PROBABILISTIC LONG-TERM AND REGIONAL SHORELINE EVOLUTION MODELING USING WAVE CLIMATE EMULATOR

Yan Ding, USACE-ERDC CHL, Vicksburg, MS 39180, USA. Yan.Ding@usace.army.mil
Dylan Anderson, USACE-ERDC CHL, Dylan.L.Anderson@usace.army.mil

INTRODUCTION

Prediction of long-term (decadal to centennial) shoreline evolution is essential for planning and managing lifecycle performance of erosion protection measures such as groins, breakwaters, and sand nourishment. Probabilistic shoreline change modeling can predict risks and uncertainties of erosion for risk-based coastal protection practice. Due to complex spatiotemporally-varying conditions of beach dynamic processes driven by waves, currents, sediment transport, wave climate changes, and sea level rise, quantifying uncertainties of shoreline changes and risks of extreme erosion by storms and cyclones in a regional (10 to 100 miles-long) coast is a challenge.

METHOD

This presentation presents a probabilistic shoreline evolution modeling by using a shoreline model and a stochastic wave climate emulator (SWCE). The deterministic shoreline model GenCade is a one-line model developed by USACE (Frey et al. 2012), capable of simulating long-term shoreline changes driven by longshore, cross-shore sediment transport (Ding et al. 2021), and inlet bypassing across barrier islands (Ding et al. 2023). It provides the capabilities of engineering design and planning in a project scale to quantify the impacts of coastal structures, bypassing/dredging, and nourishments on regional shoreline changes. For predicting uncertainties of shoreline erosion for risk-based planning and design, a SWCE model has been implemented into the GenCade shoreline model.

Including large-scale climate processes, this SWCE model uses pressure and temperatures on sea surface that reflect inter-annual oceanic variability and outgoing long wave radiation that reflects intra-seasonal variability to modulate the probability of weather occurring at a range of climate timescales (Anderson et al. 2019). Therefore, by using the wave samples generated by the SWCE, GenCade Monte-Carlo shoreline simulations can better predict uncertainty and risks of seasonal and annual variations of shoreline changes.

RESULTS

This probabilistic shoreline model is applied to simulate multiple-years shoreline changes in Duck coast, North Carolina, USA (Fig. 1a). The deterministic shoreline model has been successfully validated by simulating decadal (2000-2014) shoreline evolution driven by long-shore and cross-shore sediment transport (Fig. 1b). The validation results have confirmed that the FRF pier plays an important role on altering shoreline shapes from season to season (Fig. 2ab). For probabilistic shoreline modeling at the site, the SWCE model is used to generate samples of waves and water levels by using ERA5 reanalysis data. And the statistic features of the waves by the SWCE are compared with those by a WIS (Wave Information Study) station near the study site. This hindcast probabilistic shoreline evolution from 2000 to 2006 has captured the likelihood of seasonal and annual variations in the historical shorelines (Fig. 3). It indicates that the models would also provide reliable probability estimation of shoreline changes in the future. Further detailed results will be presented.

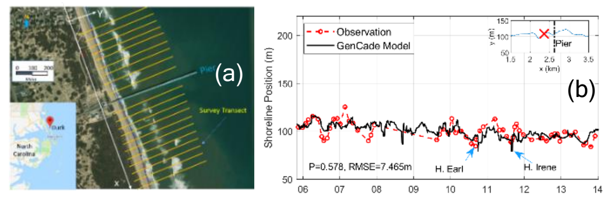

Figure 1. (a) Study site and survey transects in Duck, NC. (b)Time histories of shoreline positions at the north shore near the pier (indicated by a red symbol "*X*" in a box in the upright corner). P = Pearson correlation coefficient. RMSE = root-mean-square error of shoreline positions.

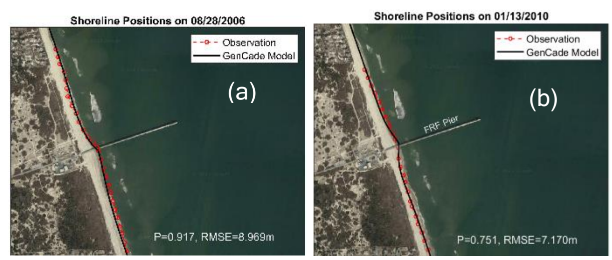

Figure 2. Comparisons of shoreline profiles on (a) 08/26/2006 (summer), and (b) on 01/13/2010 (winter).

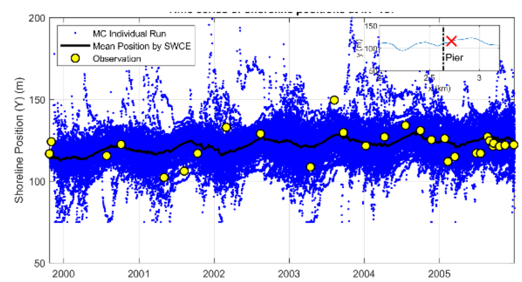

Figure 3. GenCade Monte-Carlo simulations from 2000 to 2006 at Duck, NC, by using SWCE waves. The blue dots are all the shoreline positions simulated by 100 Monte-Carlo runs. The bold black line is the mean shoreline positions of the 100 simulations.

REFERENCES

Anderson, D. et al. (2019). J. Geophysical Res.: Oceans, 124. doi:10.1029/2019JC015312.
Ding, Y., et al. (2021). J. Waterway, Port, Coastal, Ocean Eng., 2021, 147(4): 04021014.
Ding, Y. et al. (2023). In Proc. of Coastal Sediments 2023, pp. 1466-1476,
Frey, A.E et al. (2012). GenCade version 1 Model theory and user's guide. USACE, ERDC/CHL TR-12-25, 169 pp.