GENCADE MODERNIZATION AND UPDATE ON PREDICTION CAPABILITY AND UNCERTAINTY ESTIMATION OF LONG-TERM SHORELINE EVOLUTION

INLET ENGINEERING TOOLBOX

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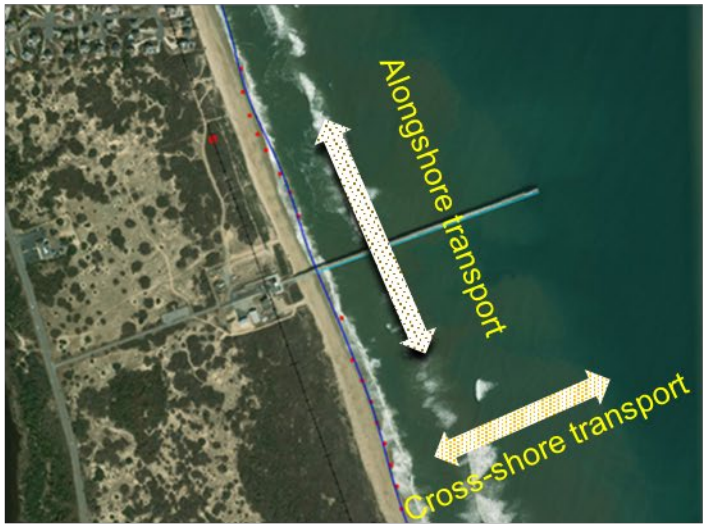
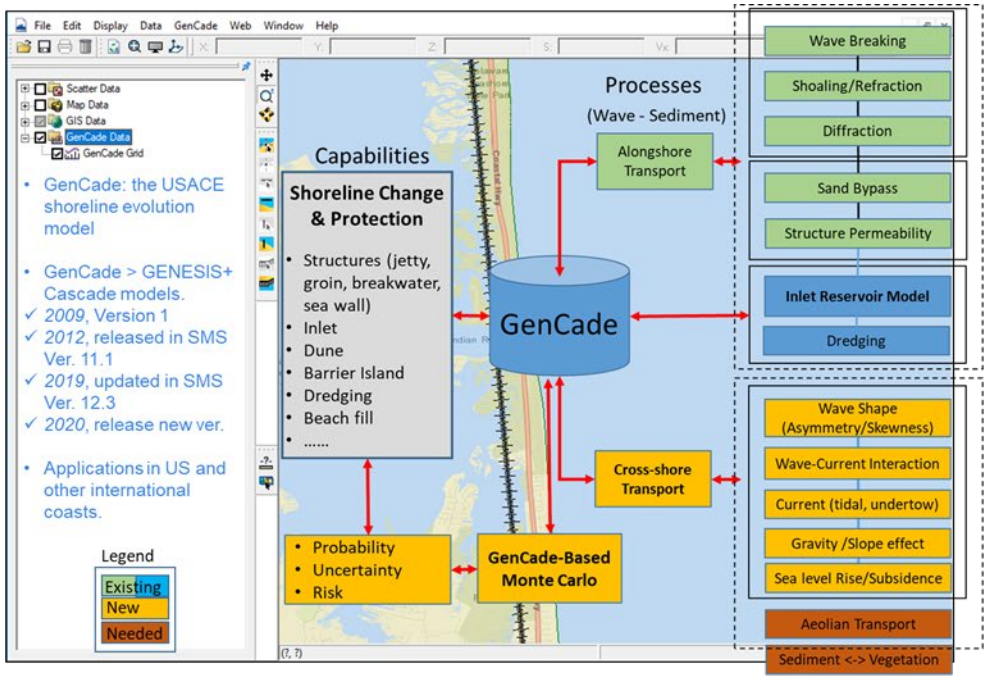
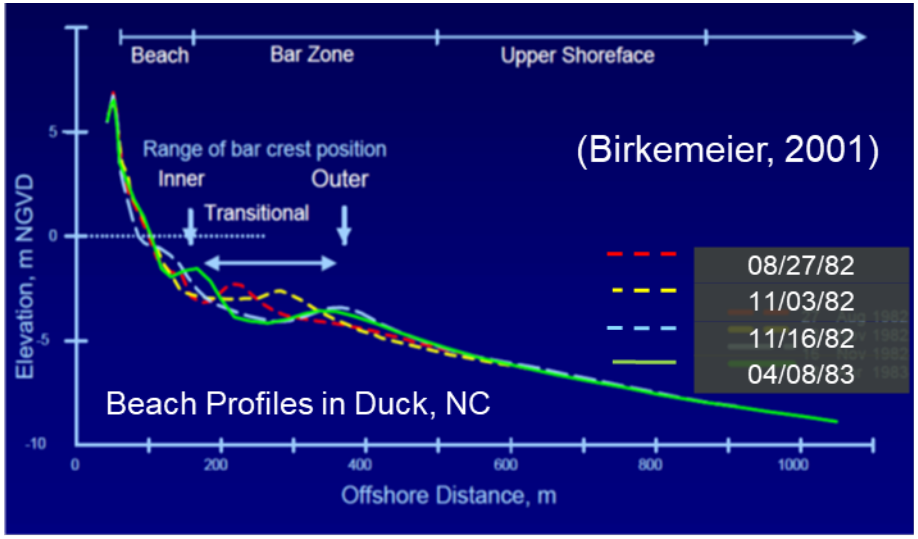
This newly-developed cross-shore sediment transport modeling capability has improved GenCade's accuracy for long-term shoreline evolution simulation. Probabilistic shoreline change modeling provide users a new application tool to quantify uncertainty and risk of shoreline changes. Model V&V is crucial to development of a robust GenCade model.



FRF, Duck, NC



Cross-Shore Sediment Transport Using Nonlinear Wave Shape Model



Contributors to Cross-Shore Transport:

- Orbital motion of small waves (onshore)
- Sandy bar migration (on-offshore directions)
- Undertow due to high-energy waves (offshore)
- Overwash and overtopping
- Gravitational Slope Effect (offshore)

Cross-Shore Transport Rate

$$\phi = \frac{\alpha_D}{1-p}(Q_V + Q_C + Q_D)$$

Q_v and Q_C are the net sediment transport due to waves and currents (Bailaid & Inman 1981, Hsu et al. 2006)

α_D=empirical parameters (=1~2)

$$Q_V = \frac{C_W}{(s-1)g}\left(\frac{\varepsilon_B}{\tan\varphi} < \left|\vec{U}_0\right|^2 U_{0,x} > + \frac{\varepsilon_S}{W_0} < \left|\vec{U}_0\right|^3 U_{0,x} >\right)$$

$$Q_C = \frac{C_C}{(s-1)g}\left(\frac{\varepsilon_B}{\tan\varphi} < \left|\vec{U}_t\right|^2 U_x > + \frac{\varepsilon_S}{W_0} < \left|\vec{U}_t\right|^3 U_x >\right)$$

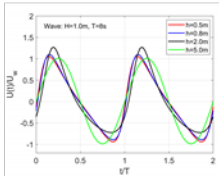
Energy Dissipation | Wave Skewness

C_w, C_C, ε_B, ε_S = empirical parameters (Fernández-Mora et al. 2015)

$$\vec{U}_0(t) = (U_{undertow} + \tilde{U}_0(t)\cos\theta)\vec{i} + (U_{alongshore} + \tilde{U}_0(t)\cos\theta)\vec{j}$$

Nonlinear Wave Shape model: Near-bed horizontal orbital velocity (Abreu et al 2010, Ruessink et al. 2012)

$$\tilde{U}_0(t) = U_w f \frac{\sin(\omega t) + \frac{r\sin\varphi_w}{1+\sqrt{1-r^2}}}{1 - r\cos(\omega t + \varphi_w)}$$



$U_{undertow}$ undertow current (Kuriyama 2010)

Q_D : a diffusive transport due to downslope move of sand:

$$Q_D = \frac{\lambda_d \nu \tan\beta}{\tan\varphi(\tan\varphi - \tan\beta)}$$

GenCade-Based Monte Carlo Simulation: Estimation of Uncertainty and Risk due to Waves

$$p(x)=\begin{cases} R(x) & x\in[0,x_0) \\ \varepsilon W(x) & x\in(x_0,+\infty) \end{cases}$$

Wave Generator

GenCade

Statistic Analysis

- Maximum Likelihood Estimation

Input wave conditions for setting up the probability density functions, i.e. wave heights, periods, angles

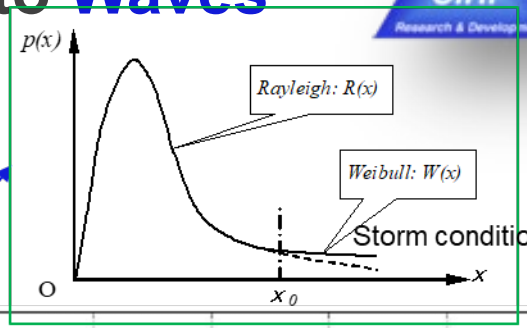
Generate time series of wave heights and angles based on probability density functions (pdfs)

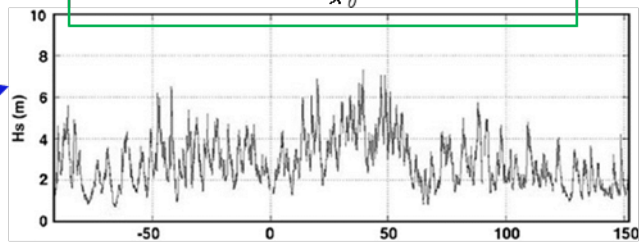
Simulation of shoreline changes by the one-line model, **GenCade**

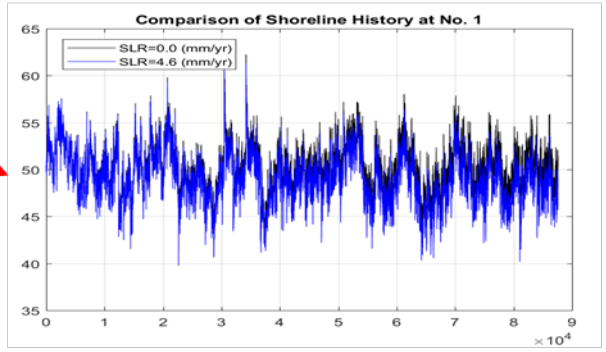
Repeat *N* times

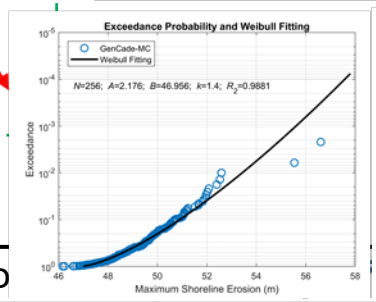
Statistic analysis of shoreline

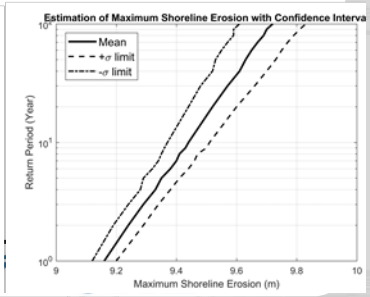
Stop





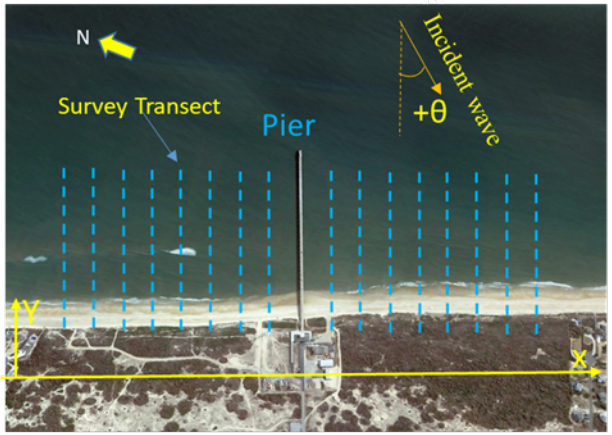




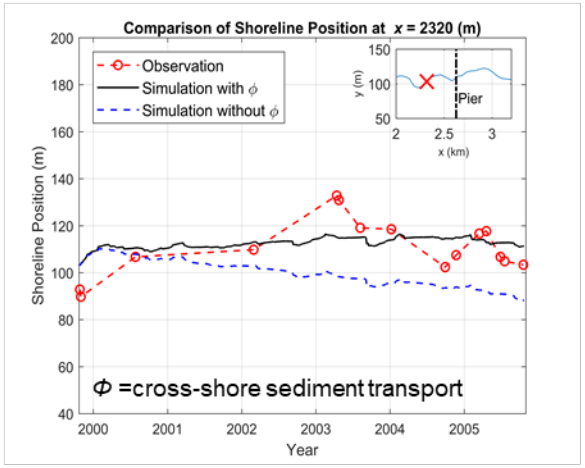


The more test samples (N), the better statistic results

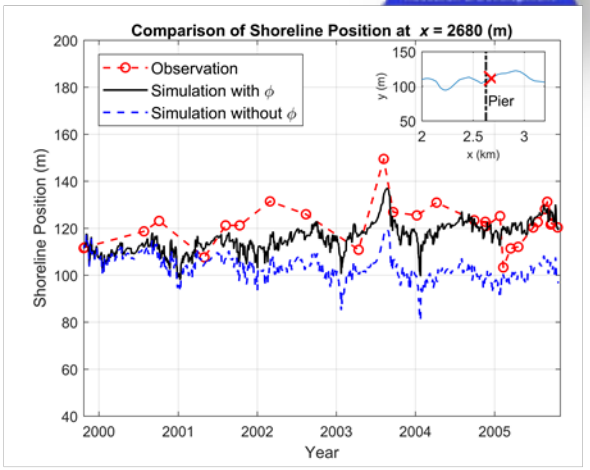
V&V (Model Skill) of Shoreline Changes (1999-2006) in Duck, NC



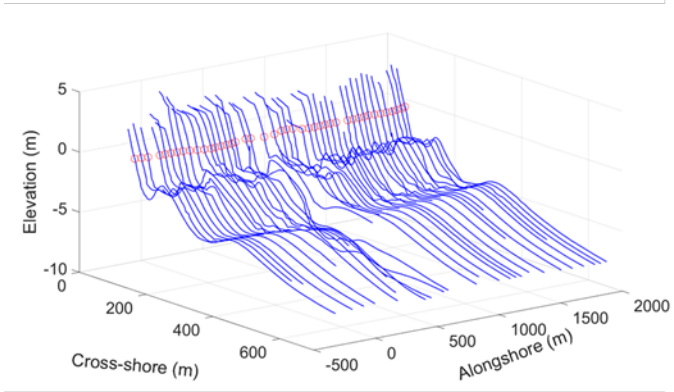
(a) Study site at FRF, Duck, NC



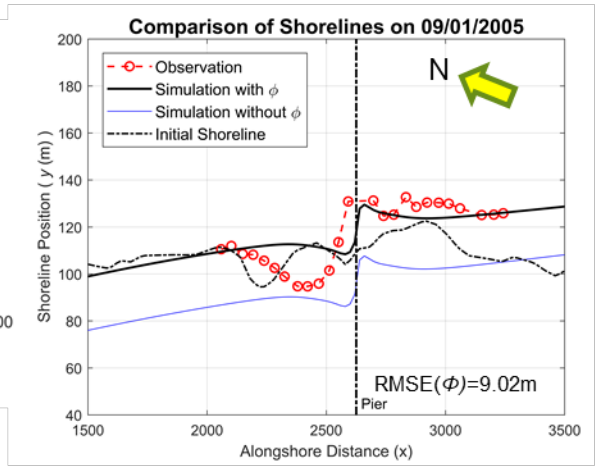
(b) History of Shoreline Positions at the north



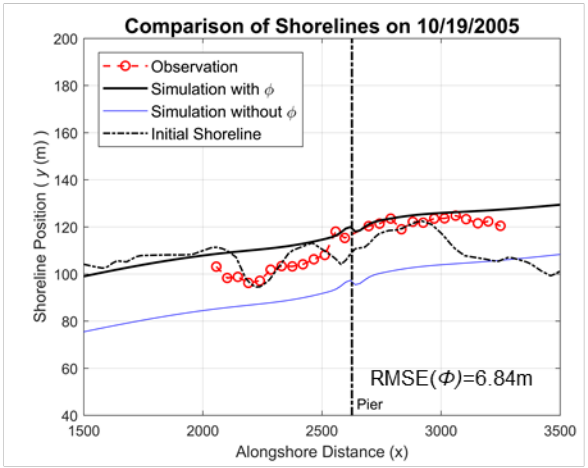
(b) History of Shoreline Positions at the south



(d) 48 beach profiles, 10/23/1999

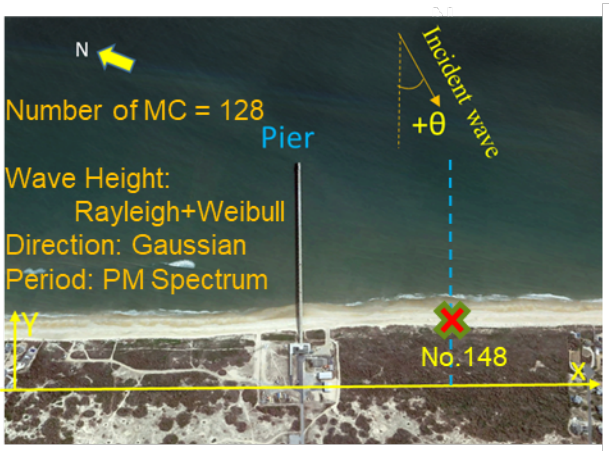


(e) Shorelines on 09/01/05

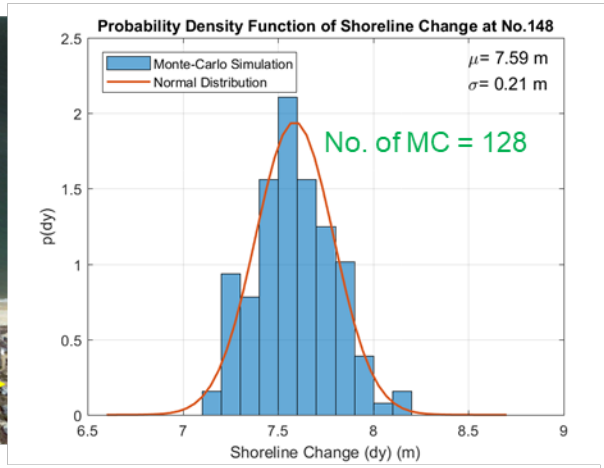


(f) Shorelines on 10/19/05

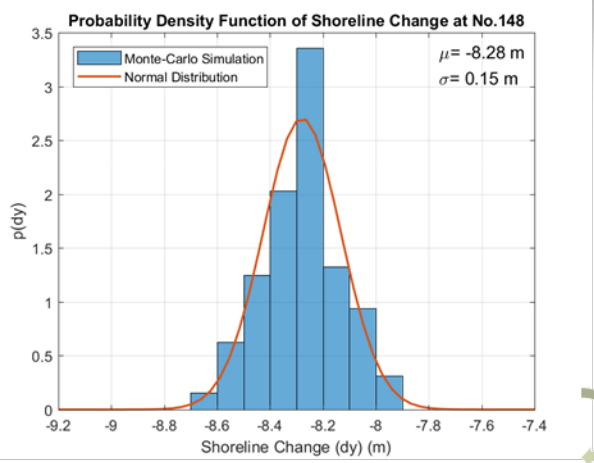
Monte-Carlo Simulation and Uncertainty of Shoreline Changes in Duck, NC



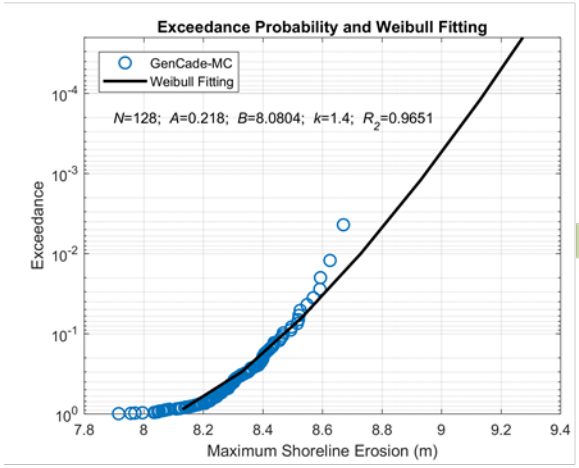
(a) Study site at FRF, Duck, NC



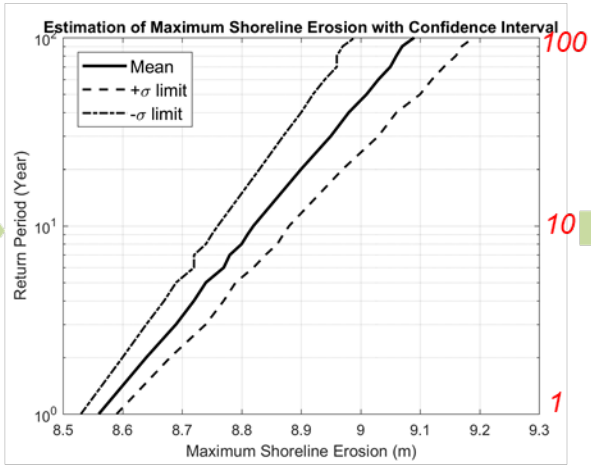
(b) Probability of seawardmost change



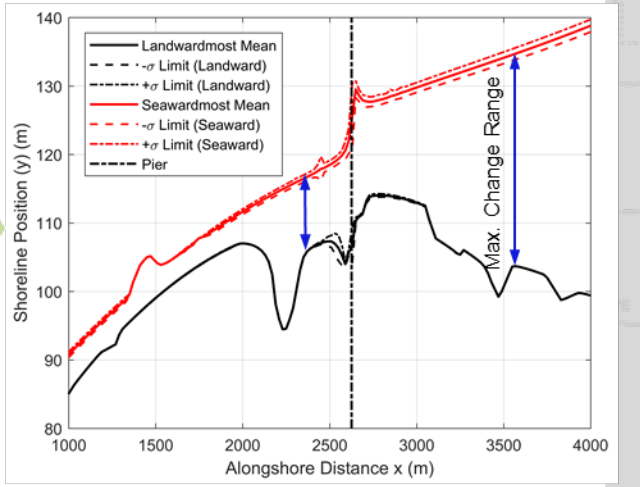
(c) Probability of landwardmost change



(d) Exceedance of max. erosion at No.148



(d) Max. erosion at No. 148 in return period



(f) Max. change range and confidence

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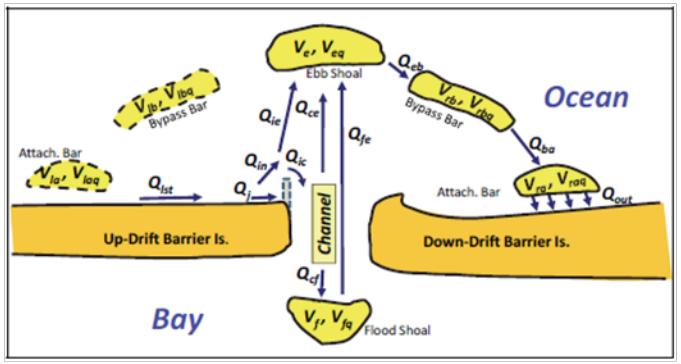
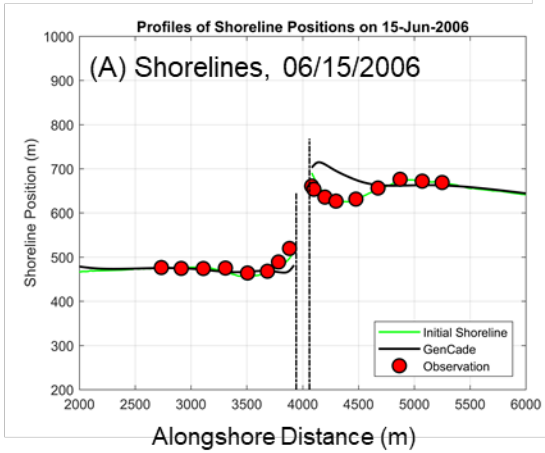
Modeling of Shoreline Change near Indian River Inlet

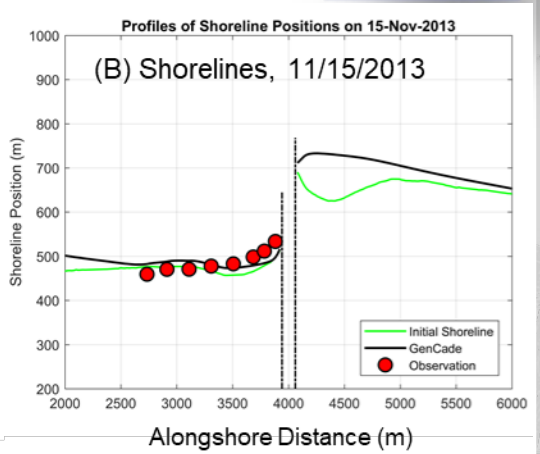
Objectives: (1) to validate the GenCade model by using shoreline survey data provided by NAP and DNREC (Gilbert, Eisemann, & Dunkin, 2018), and (2) to evaluate sand bypass operation.

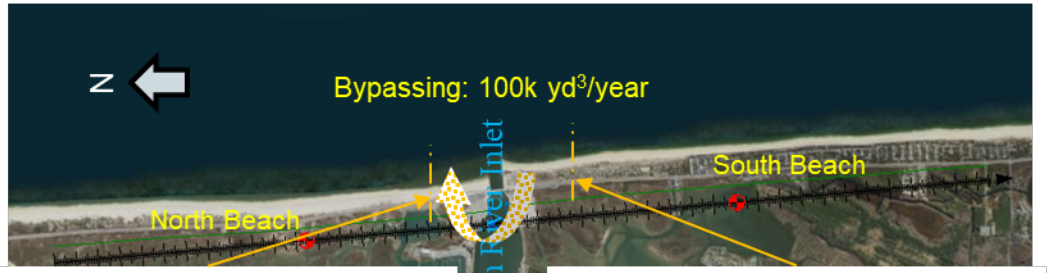
Sand Bypassing: 100,000 yd^3 / year
Beach nourishment: 527,850 yd^3, May-Nov 2013

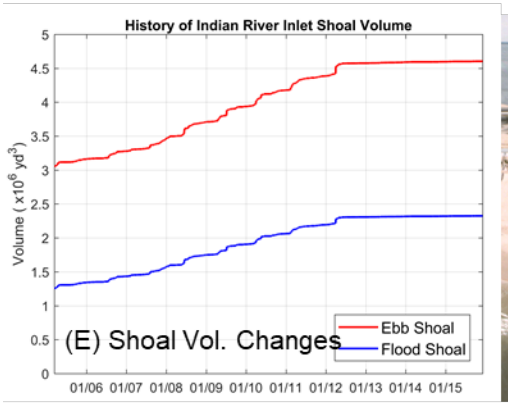


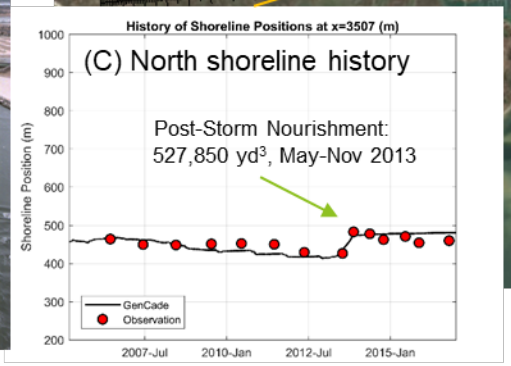
Inlet Reservoir Model

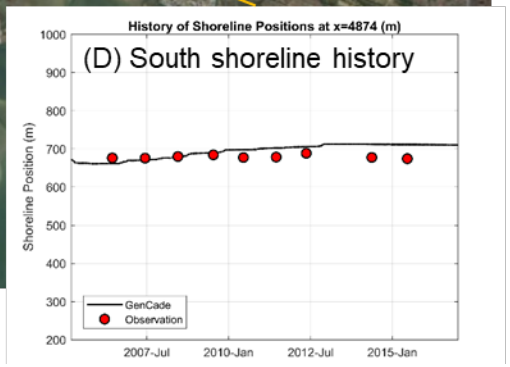






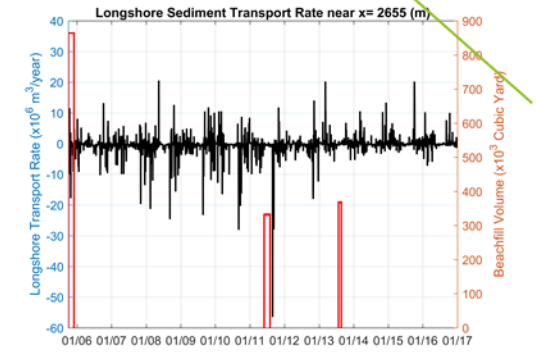


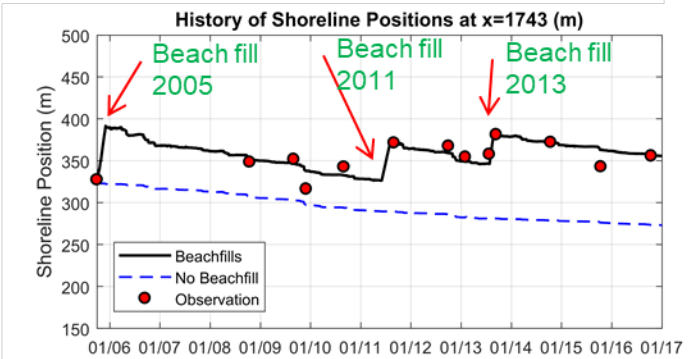


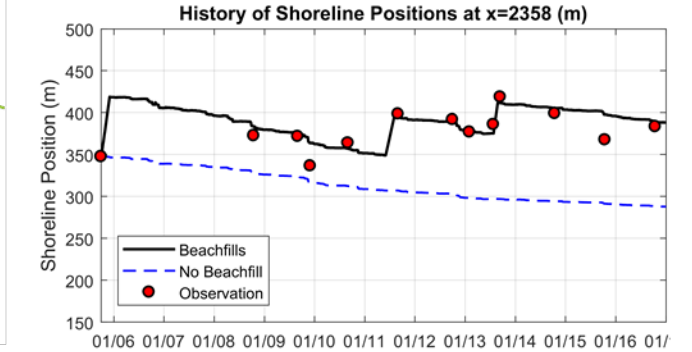


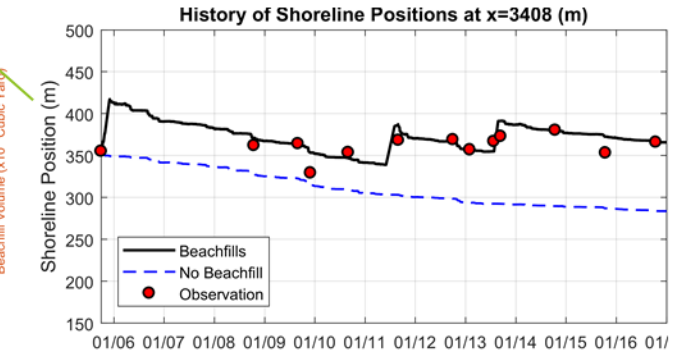
Long-term Shoreline Change in Fenwick Island, DE

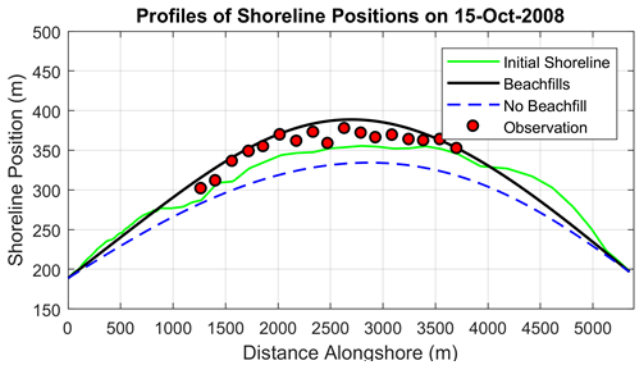
- 12-year Shoreline Changes (2005-2017)
- Periodical beach fills : 2005, 2011, & 2013

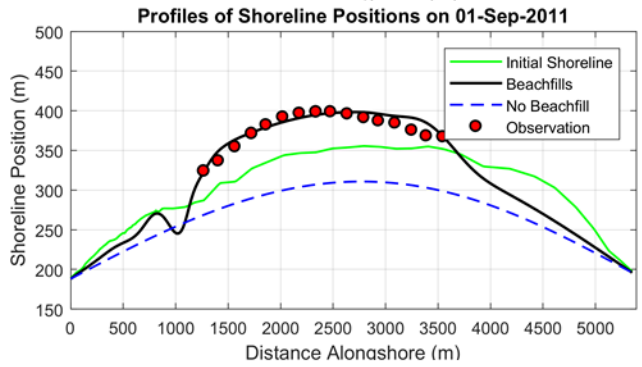


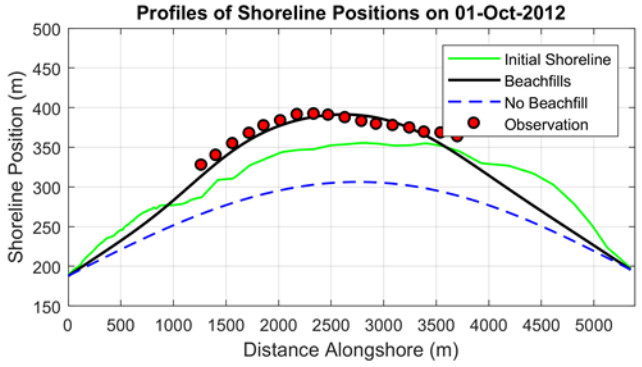












Summary

FY19 Major advances

- Development and validation of cross-shore transport model
- Simulation of long-term shoreline changes in DE coast (modeling inlet sediment exchange, beach fill events)
- Observation Datasets of Shorelines in Duck, NC, and DE coasts
- Release new GenCade, Short Course in Coastal Sediment'19, Technical Transfer
- Publications: TN (2), JA (1), Conference Papers (2), Conference Presentations (5), Short Course materials (tutorial cases, ppts)

FY20 2-3 key products/advances

- Develop New User Interface in SMS for new capabilities (Cross-shore, SLR, etc)
- Develop a dynamic interface for GenCade Monte-Carlo simulation (new codes for maximum likelihood estimation are needed)
- Test and release codes
- Develop and validate a regional-scale GenCade model for simulating shoreline evolution on the entire Delaware coast (focus on inlet model and including all the coastal protection practices)
- Version Control, Technical Transfer, Documentation