

GENCADE MODEL DEVELOPMENT AND APPLICATIONS

INLET ENGINEERING TOOLBOX

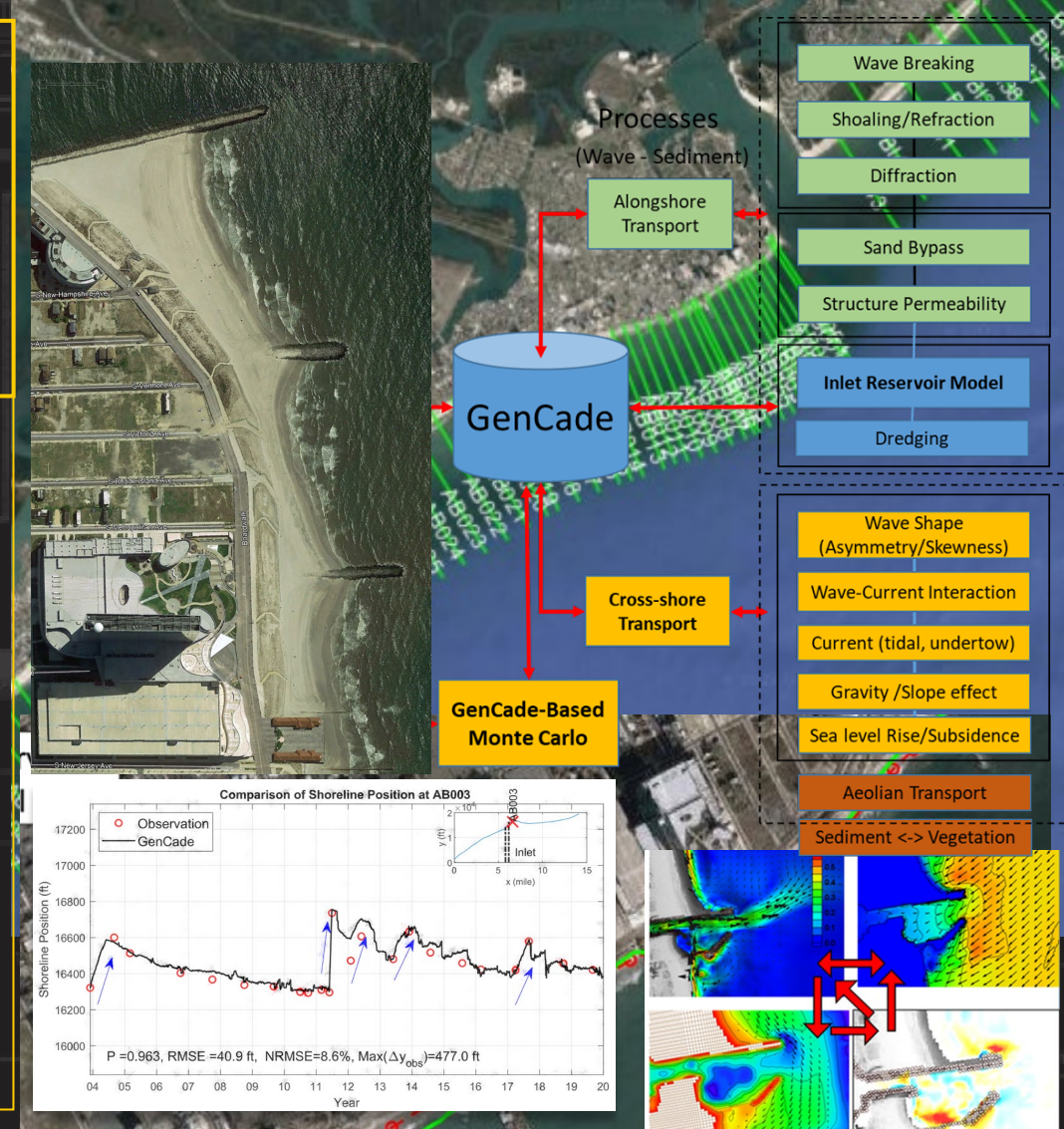
Yan Ding, Mitchell Brown, Rusty Permenter, Scott Spurgeon, Richard Styles

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District PDT Members

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COASTAL INLETS RESEARCH PROGRAM
FY23 IN PROGRESS REVIEW



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COASTAL INLETS RESEARCH PROGRAM
IN PROGRESS REVIEW

Tiffany Boroughs
HQ Navigation Business
Line Manager

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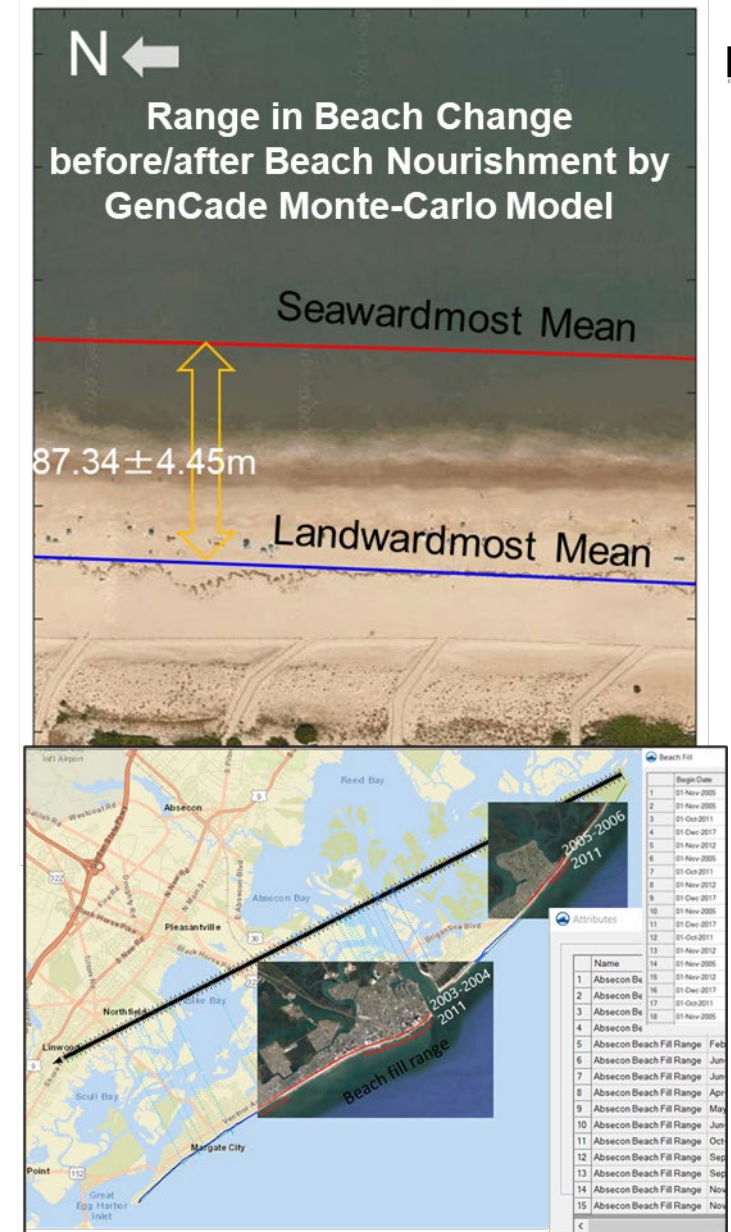
- Prediction of long-term (decadal) and regional ($10^1 \sim 10^2$ km) shoreline changes is a key task in regional coastal management practices.
- A range of methods including beach fills/nourishment, sand bypassing and structures have been utilized to mitigate coastal erosion. The Regional benefits and interactions of these methods are difficult to quantify along regional-scale coastlines.
- Quantifying erosion risk and uncertainty in simulating long-term shoreline changes is essential for risk-based coastal management practice.
- GenCade provides various capabilities for predicting long-term and regional shoreline evolution driven by longshore and cross-shore transport and coastal protection measures. The model has to be validated by applying to engineering practices.

Strategic R&D: Innovation in Sediment Management (Shoreline Erosion)

SoN #1846 - Development of Long-term Simulation Capabilities to Predict Risk-Based Shoreline Changes in Regional-Scale Coast

SoN-NAV-1726 (Nearshore Nourishment Best Management Practices)

SoN-1386 (Strategic Nearshore Placement of Dredged Material to Sustain Coastal Beach & Dune Resilience)





Capability and Strategic Impact Statement



CAPABILITIES

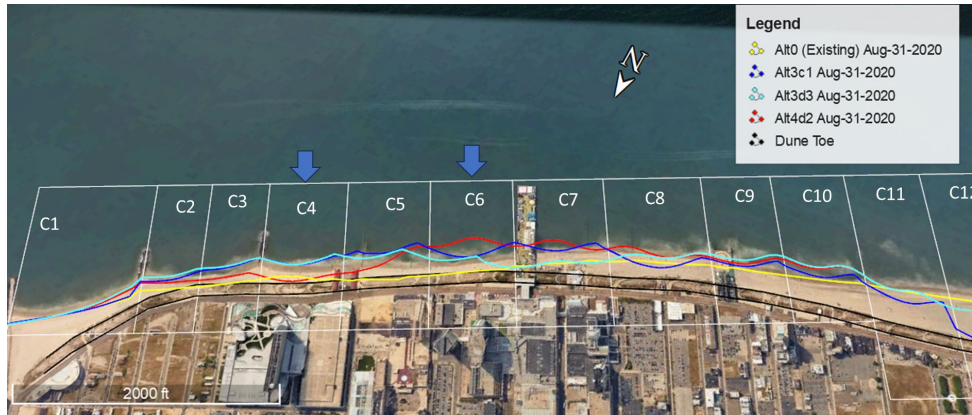
- GenCade simulates **long-term** shoreline change, longshore and cross-shore sand transport, and inlet morphology on a local to **regional** scale.
- Provides long-term impact assessment of structure and non-structural protection measures for engineering planning.
- Operated in SMS, GenCade brings functionality of a georeferenced environment together with accessibility of other USACE numerical models (CMS, SBAS, etc).
- The GenCade team provides training workshops, technical services, and trouble shooting.

APPLICATIONS

- GenCade shoreline evolution model has been successfully applied to reproduce long-term shoreline changes with various erosion protection measures.
- Long-term shoreline simulations are essential to evaluate long-term (e.g. a life cycle) effect of erosion protection.
- GenCade Monte-Carlo simulation provides an effective tool to estimate uncertainties of shoreline changes and sediment transport driven by wave conditions and erosion protections.

BENEFITS

- Predictions of shoreline changes and sediment transport volumes facilitate optimization of regional sediment management, which can provide cost-effective solutions.
- Quantify erosion risks and uncertainty of protection measures for risk-based coast design.
- Continuous improvement of simulation capabilities, user training, and technical services broaden benefits of GenCade for CSRM practices.





GenCade – SMS 13.3+ interface (DMI and others)



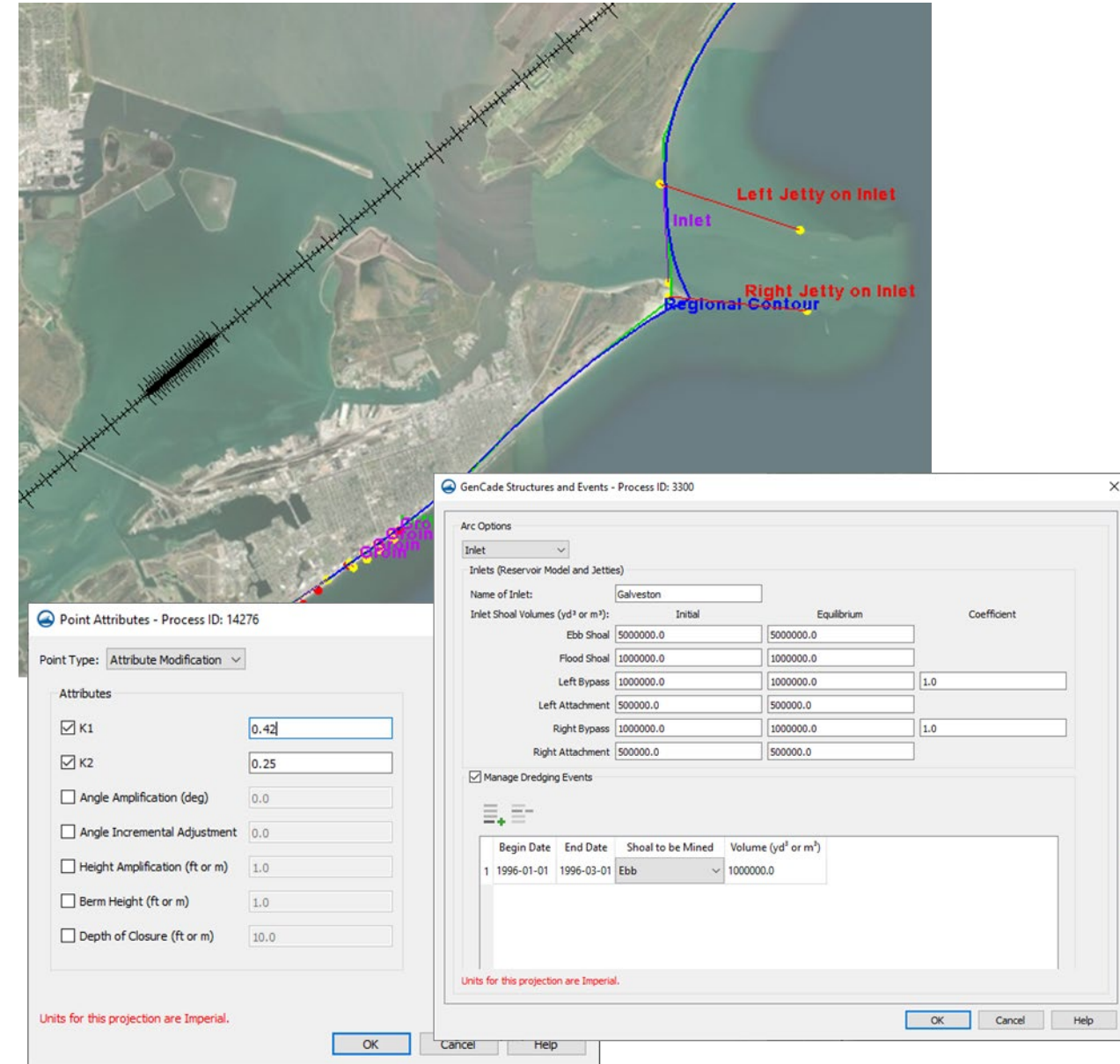
Approximately **90%** complete.

Completed:

- All Input from User for Grid, Structures, Events, and Point attributes
- Creation of 1-D grid
- Model Control including new Cross-shore and Monte Carlo
- Saving out all necessary input files for GenCade to run

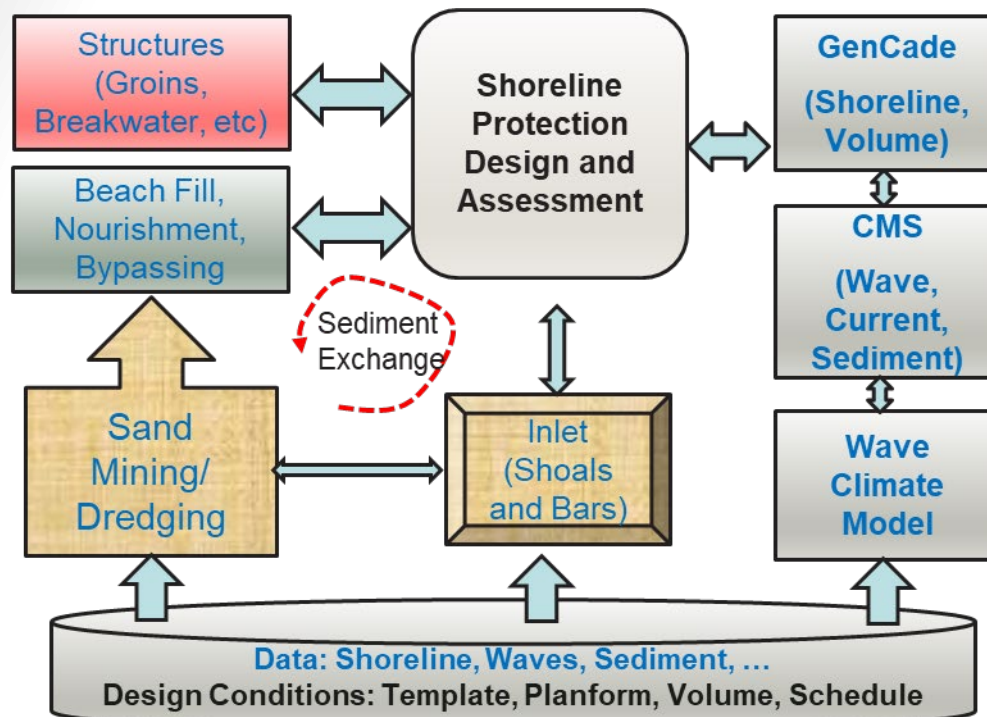
Remaining:

- Import model native files (*.gen) into SMS
- Visualize results from GenCade simulation



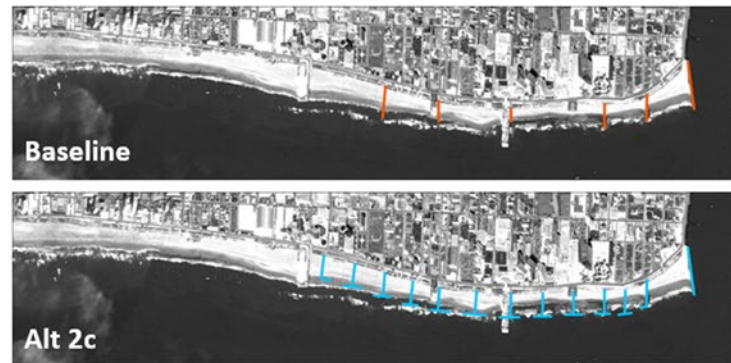
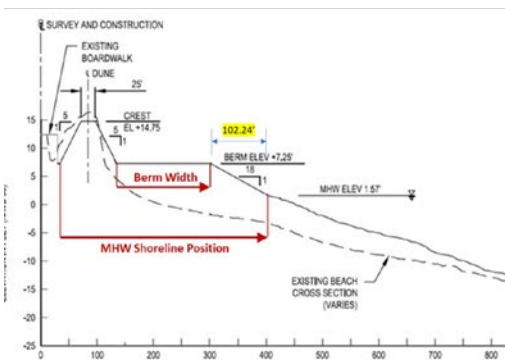


GenCade +CMS For shoreline evolution Modeling



Problem Solving Capabilities

Relevant Processes	CMS	GenCade
Changes in Shoreline Position	Limited	✓
• Long-term Evolution	Limited	✓
• Long-term Beach Fill Impacts	Limited	✓
Bathymetry Change	✓	—
• Shoal/Bar Behavior	✓	Limited
• Channel Infilling	✓	—
• Nearshore Placement	✓	—
• Sediment Pathways	✓	Limited
Cross-shore Transport	✓	Limited
• Non-equilibrium Profiles	✓	—

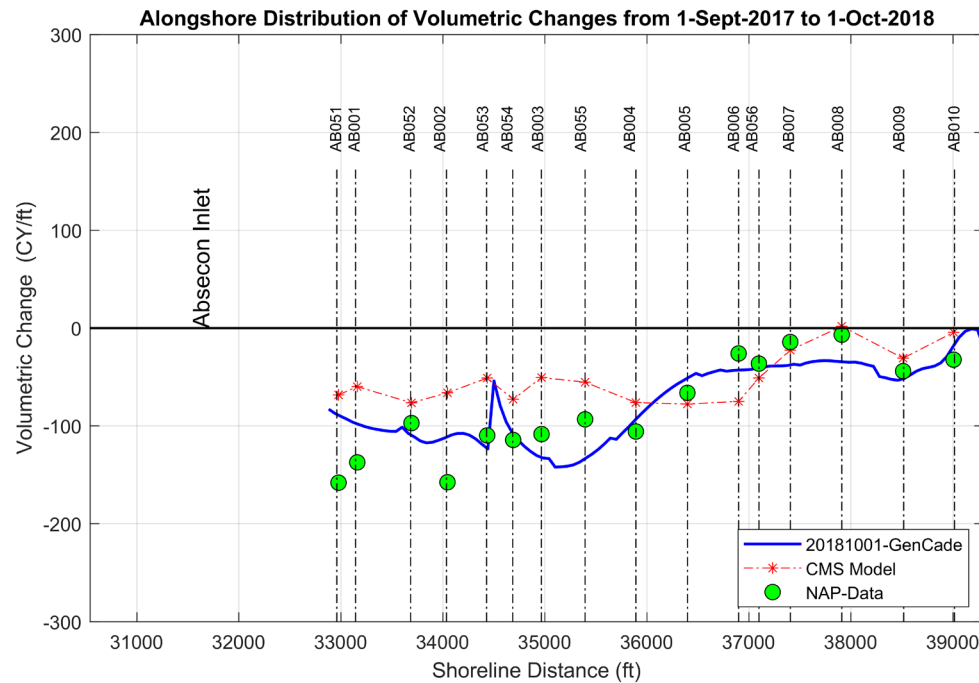




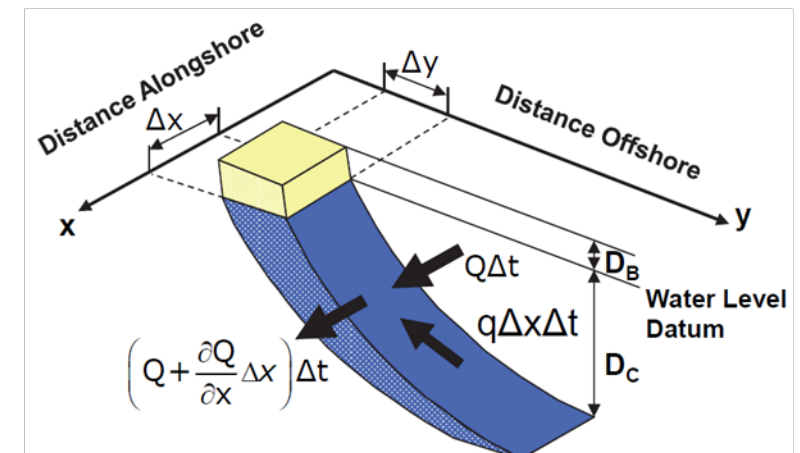
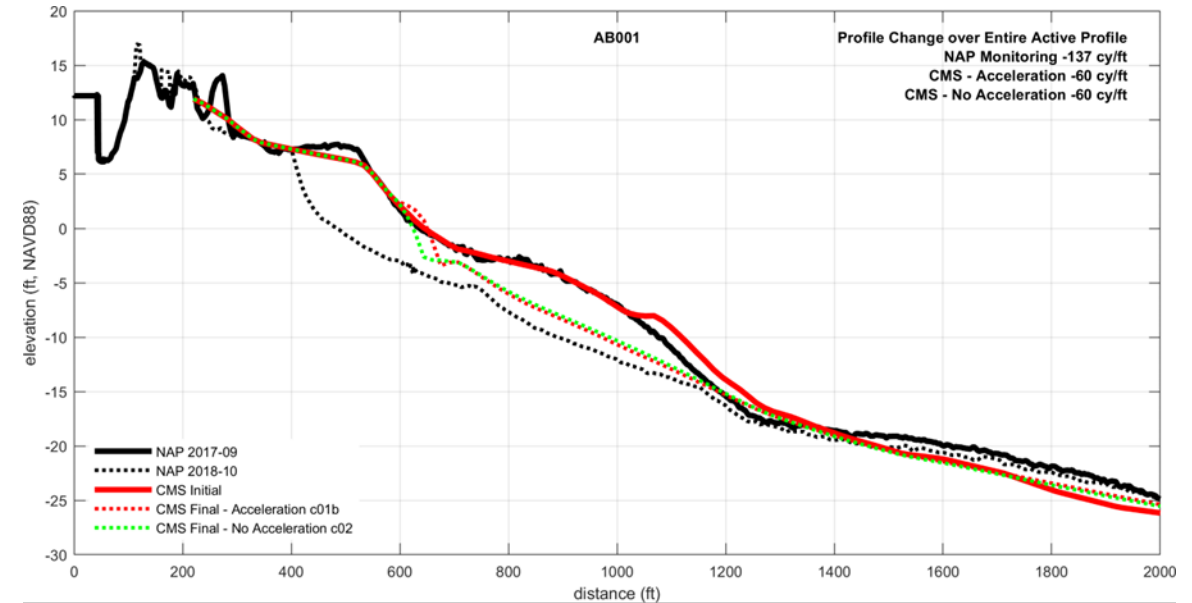
Leverage GenCade's Capabilities by Coupling with CMS



- Develop more coastal processes using CMS results to enhance predictability of long-term and regional shoreline changes.
- Leverage GenCade's capability to sediment volume management in a regional CSRM project scale and lifecycle of beachfills.

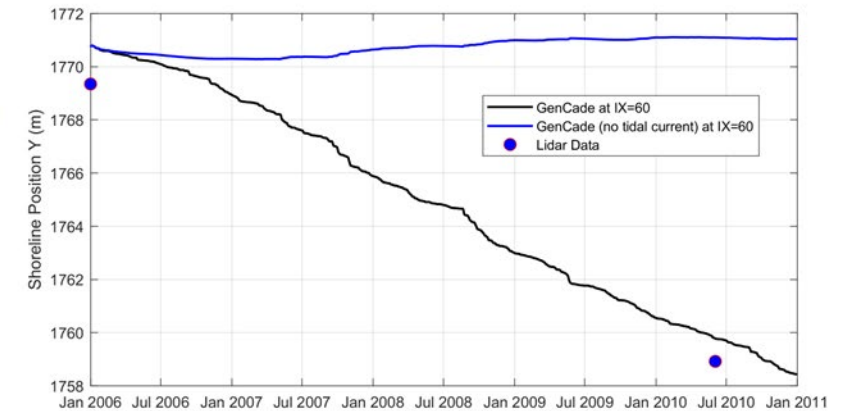
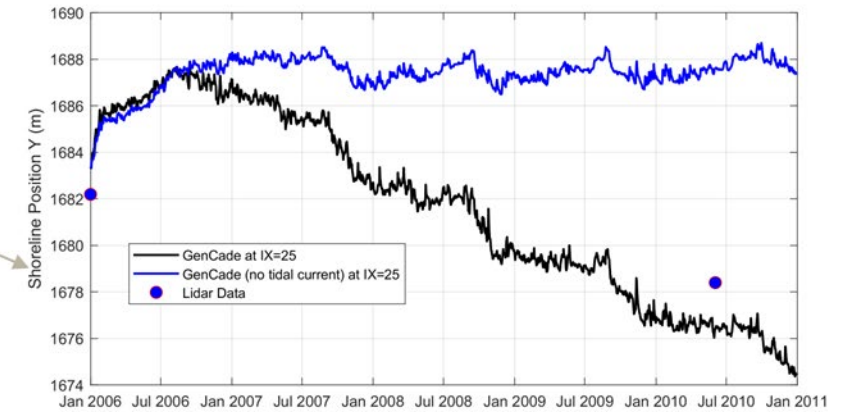
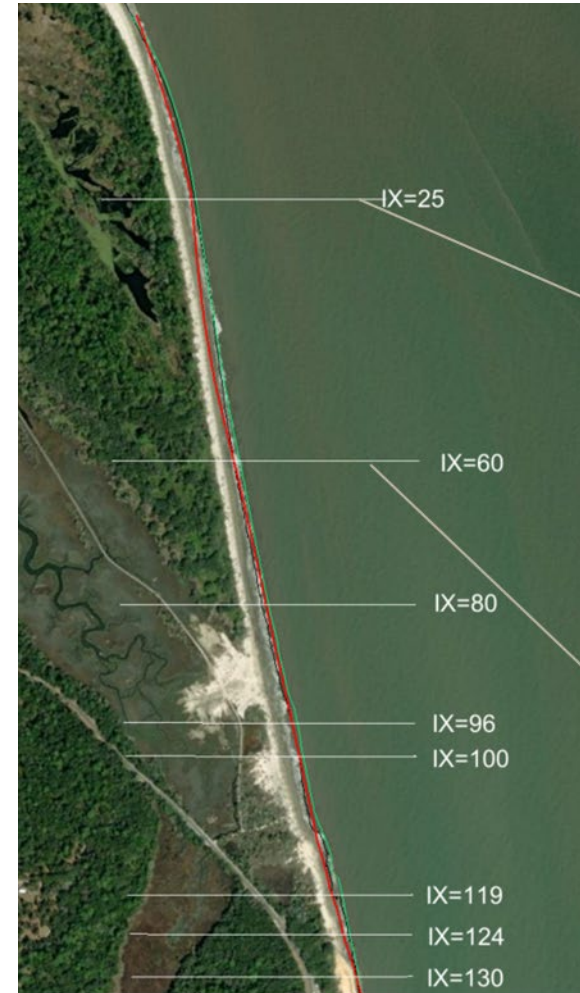
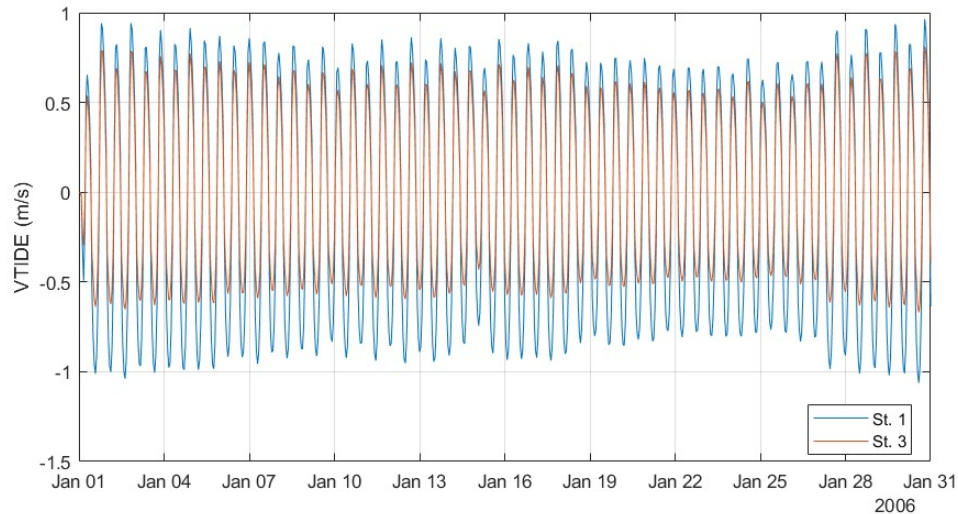
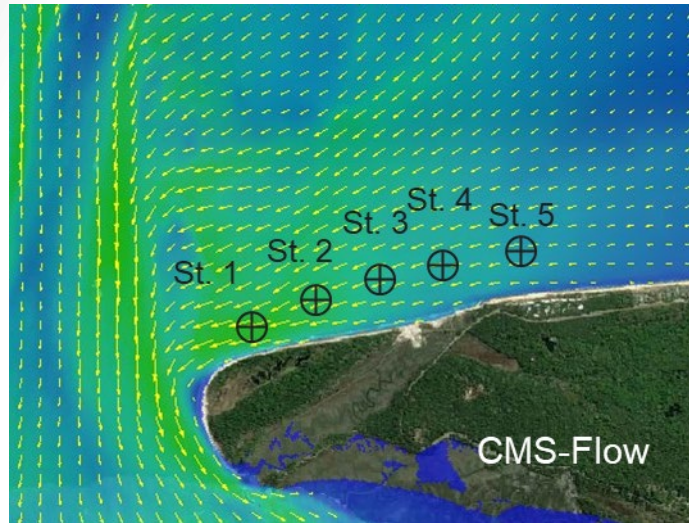


Model	Pearson Coeff.	RMS (CY/ft)	NRMSE* (%)
CMS	0.619	48.409	32.01
GenCade	0.806	28.805	19.05



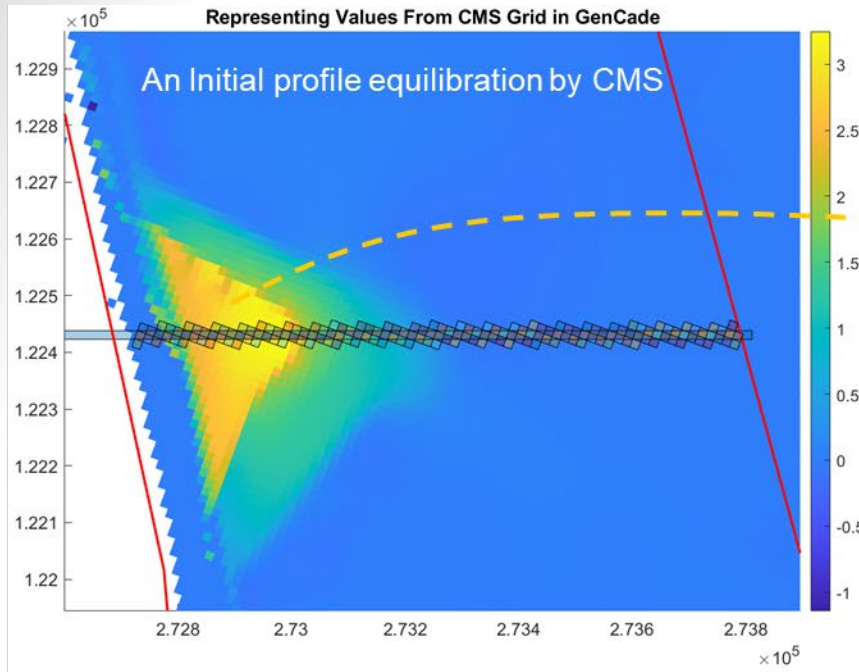


Tidal Currents by CMS-Flow for GenCade

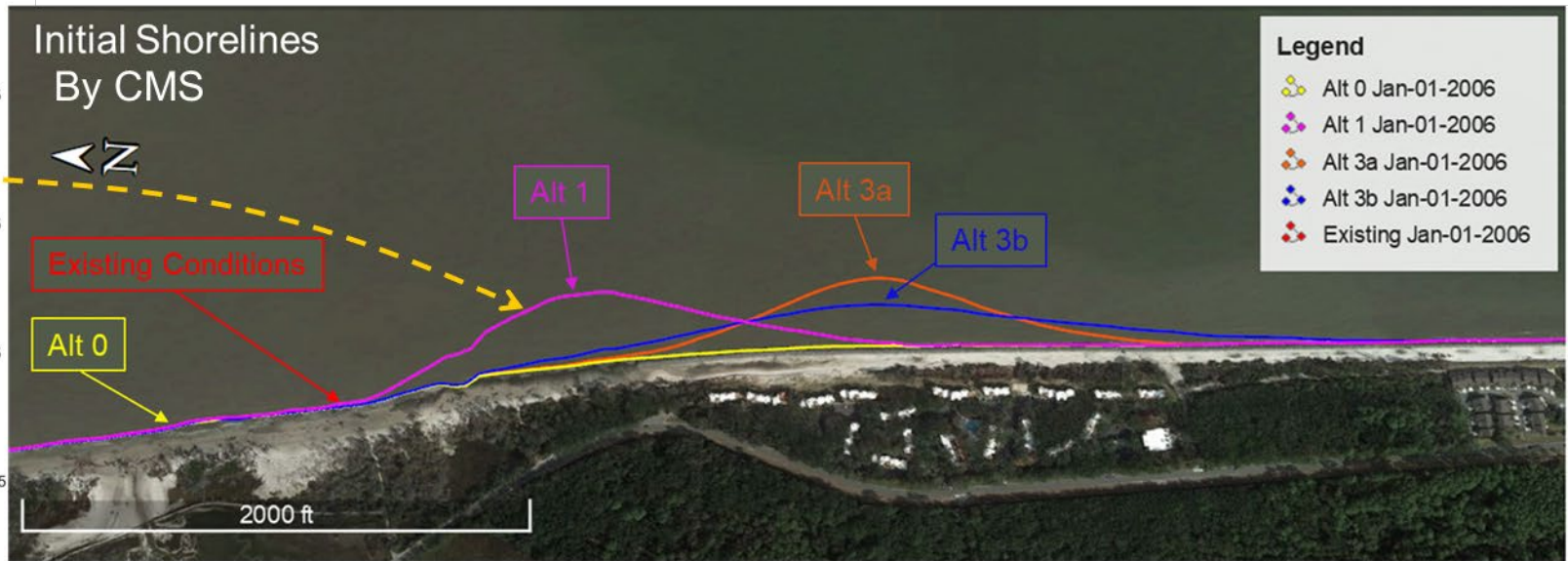




CMS and GenCade for Assessment of Beach Nourishment



- Run CMS with Initial placement volume and new beam over a short term (4 months)
- Estimated shoreline changes driven by CMS volume changes
- Continue to run GenCade from the CMS-initial shoreline for a long-term period (~10years)

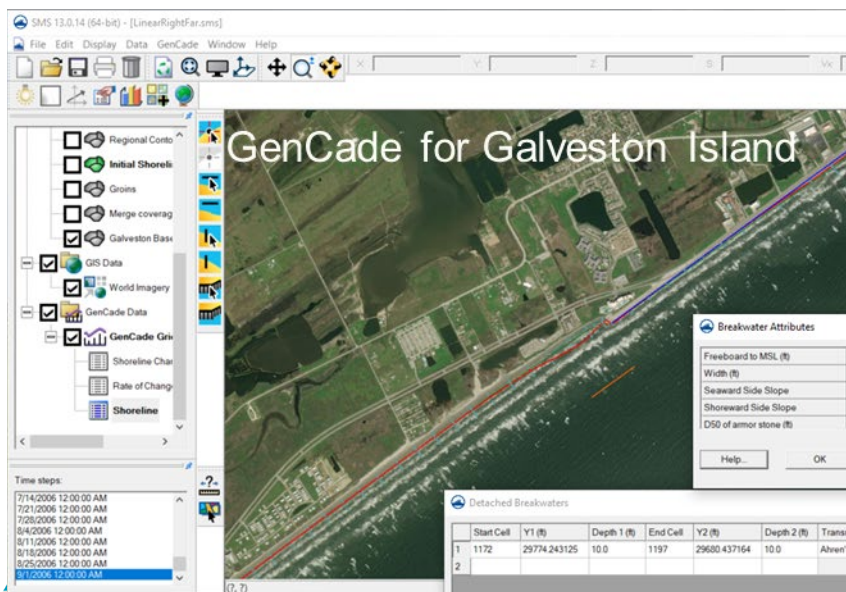


Yan Ding, Doug Krafft, Lihwa Li, Brian McFall, Numerical Modeling of Dredged Sediment Placement at Jekyll Island, Dec. 2023.



GenCade: Technical Transfer

- Internally release GenCade v2.0 (to SWG, SPL)
- GenCade Workshop, Los Angeles District, LA, 06/12-16/2023
- CIRP TD on GenCade and CMS for Absecon Inlet, 10/28/2023
- Presentations in AGU Fall Meeting, Dec. 2023, and AGU OSM, Feb. 2024 (GenCade Monte-Carlo, GenCade+CMS, etc.)
- One presentation about GenCade to NASA-NAO Wallops Island, Mar. 2024
- One oral-presentation planned for ASCE-EWRI' 24, 05/21/2024
- 2 TRs under Review/Preparation, 1 CHETN under preparation, CW-r&D VTN book chapter
- Serving District engineers (NAP, NAP, SAM) for problem solving, reviewing, and program development



Coastal Inlets Research Program

US Army Corps of Engineers

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CIRP Technology-Transfer Workshop

CMS/GenCade Workshop
USACE Los Angeles District,
915 Wilshire Blvd, Ste 1101, Los Angeles, CA 90017
12-16 June 2023

The Coastal Inlets Research Program (CIRP) conducted its 16th Technology Transfer Workshop from 12 - 16 June 2023. The workshop was held at the U.S. Army Corps of Engineers' Los Angeles District Area Office, located in Downtown LA.

The focus of this workshop is on the [Surface-Water Modeling System \(SMS\) Version 13.2](#), [Coastal Modeling System \(CMS\) Version 5.3](#), and [GenCade Version 1.1.8](#).

A link to download Workshop Materials is provided [here](#). Presentation and other Documents are in the main folder. All relative data files are underneath the 'Workshop' folder.

Time	Mon, 12 June	Tue, 13 June	Wed, 14 June	Thu, 15 June	Fri, 16 June
0830 - 1200		CMS (v5.3) Flow grid creation Flow model	CMS (v5.3) Steering Post-processing	GenCade (v1.1.8) Introduction to GenCade Simple Example Walk-Thru hands-on	CMS (v5.3) Advanced Topics Final Questions Workshop Concludes
1300 - 1700		ERDC Hydro-validation hands-on	on your own IS (v5.3)	GenCade (v1.1.8)	

Coastal and Hydraulics Laboratory

PROBLEM

SOLUTION

IMPACT

SHORELINE EVOLUTION MODELING FOR PLANNING COASTAL EROSION PROTECTION

CIVIL WORKS R&D

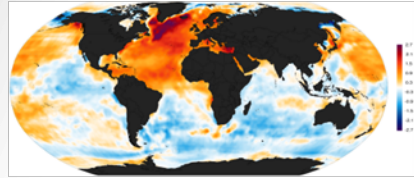


GenCade-Monte-Carlo with SWCE model (CODS)

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- New Wave Emulator using Climate Prediction

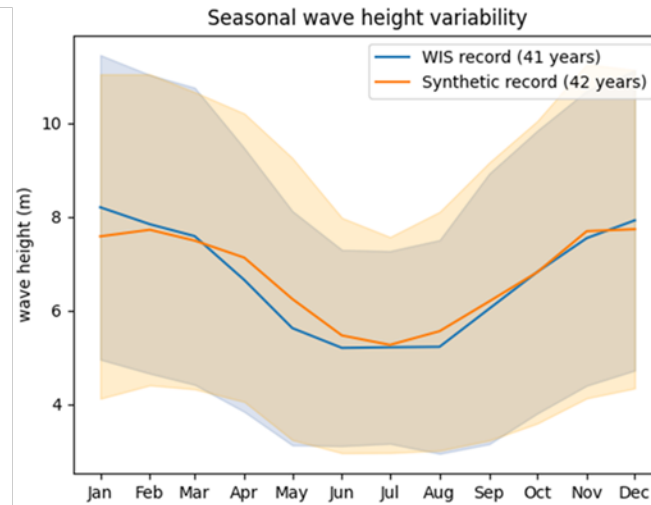
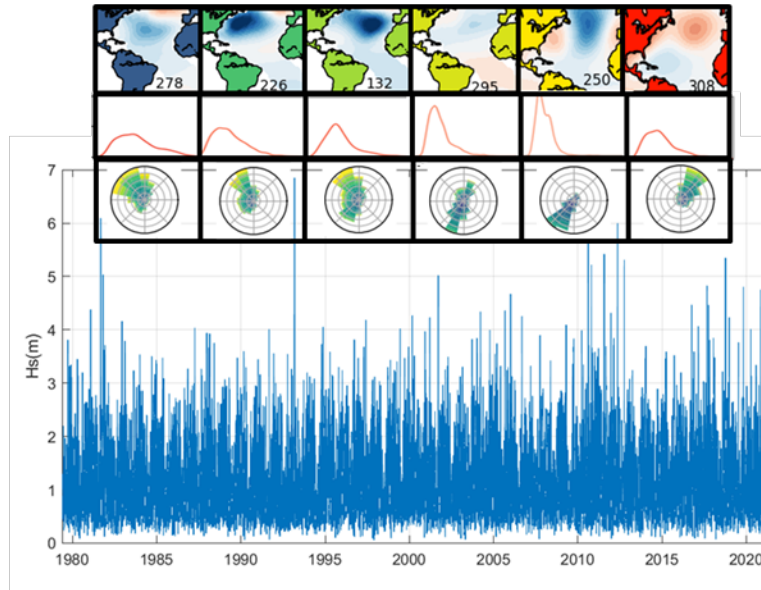


Create “daily weather type” using SLP fields from ERA5

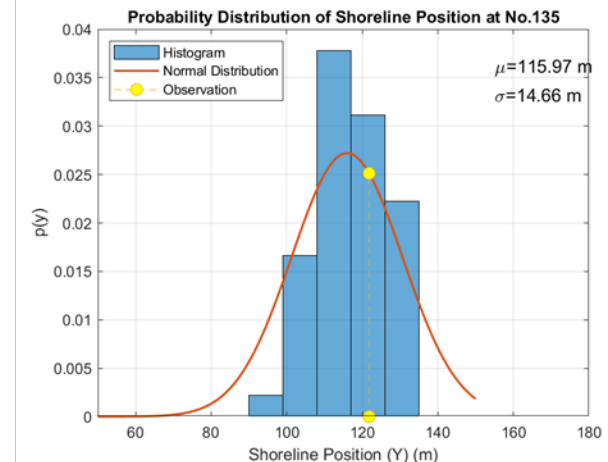
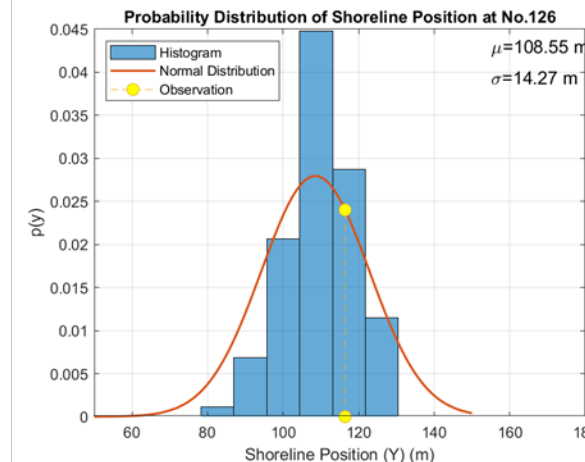
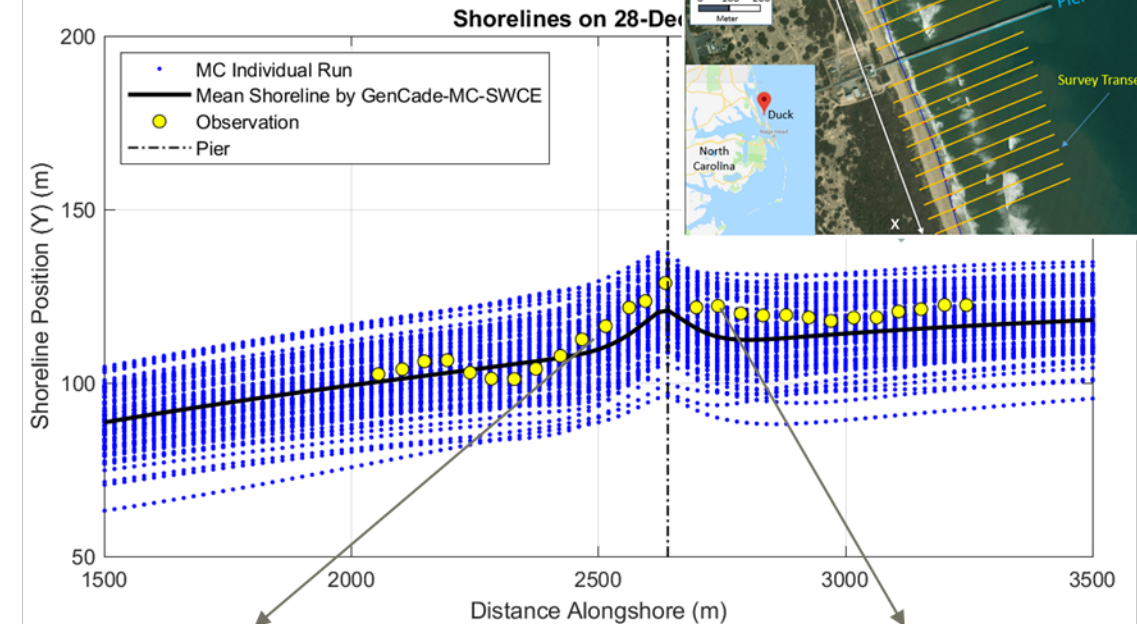
Auto-logistic model
→ Markov Chain of historical weather types

Gaussian copula for unique conditional probabilities of waves and WLs within each weather type

Create new time series of waves and water levels from the auto-logistic model



GenCade-MC results with Maximum Likelihood



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Summary

FY23 Major Advances in Capability

- Internally release GenCade v2.0
- Develop DMI GenCade Interface (near completion)
- Upgraded GenCade to include Monte-Carlo and Cross-Shore transport
- Debug and optimize codes
- Reimbursable projects (NAP, NAO, EWN/SAS)
- Updated GenCade wiki
- Publications and technical transfer

FY23 Major Products & Collaborations



- **4 TRs under preparation:** GenCade M-C, Jekyll Island Sand Motor, Lynnhaven Inlet, Absecon Inlet
- **1 Training Workshop:** 06/12-16/2023
- **4 Oral Presentations:** CIRP-TD, CE-PROSPECT, AGU OSM, NASA-NAO Wallops
- **1 Poster:** AGU Fall
- **5 Reimbursable Projects:** NAP-Absecon, NAO-Lynnhaven, Wallops, SAS-Jekyll Island, LRC-Crescent Beach
- **Leveraging to other Programs:** EWN – Deer Island Restoration, CMS (wave/flow/sediment)

Planned Outyear Products/Advances

- Continue working on DMI development with Aquaveo (**FY24**)
- GenCade with subaerial sediment transport (Aeolian process, interacting berm with dune) (**FY24**)
- Validate a coupling algorithm for shoreline evolution and sediment transport by GenCade+CMS (**FY24-25**)
- Release GenCade V.2.0 (Cross-shore + Monte-Carlo), publish TR (**FY24**)
- Cross-shore transport for beach fill / nourishment and nearshore placement (**FY25**)
- Stochastic Wave Climate model (SWCM) under CODS will leverage the capability of GenCade-MC (FY24-25)
- CoastSat or SSM for GenCade (FY24-25)
- Collaboration with universities and other agencies (USGS-CoSMoS)



Civil works – value to the nation

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PROBLEM

Many eroding U.S. shorelines rely on hard structures, supplemented by periodic beach fill. Barrier islands with intricate geological features like inlets challenge multi-dimensional coastal models. Users are often forced to choose either higher-dimensional modeling of limited scenarios or a reduced-order model. Inadequate study characterization can cause project failure due to cost or performance.

**17:1 ROI VIA
OPTIMIZATION
OF SAND VOLUME
IN A TYPICAL
COASTAL STORM
RISK MANAGEMENT
PROJECT**

SOLUTION

GenCade provides an efficient one-dimensional approach to capturing relevant coastal processes while allowing users to apply the full range of probable scenarios through the Monte Carlo functionality. Addition of cross-shore sediment transport results in a more robust model with improved fidelity. Integrating these models equips GenCade to capture diverse outcomes at project sites, enhancing precision in coastal modeling and erosion risk assessment.

IMPACT

Validated through a decade-long simulation in Duck, North Carolina, and Absecon Island, New Jersey, GenCade's enhanced features allow quantification of sediment transport impacts from coastal structures, bypassing, dredging and nourishments. Essential for USACE projects on open coast sandy beaches, GenCade is a critical tool for efficient coastal engineering studies.

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SHORELINE EVOLUTION MODELING FOR PLANNING COASTAL EROSION PROTECTION

The USACE GenCade shoreline model, formulated using equations for longshore transport and equilibrium beach profile response, has been pivotal in coastline modeling. However, nearshore processes and inlet dynamics on barrier islands introduce complexity due to the uncertainty inherent in waves, tidal currents and meteorological phenomena. Extensions to GenCade for cross-shore sediment transport and the Monte Carlo simulations through wave climate emulators provide solutions for these issues. The refined GenCade model proves effective in USACE coastal protection planning, guiding decisions on beach fills, sand bypassing and coastal structure design.

These efforts resulted in an advanced tool that enhances understanding of shoreline dynamics for USACE districts and users worldwide. GenCade model advancements provide rigorous simulations and comprehensive understanding of multifaceted factors influencing shoreline evolution, ensuring coastal management strategies do not solely rely on empirical data.



**CIVIL
WORKS
R&D**
Value to
the Nation
2024 Edition



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Recent Publications on GenCade



- USACE Reports
 - Ding, Y., Hampson, R., Friebel, H., Watson, K., and Kim, S.-K. (2022). Calibration and Validation of Shoreline Evolution Model on the Erosion Hot Spot near Absecon Inlet, Atlantic City, New Jersey, ERDC-CHL LR-23-1.
 - Ding, Y., S. C. Kim, R. Permenter, R. Styles, and Gebert, J. A. (2021). Simulations of Shoreline Changes along the Delaware Coast, ERDC/CHL TR-21-1, Vicksburg, MS: US Army Engineer Research and Development Center, <http://dx.doi.org/10.21079/11681/39559>, January 2021
 - Ding, Y., Styles, R., Kim, S-C, Permenter, R., Frey, A. (2020). Cross-Shore Transport Feature for GenCade, ERDC/CHL CHETN-IV-123, April 2020.
 - Kim, S. C., Styles, R., Rosati, J., Y. Ding, and R. Permenter (2020). A Comparison of GenCade, Pelnard-Considere, and LITPACK, ERDC/CHL CHETN-IV-124, April 2020
- Journal Publications
 - Ding, Y., Styles, R., Kim, S.-C., Permenter, R.L., and Frey A.E. (2021). Cross-shore sediment transport for modeling long-term shoreline evolution, J. Waterway, Port, Coastal, Ocean Eng., 2021, 147(4): 04021014, 25pp., DOI: 10.1061/(ASCE)WW.1943-5460.0000644
 - Whitley, A. E., Figlus, J., Valsamidis, A., and Reeve, D. E. (2021). One-line modeling of mega-nourishment evolution. Journal of Coastal Research, 37(6), 1224–1234. <https://doi.org/10.2112/JCOASTRES-D-20-00157.1>
- Conference Papers and Posters
 - Ding, Y., et al. (2023). Modeling of Long-Term Shoreline Evolution along Barrier Islands for Coastal Erosion Assessment, AGU Fall Meeting, San Francisco, CA, Dec. 11-15, 2023.
 - Ding, Y., Hampson, R., Friebel, H., and Watson, K. (2023). Long-term and regional shoreline evolution along Ab second Island, New Jersey, In: Proceeding of Coastal Sediments 2023, pp1466-1476. World Scientific, https://doi.org/10.1142/9789811275135_0136
 - Ding, Y. (2022). Long-term and Regional Shoreline Evolution around Coastal Inlets, in Proceedings of the ASCE-EWRI 2022 Congress, 11p, pp379-389, <https://doi.org/10.1061/9780784484258.035>.
- Training Materials
 - GenCade Workshop (Hands-on example, ppts, etc.) ,