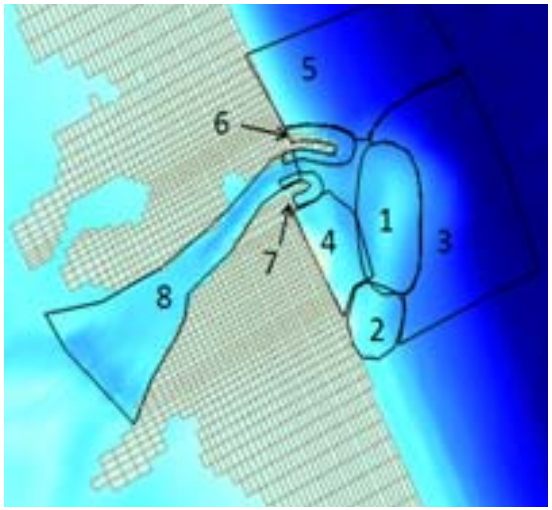
- Morphologic model:
  - Successfully reproduced long term sedimentation patterns
  - Complex reef interactions south of R5
  - Long term transport to the south BUT reversals in transport direction (R15)

- Potential effect of modifications:
  - Dredging: deposition in dredge cut, decrease in bypassing
  - South jetty extension: increase scour at tip of jetties, deposition on south jetty beach

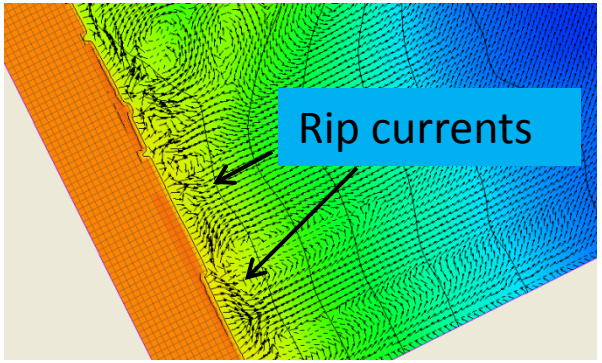
- BOUSS2D model:
  - Successfully reproduces wave propagation and breaking over ebb shoal
  - Wider breaking zone under dredging case: more close-outs ?
  - Morphologic evolution is very important (deposition in dredge cut)

Ongoing Work

- Additional model calibration
- Long term runs from 2004 to 2009
- Evaluate model performance (skill)
- Interactions with nearshore reefs, rip currents
- BOUSS2D runs under multiple wave conditions and also irregular waves (uni- and multi- directional)
- Update BOUSS2D bathymetry with outputs from CMS runs under dredging case
- Calculate ebb-shoal seabed gradient evolution (1990 to 2009)



Volume calculations



Questions ?