Simulation of Long-Term Shoreline Changes near Indian River Inlet on the Delaware Coast

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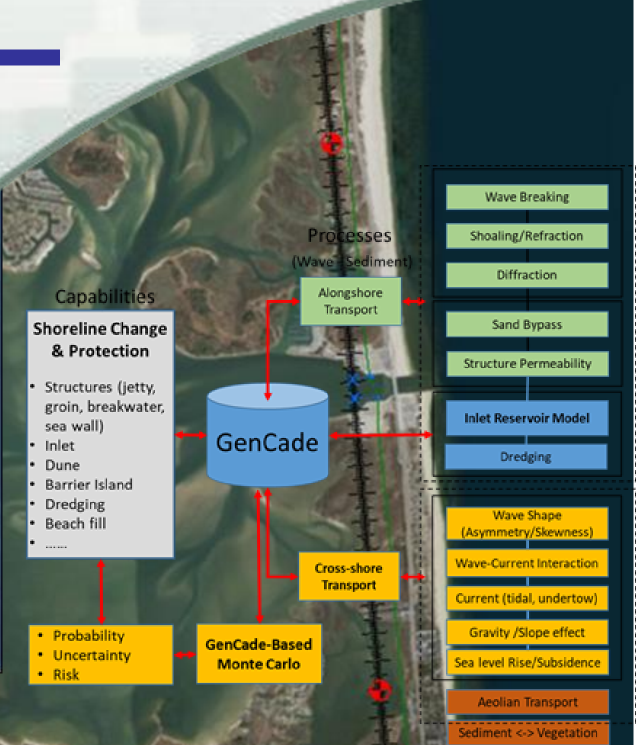
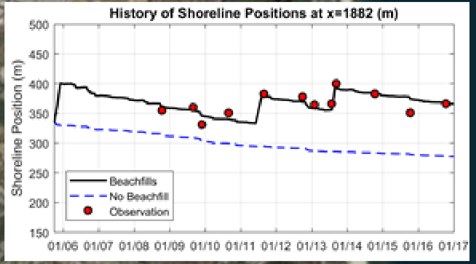
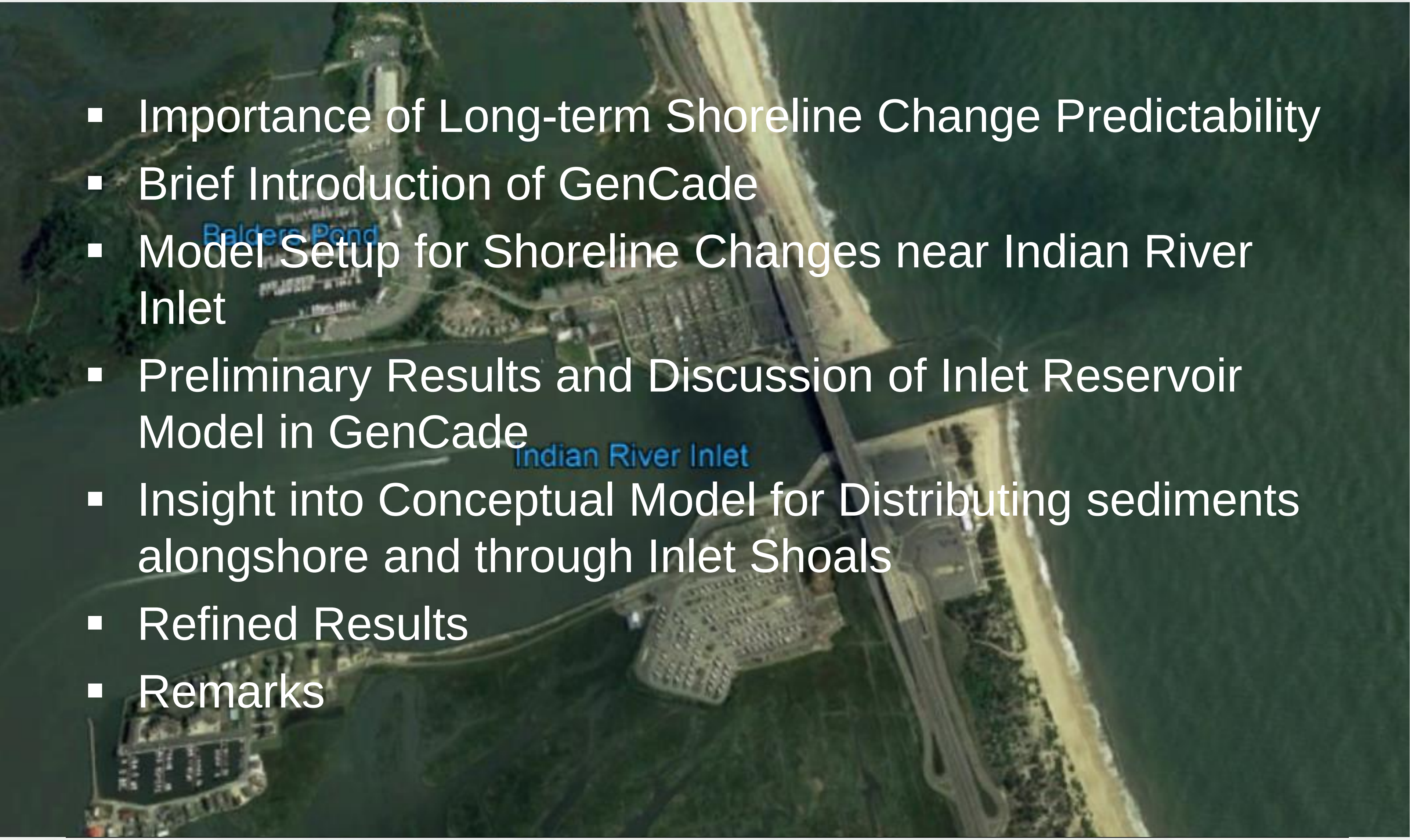


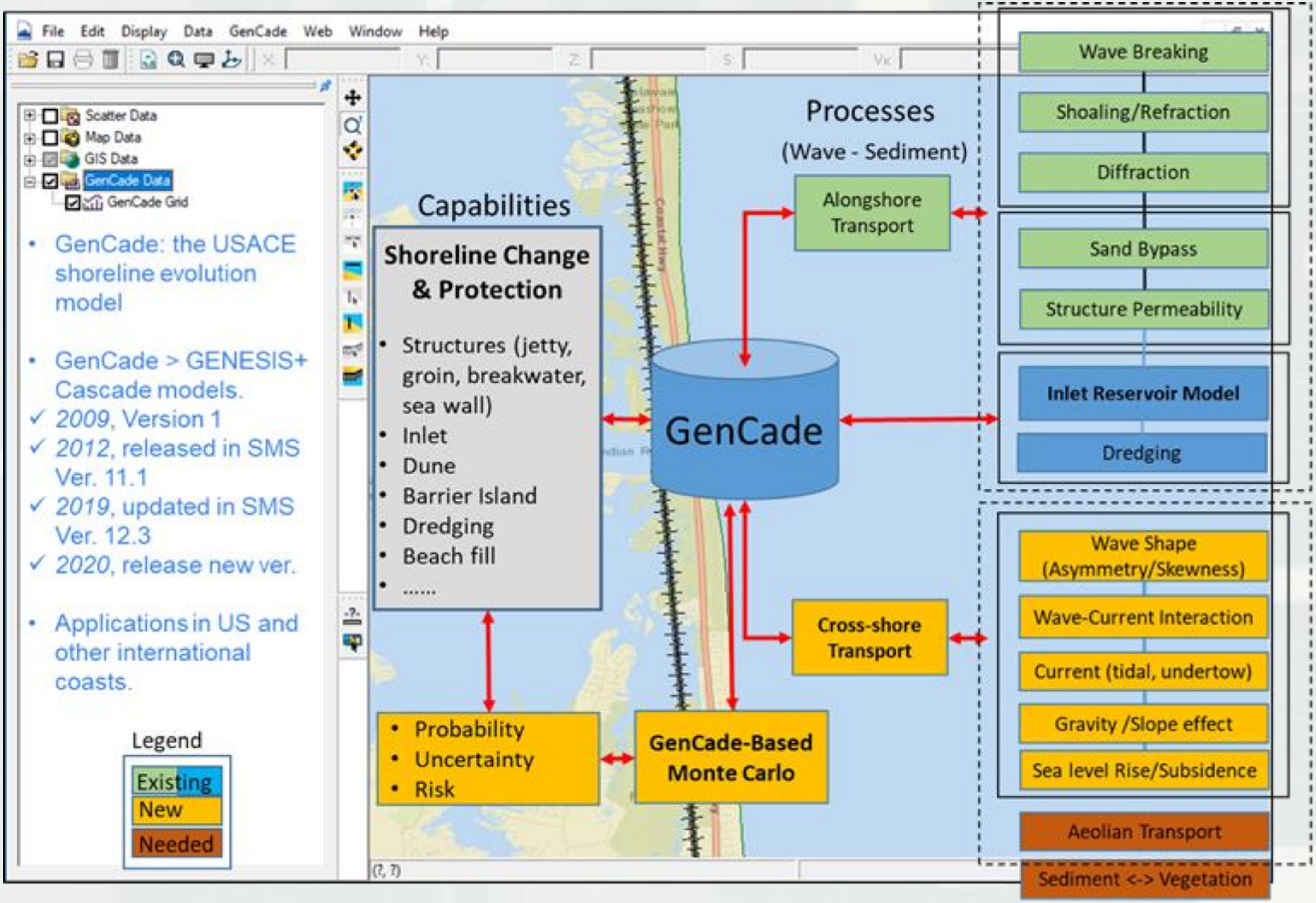


Outline



- Importance of Long-term Shoreline Change Predictability
- Brief Introduction of GenCade
- Model Setup for Shoreline Changes near Indian River Inlet
- Preliminary Results and Discussion of Inlet Reservoir Model in GenCade
- Insight into Conceptual Model for Distributing sediments alongshore and through Inlet Shoals
- Refined Results
- Remarks

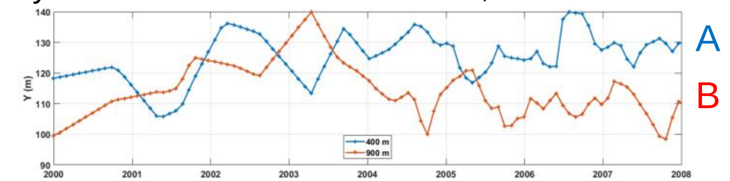
GenCade:
USACE Shoreline Evolution Simulation Model



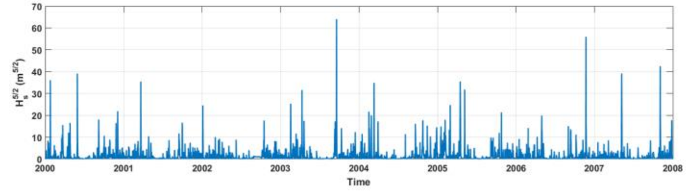
Long-Term Shoreline Changes

- Prediction of long-term shoreline changes is a key task in coastal management practice.
- Multiple physical processes drive shoreline changes: wave, wind, tide, storm, current, **sea level change/subsidence**, sediment properties, **longshore/cross-shore sediment transport**, **human activities** (structure installation, beach refill, beach recreation),etc.
- Shoreline changes induced by natural physical processes in general are highly irregular.
- **Probabilistic shoreline change prediction** is needed for best shoreline management practice for long-term protection purpose.
- **Uncertainty estimation** of shoreline changes is required for best shoreline erosion control management.

History of Shoreline Positions in Duck, NC



Wave Climate



Shoreline Change due to Coastal Management Practices

- Construction or modification of inlets for navigational purpose
- Construction of harbors with breakwaters built in nearshore regions
- Beachfills (sand nourishment)
- Sand Bypass
- Sand Mining
- Dredging Material Disposals

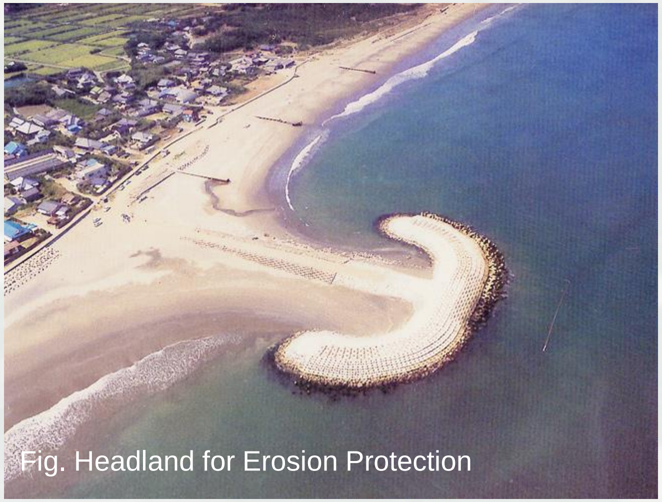
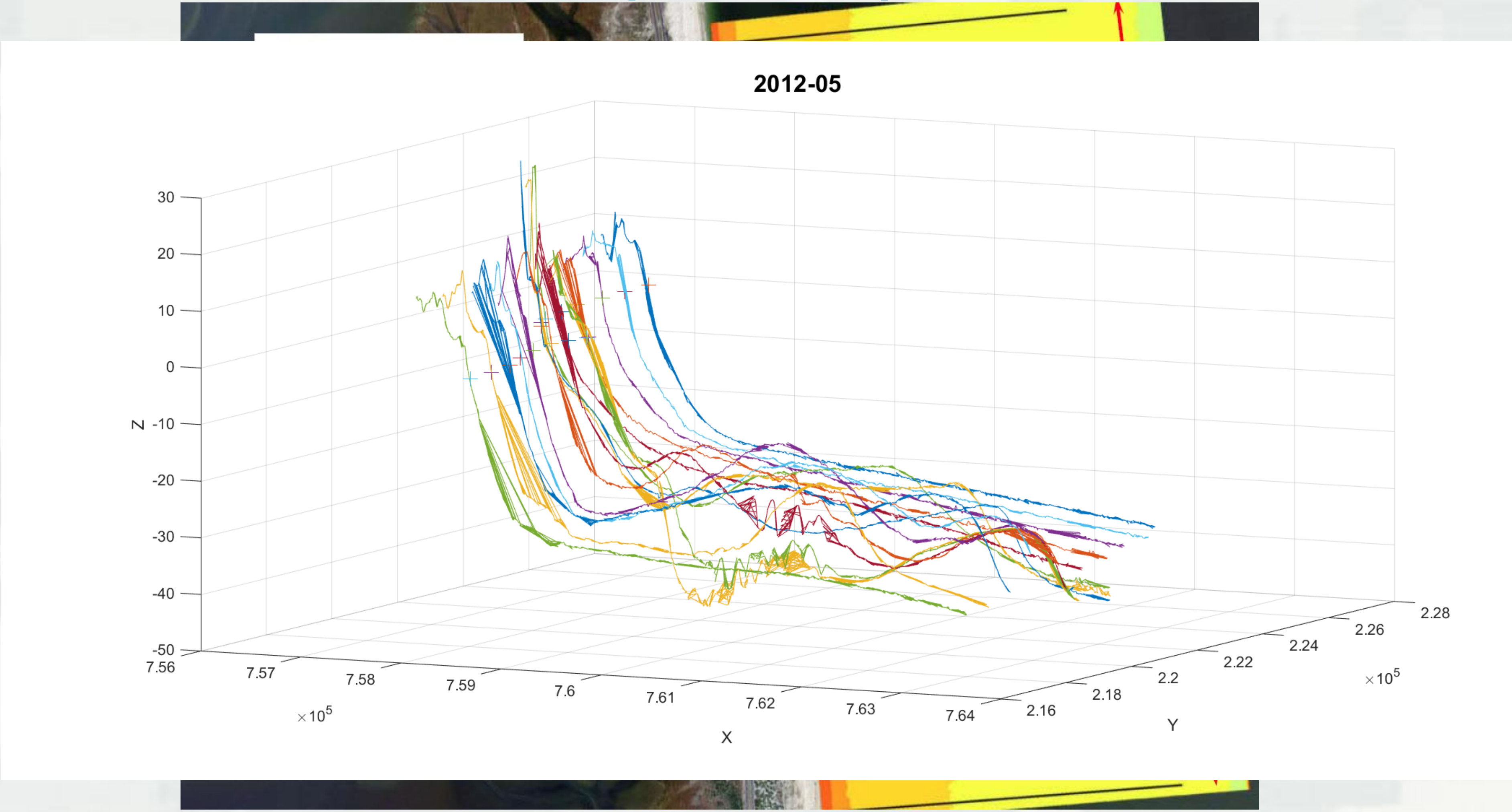


Fig. Headland for Erosion Protection

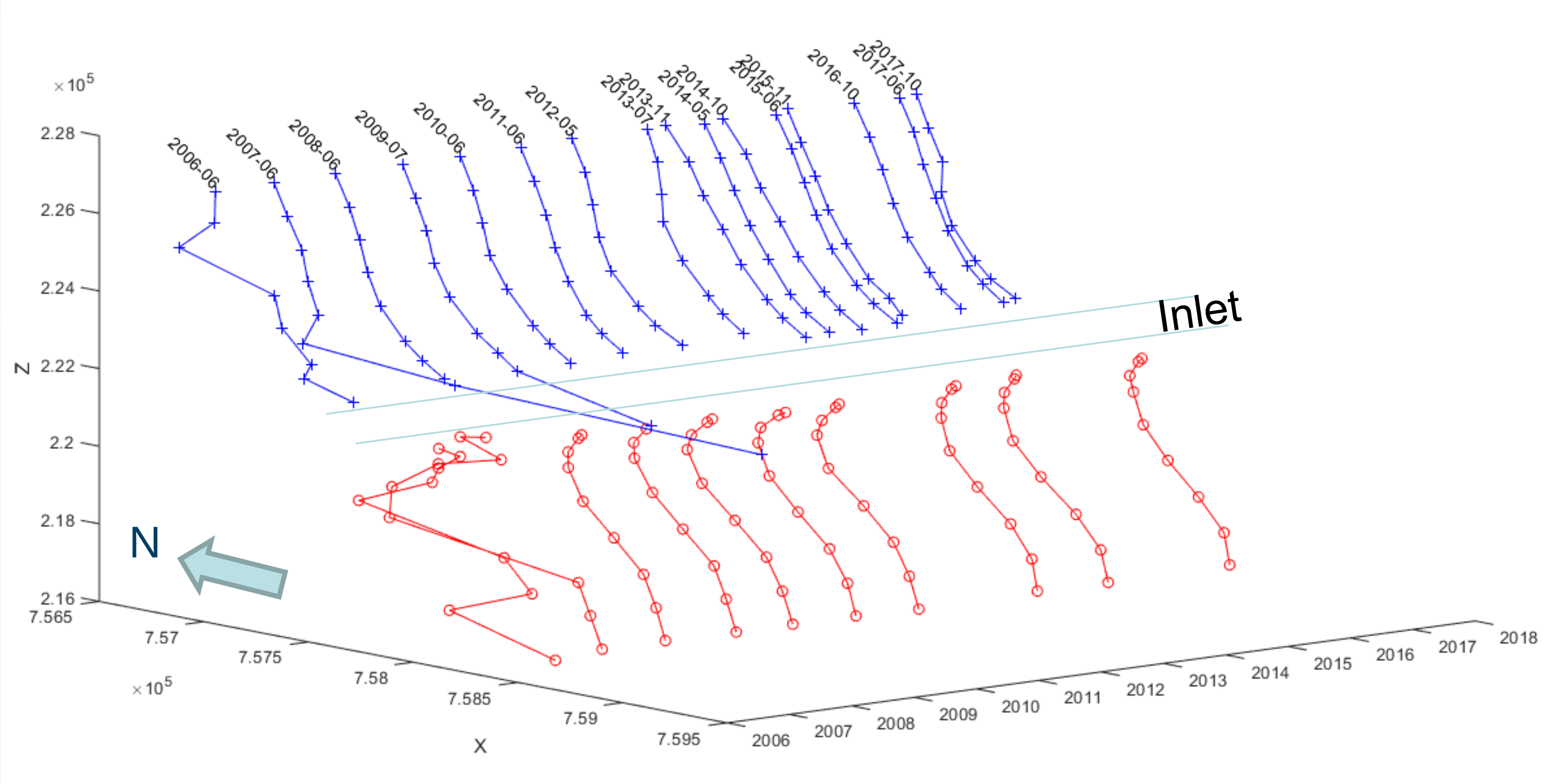
Fig. Sand Bypass in Indian River Inlet, DE

Transect Survey Data in Coasts near Indian River Inlet (2005-2017)

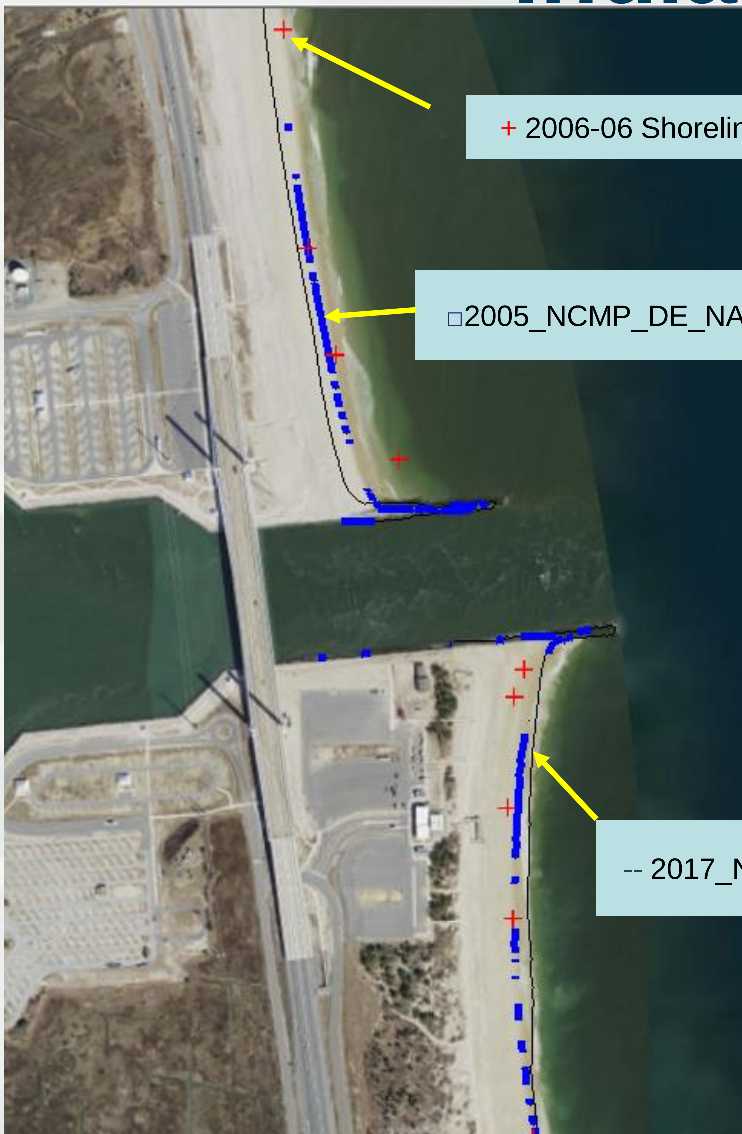


Gebert (2006), presentation in ASBPA 2006

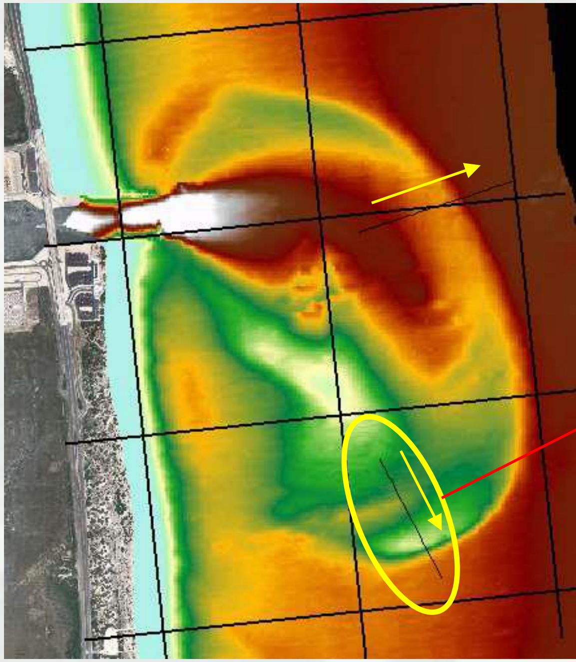
Historical Shoreline Changes Near Indian River Inlet

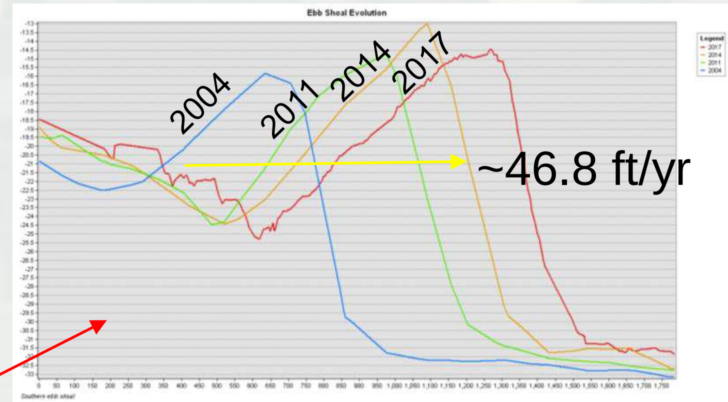


Historical Shoreline Changes Near Indian River Inlet



Indian River Inlet Shoal Evolution





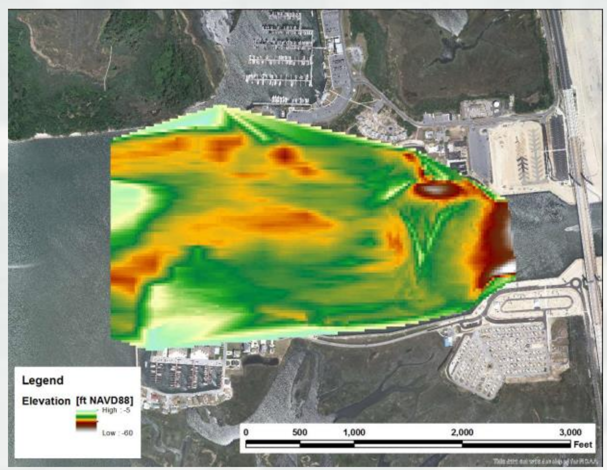
Southern Outer Ebb Shoal Evolution

Ebb Shoal Volume (V_e)?
~4.0 Mcy in 2017 (Hayden?)
~4.7 Mcy in 2017 (Mann et al. 2017, CB&I)

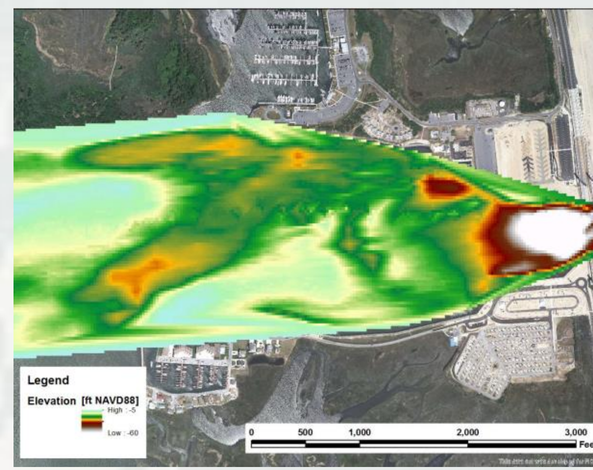
Equilibrium (V_{eq}): ~7.0 Mcy (Larson et al. 2006)

Flood Shoal Volume ?

Jetty Length Loss Rate
North: ~6.5 ft/yr
South: ~1.0 ft/yr



2014 Flood Shoal



2017 Flood Shoal

Hayden (2017), Review of Ebb and Flood Shoal Geomorphologies, DNREC, 2017

GenCade for Modeling of Shoreline Change in Indian River Inlet

Objectives: (1) to validate the GenCade model by using shoreline survey data provided by NAP and DNREC, and (2) to evaluate sand bypass operation.

Computational Parameters

Computational Period: 12 years
2005/03/12 0:00 - 2016/12/31 0:00

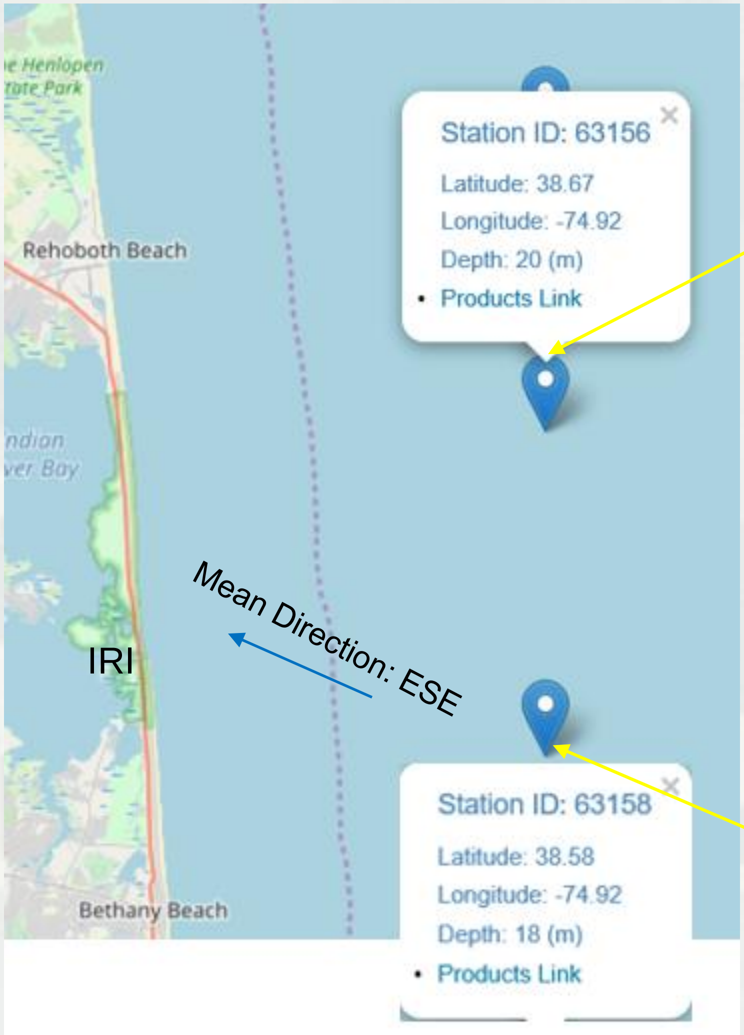
Including beach construction projects:
Sand Bypassing: 100,000 yd^3 / year
Beach nourishment: 527,850 yd^3, May-Nov 2013

Time step = 3 minutes
Grain size = 0.30 mm
Berm Height = 2.0 m
Closure depth = 10.0m
Smooth parameter = 5
No regional contour
Boundary Conditions: no moving bc
Grid Size = 25 m

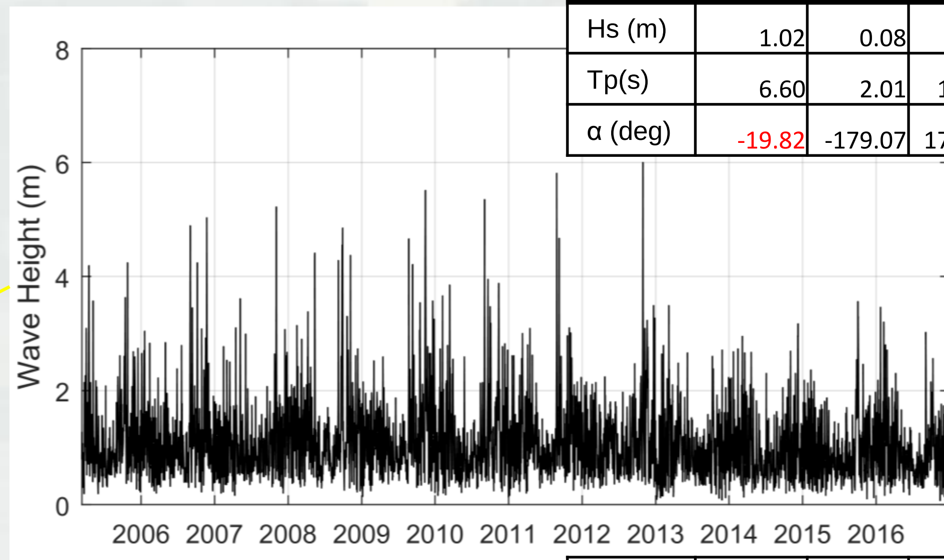
Calibrated Model Parameters:
K1 = 0.17 at the north of inlet, 0.35 at south
K2 = 0.085 at the north, 0.175 at the south

No cross-shore transport included

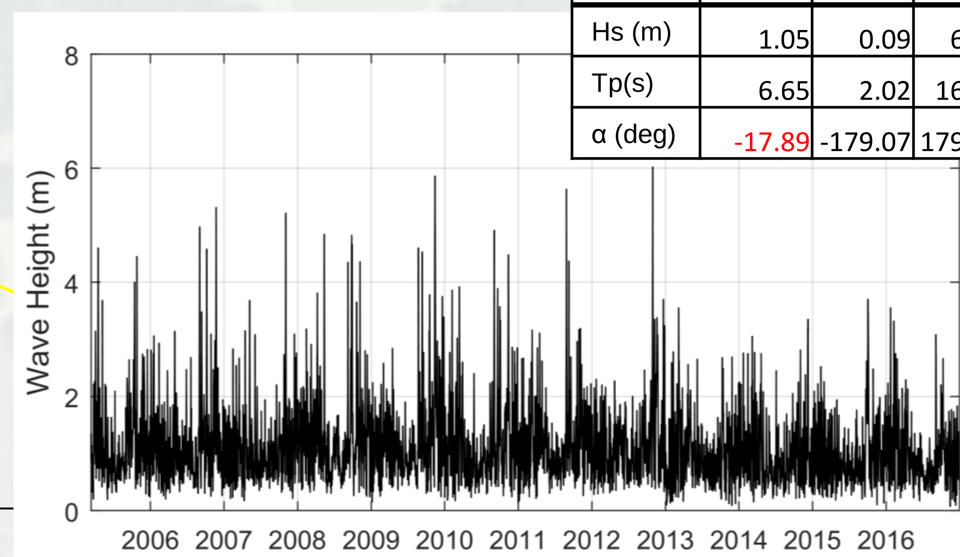
WIS Wave Conditions



Var.	Mean	Min	Max	Std
Hs (m)	1.02	0.08	6.00	0.57
Tp(s)	6.60	2.01	16.45	1.75
α (deg)	-19.82	-179.07	179.93	53.70



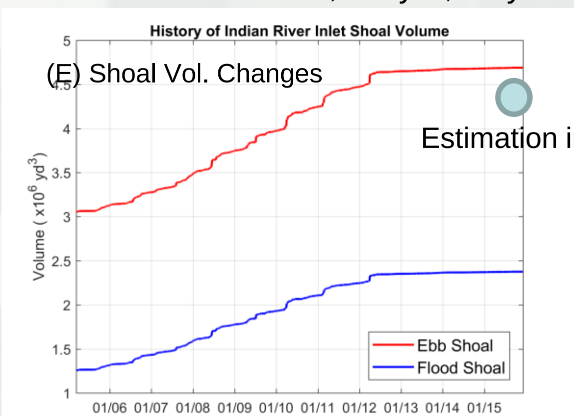
Var.	Mean	Min	Max	Std
Hs (m)	1.05	0.09	6.02	0.60
Tp(s)	6.65	2.02	16.63	1.75
α (deg)	-17.89	-179.07	179.93	51.57

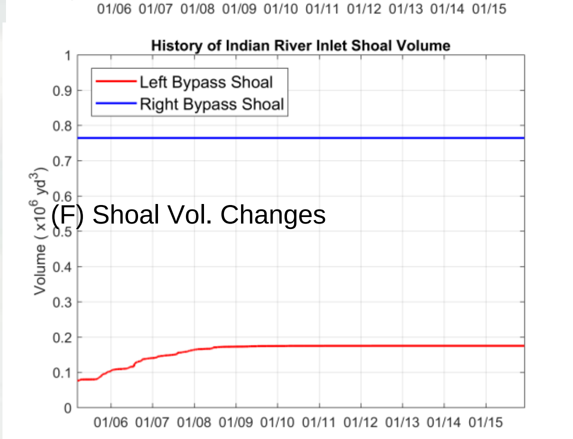


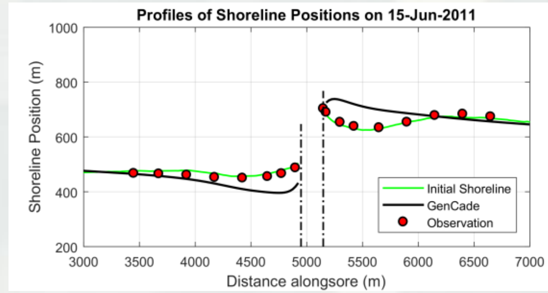
Modeling of Shoreline Change near Indian River Inlet

Objectives: (1) to validate the GenCade model by using shoreline survey data provided by NAP and DNREC (Gilbert, Eisemann, & Dunkin, 2018), and (2) to evaluate sand bypass operation.

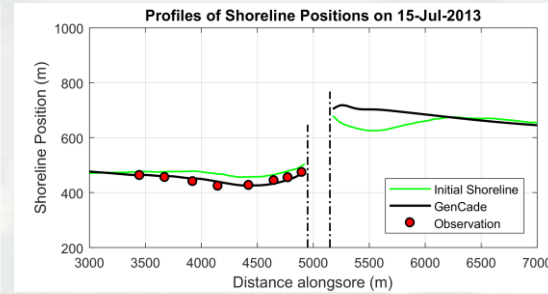
Sand Bypassing: 100,000 yd^3 / year
Beach nourishment: 527,850 yd^3, May-Nov 2013



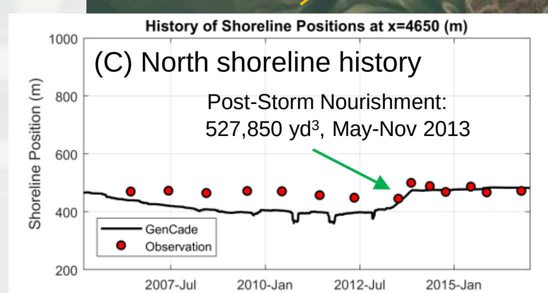


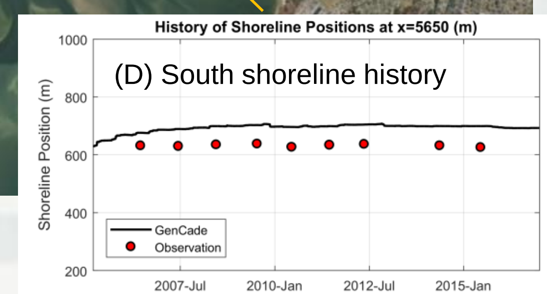


(A) Shorelines, 06/15/2011, RMSE = 45.84 m



(B) Shorelines, 11/15/2013 RMSE = 8.58 m



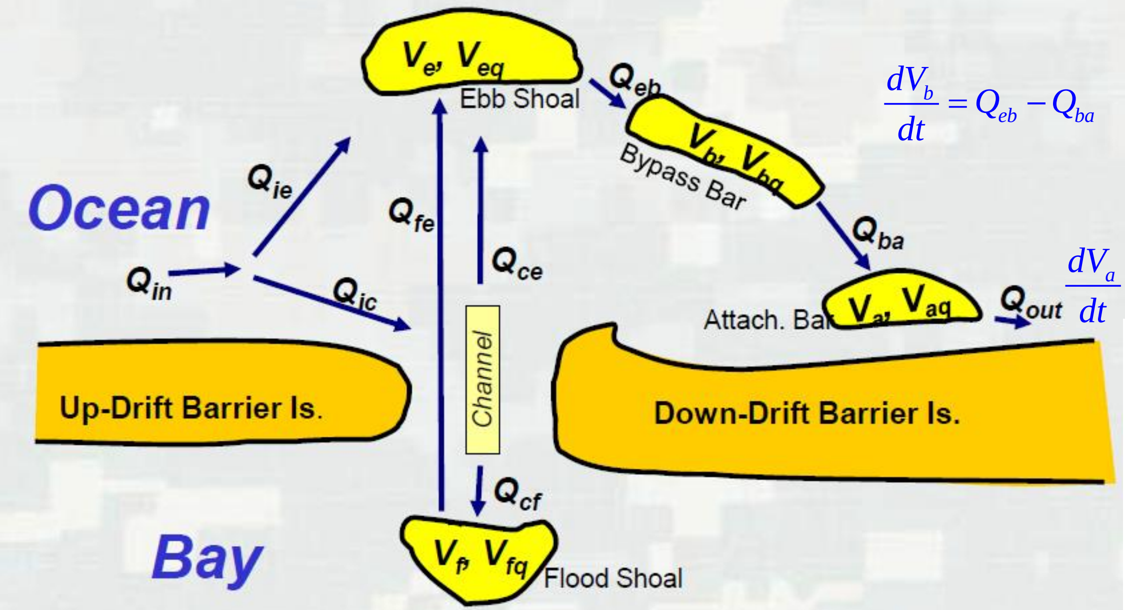


Inlet Reservoir Model Inlet Bypassing and Shoal Evolution (2)

$$\frac{dV_e}{dt} = Q_{ie} + Q_{fe} + Q_{ce} - Q_{eb}$$

$$\frac{dV_b}{dt} = Q_{eb} - Q_{ba}$$

$$\frac{dV_a}{dt} = Q_{ba} - Q_{out}$$



$$\frac{dV_f}{dt} = Q_{cf} - Q_{fe}$$

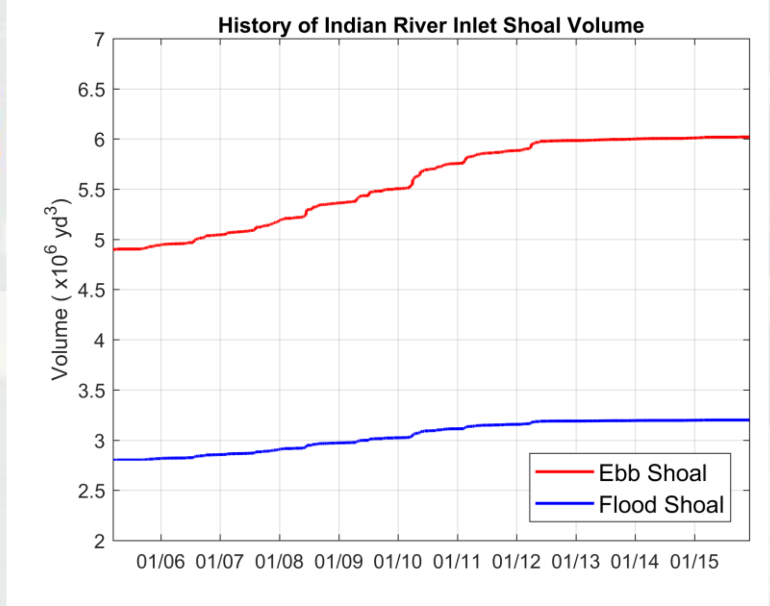
$$\delta = \frac{V_e + V_f}{V_{eq} + V_{fq}}, \qquad \beta = \frac{1 - V_e / V_{eq}}{2 - V_e / V_{eq} - V_f / V_{fq}}$$

Alongshore Sediment Transfer Function:

$$Q_{out} = \gamma Q_{in}$$

$$\gamma = \frac{V_e}{V_{eq}} \frac{V_b}{V_{bq}} \frac{V_a}{V_{aq}} \left(\delta + \beta(1-\delta)\right), \quad V_f \le V_{fq}$$

$$\gamma = \frac{V_e}{V_{eq}} \frac{V_b}{V_{bq}} \frac{V_a}{V_{aq}} \left[\left(\delta + \beta(1-\delta)\right) + \frac{V_f - V_{fq}}{Q_{in} dt}\right], \quad V_f > V_{fq}$$



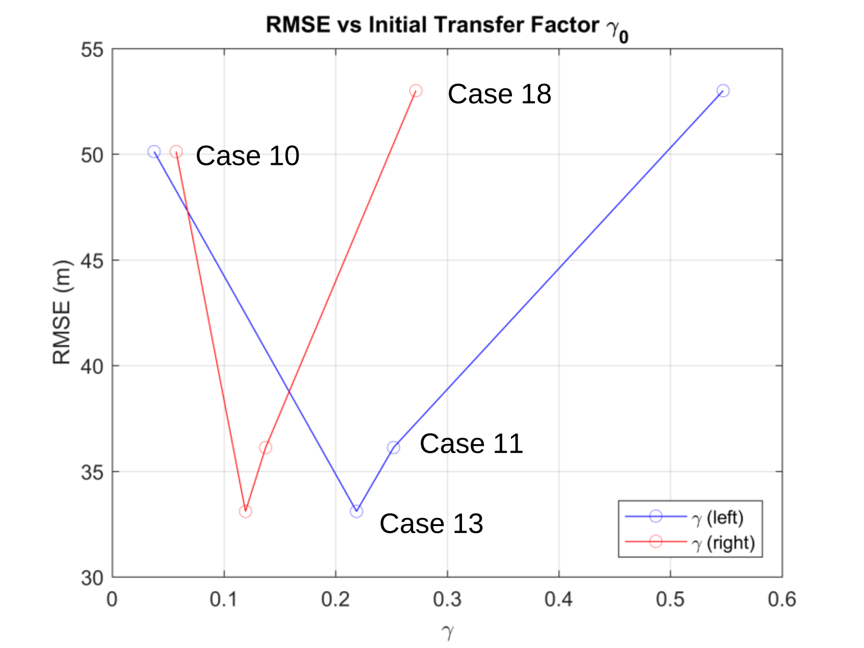
Alongshore Sediment Transfer Factor vs Errors

Shoal Volumes (Case 10, Initial Guess)

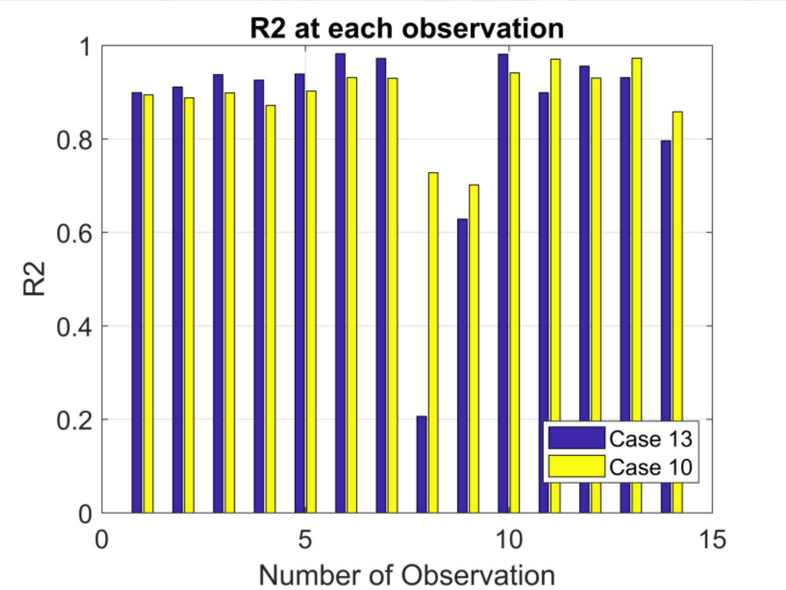
	Initial (Cyd)	Equilibrium (Cyd)	Vi/Vq
ebb	3,057,999	7,000,000	0.44
flood	1,258,999	3,499,998	0.36
left bypass	437,500	875,000	0.50
left attachment	305,800	1,223,199	0.25
right bypass	764,500	1,749,999	0.44
right attachment	305,800	700,000	0.44
γ (left)	0.04		
γ (right)	0.06		

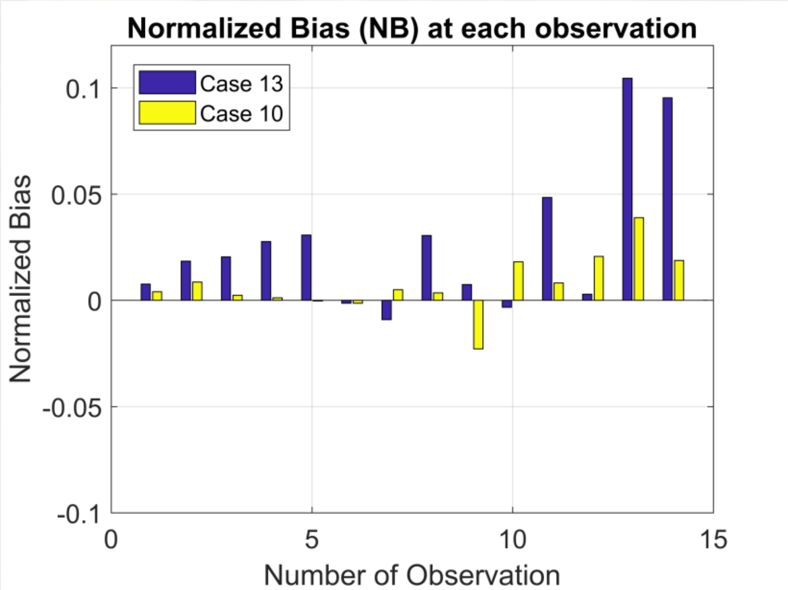
Shoal Volumes (Case 13)

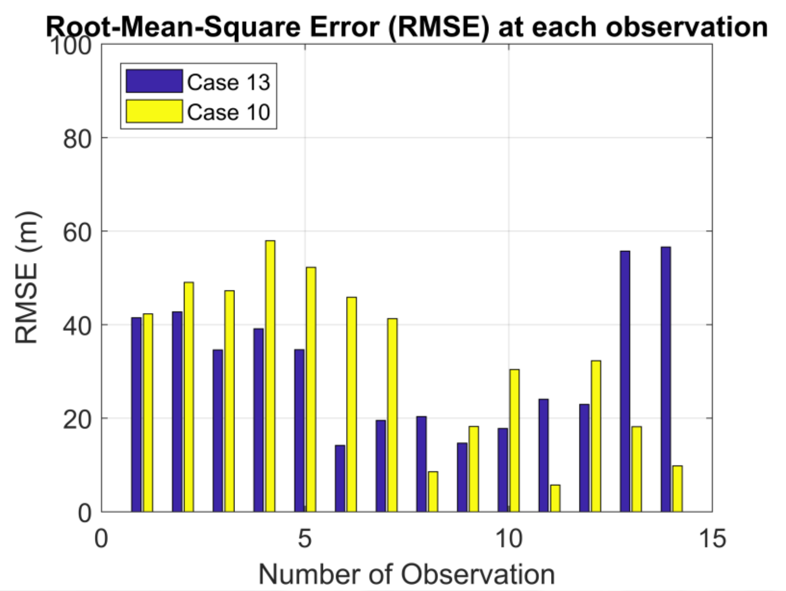
	Initial (Cyd)	Equilibrium (Cyd)	Vi/Vq
ebb	4,899,998	7,000,000	0.70
flood	2,799,999	3,499,998	0.80
left bypass	76,540	175,000	0.44
left attachment	56,000	70,000	0.80
right bypass	764,500	1,749,999	0.44
right attachment	305,800	700,000	0.44
γ (left)	0.22		
γ (right)	0.12		

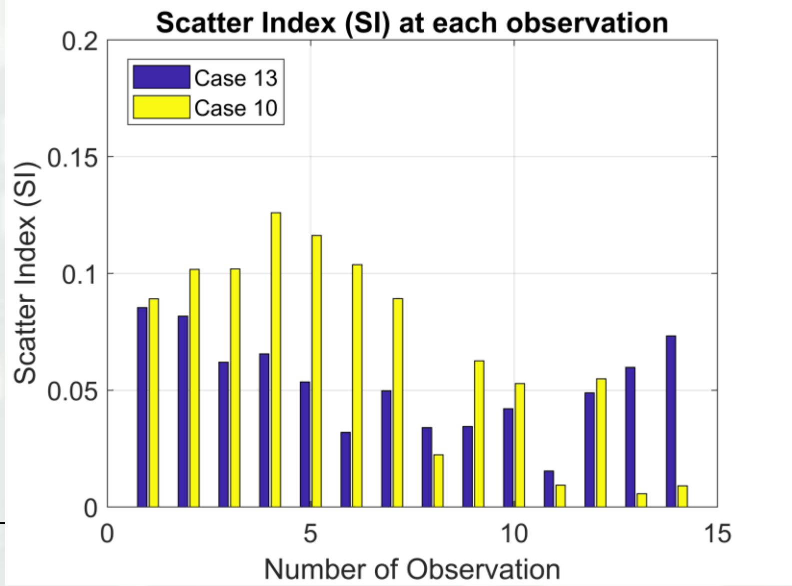


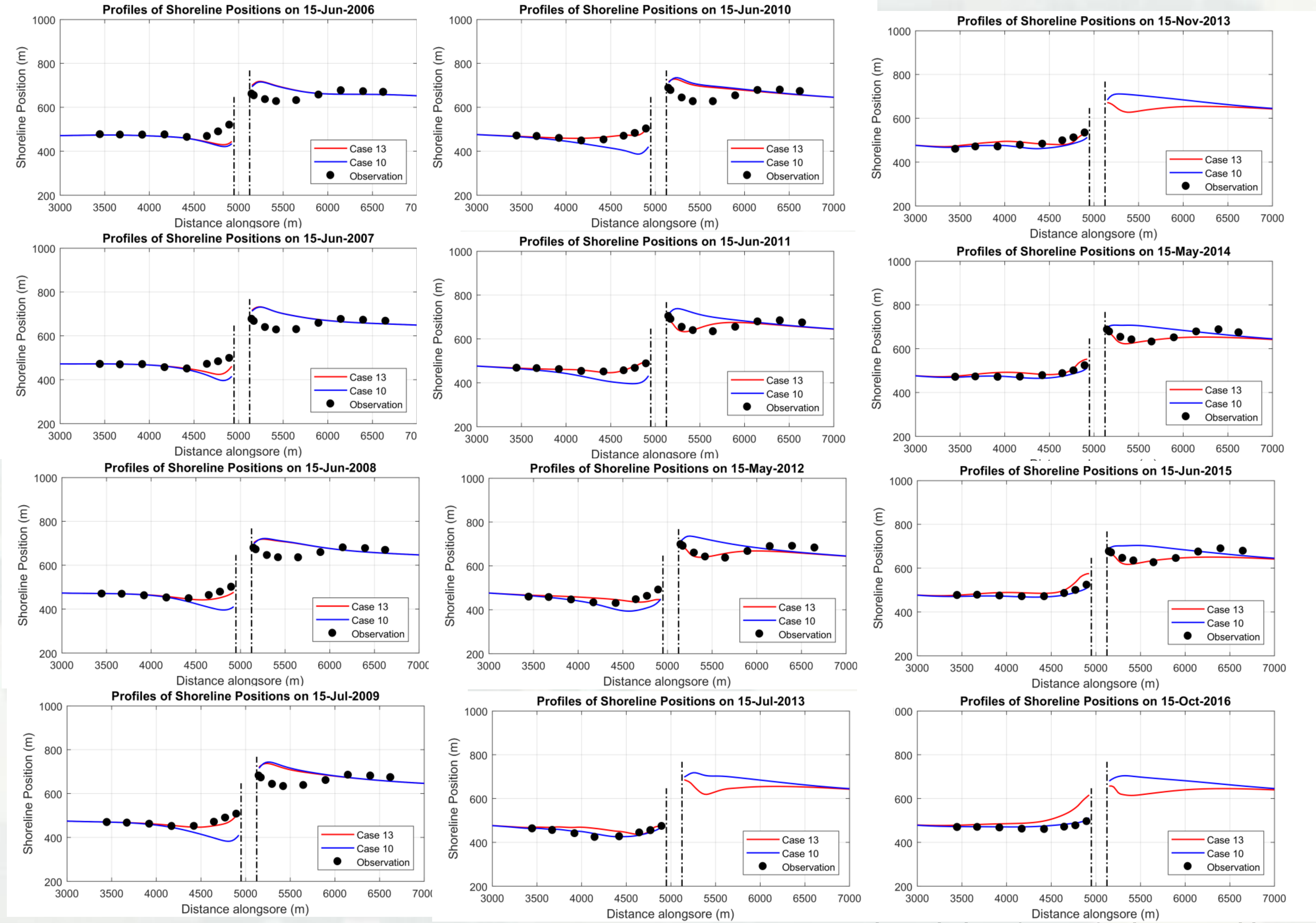
Model Skill Assessment



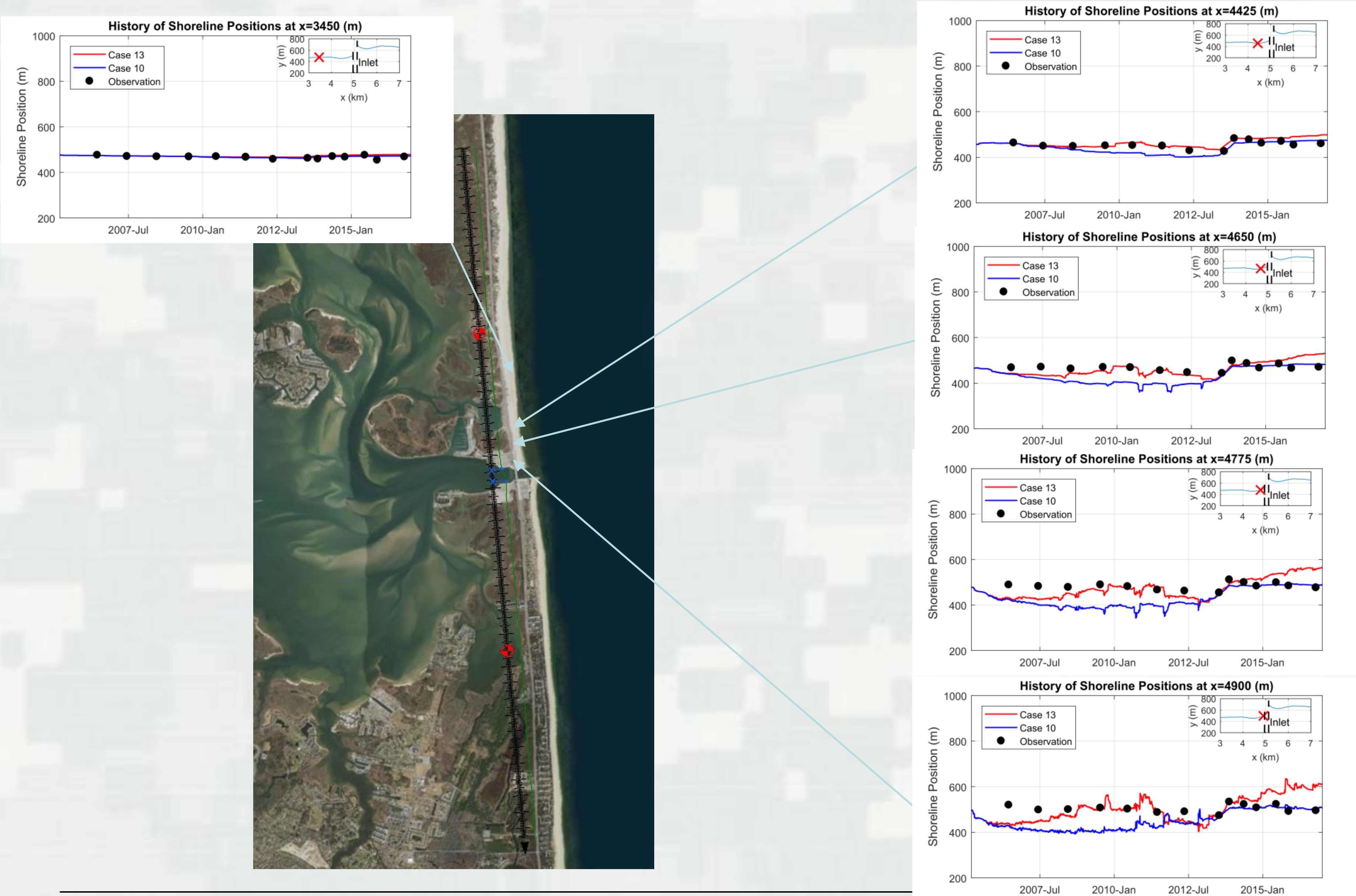




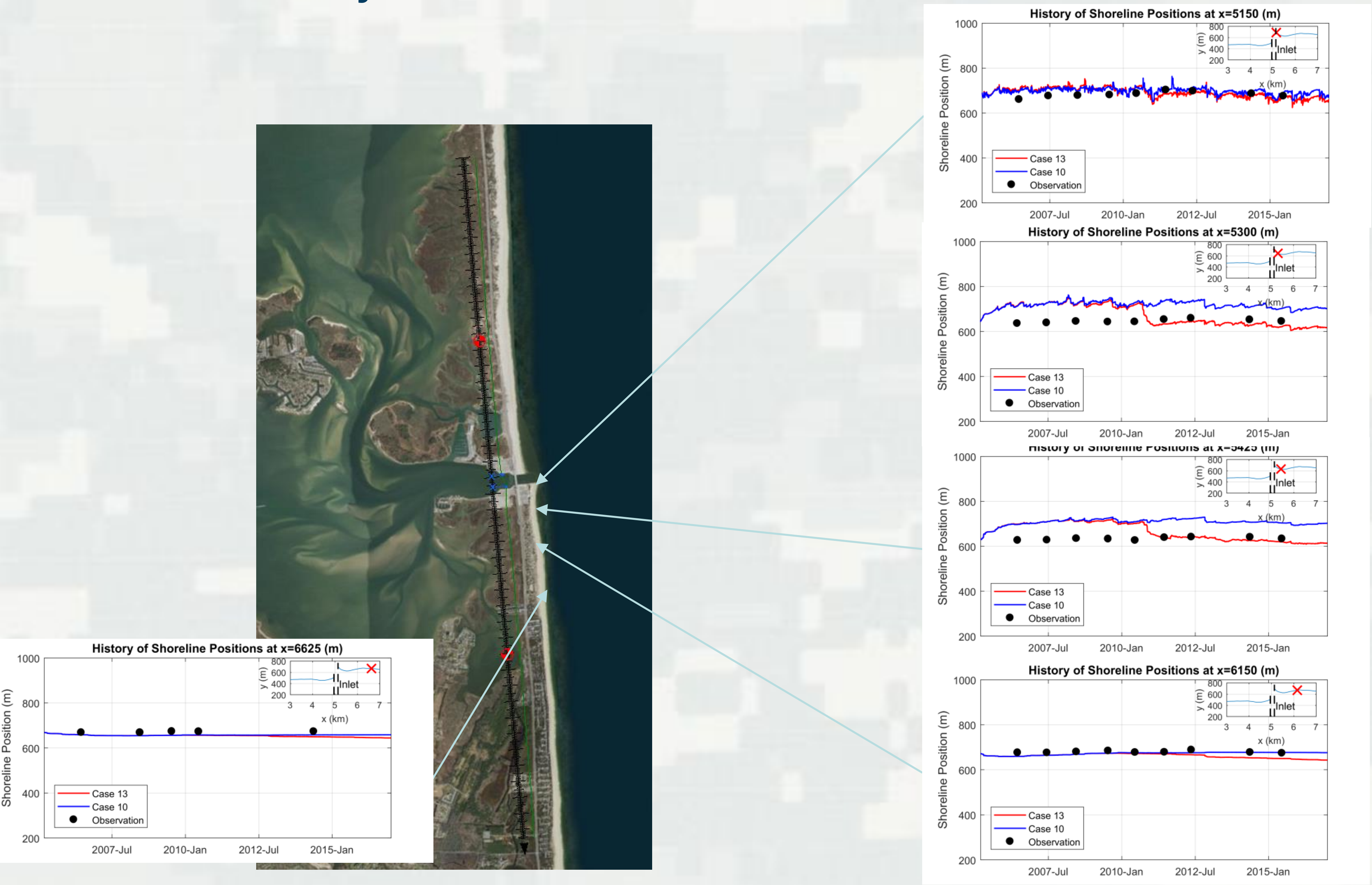



Profiles of Shoreline Positions on 15-Jun-2006
Profiles of Shoreline Positions on 15-Jun-2010
Profiles of Shoreline Positions on 15-Nov-2013
Profiles of Shoreline Positions on 15-Jun-2007
Profiles of Shoreline Positions on 15-Jun-2011
Profiles of Shoreline Positions on 15-May-2014
Profiles of Shoreline Positions on 15-Jun-2008
Profiles of Shoreline Positions on 15-May-2012
Profiles of Shoreline Positions on 15-Jun-2015
Profiles of Shoreline Positions on 15-Jul-2009
Profiles of Shoreline Positions on 15-Jul-2013
Profiles of Shoreline Positions on 15-Oct-2016
Shoreline Position (m)
Distance alongsore (m)
Case 13
Case 10
Observation

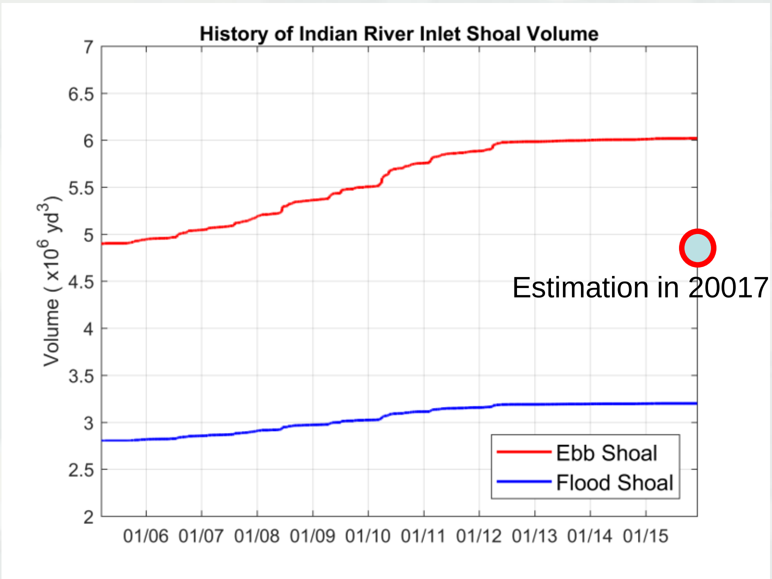
History of Shoreline Positions in the North Shore

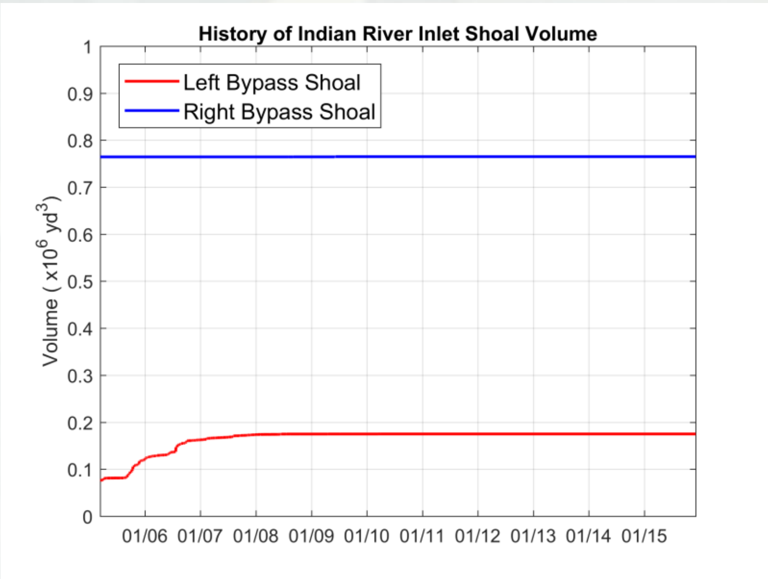


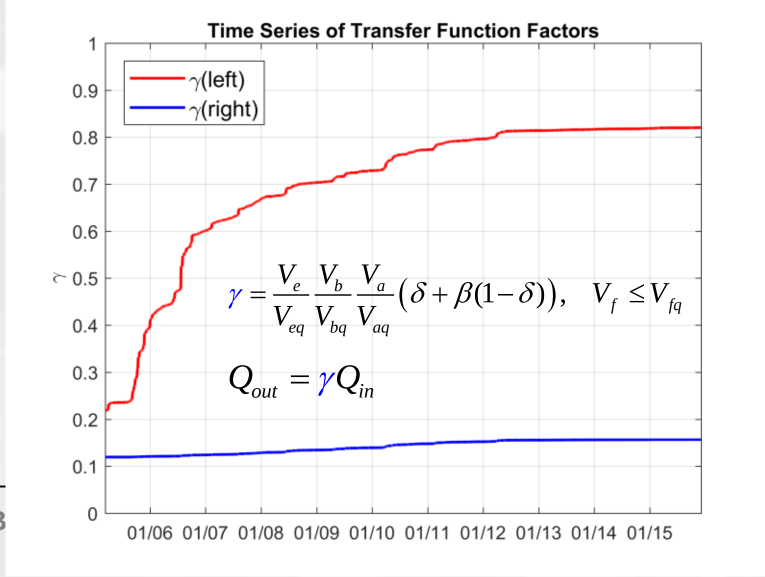
History of Shoreline Positions in the South Shore

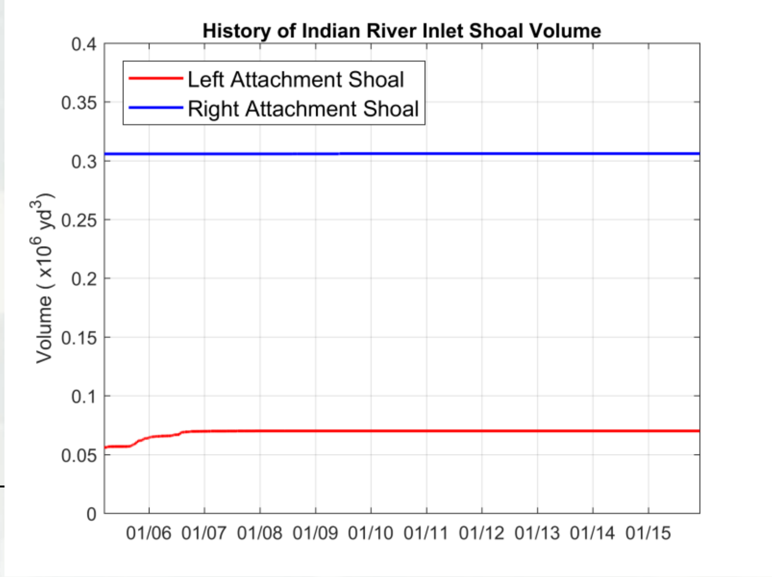


Evolution of Inlet Shoals and Bypass



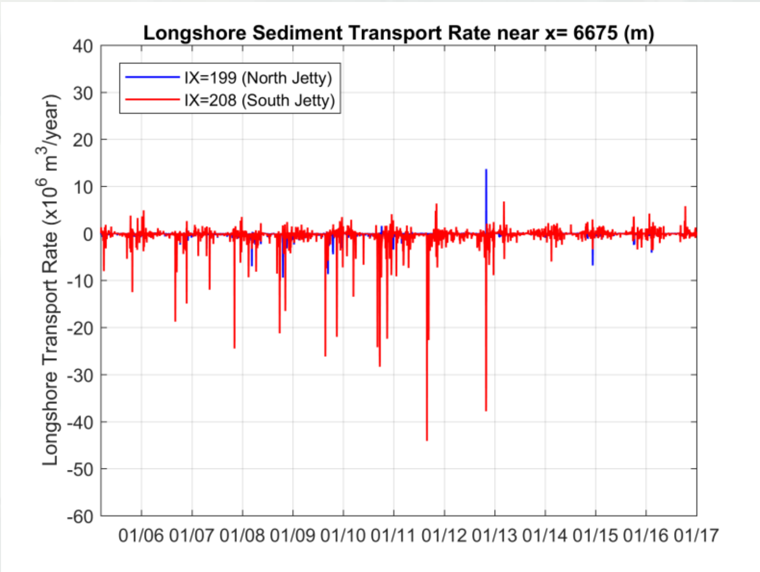


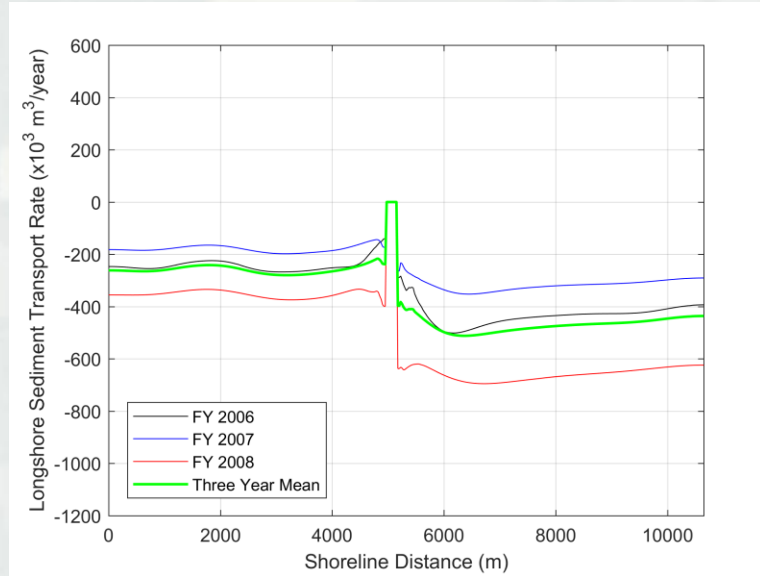


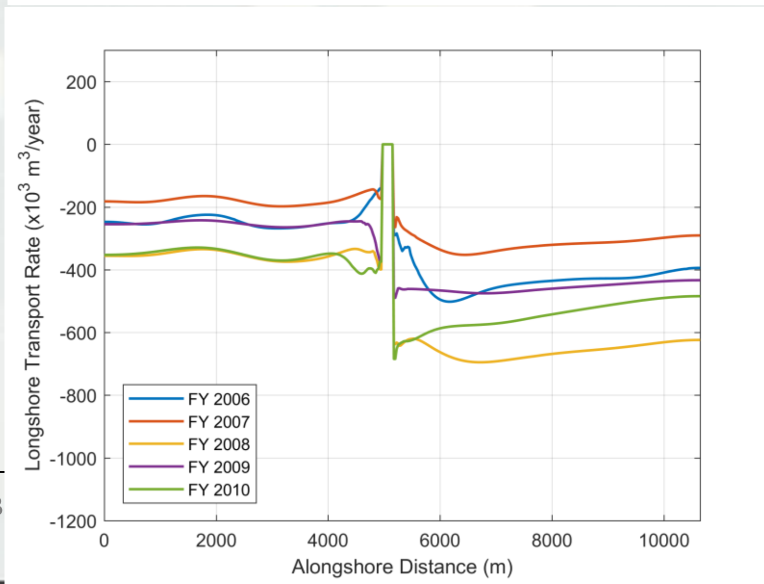


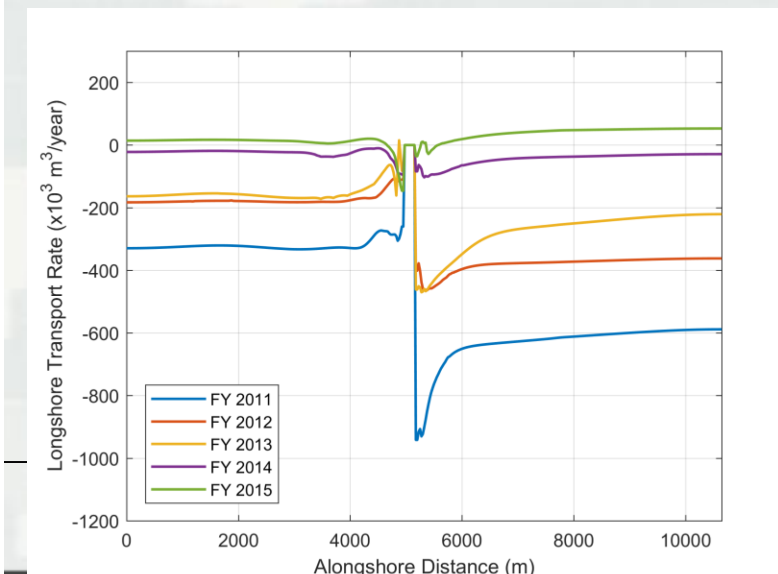
Case 13

Longshore Sediment Transport

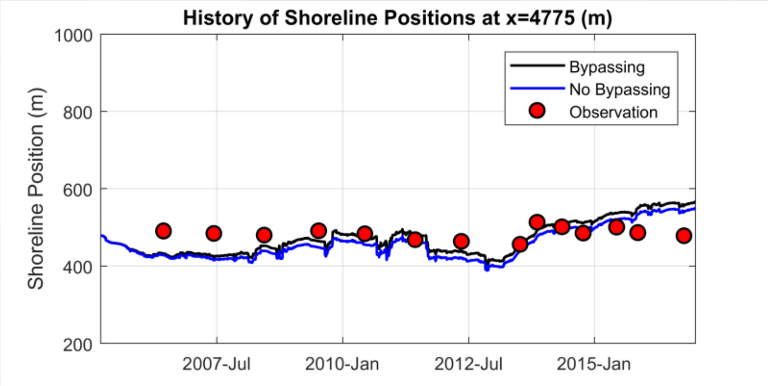


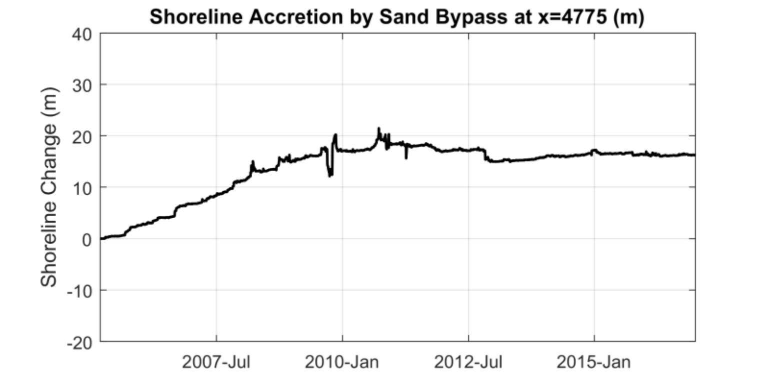




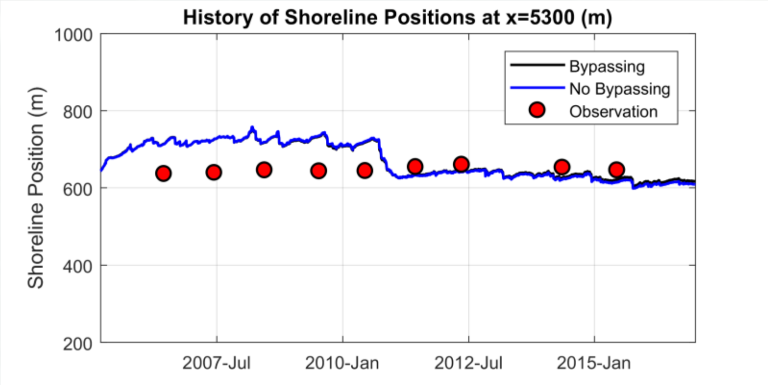


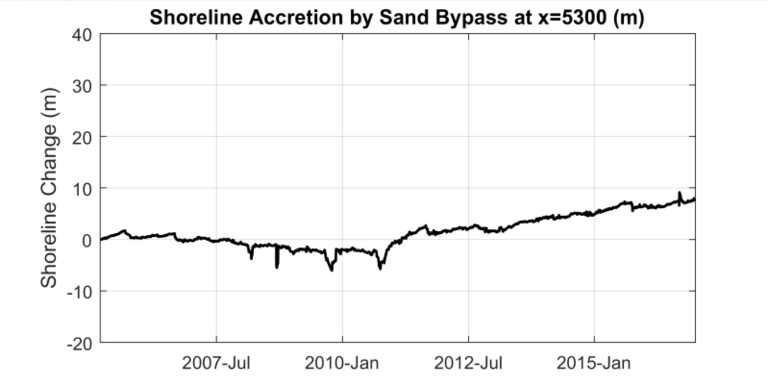
Bypass Effect





North





South

Remarks

- Preliminary V&V results demonstrate the GenCade model is capable of simulating long-term shoreline evolution in the coast near the Indian River Inlet, by including the inlet reservoir model (IRM), beach fill, and sand bypass.
- The new parameter, sediment transfer factor (γ) successfully reduced the total number of calibration parameters in IRM (Parameter Space Reduction). It reveals the mechanism of bypass in IRM, which can guide calibration of multiple parameters in IRM (12 values), and significantly reduce the V&V efforts.
- Assessment of model skill is crucial to quantify simulation errors, but also to validate each sub-model (closure model, such as IRM, bypass, beach-fill model, etc.). Sensitivity study is necessary for validation of multi-parameter empirical models such like GenCade.

Issues and questions:

- Is IRM able to simulate evolution of shoals (volumes)? We needs field data and 2DH model morphology sensitivity results to validate this (complex) process of sediment exchange through inlet.
- How to define (the areas of) inlet shoals?
- Current (tidal, wave-driven) effects need to be included, as it drives sediments moving from shoal to shoal.
- Uncertainty and errors in observation data is a challenging issue (zero contour (LIDAR data) vs hydro survey).
- Further validation of bypass model is needed.

Thank you for your attention!

North Shore, IRI, 09/26/2019

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