

BASIN-SCALE MODEL FOR PREDICTING MARSH EDGE EROSION

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INTRODUCTION

Recent attempts to relate marsh edge retreat rate to wave power have met varying levels of success. Schwimmer (2001) correlated wave power to marsh boundary retreat rates over a five-year period along sites within Rehoboth Bay, Delaware, USA. Marani et al. (2011) derived a linear relationship between volumetric retreat rate and mean wave power density using Buckingham's theorem of dimensional analysis. Leonardi and Fagherazzi (2015) added an exponential function to the Schwimmer (2001) equation to account for variability in soil resistance and mean wave height. These equations factor in soil type, water elevation, vegetation, and macrofauna through field-calibrated empirical constants, i.e., they are not explicitly considered. Consequently, the existing capability of predicting marsh edge erosion rate as a function of wave power and soil and vegetation properties is rather limited for engineering applications. For instance, Allison et al. (2017) show that without taking the marsh platform, soil, and vegetation into account, the relationships between marsh edge erosion rates and wave power on a basin or coastal-wide scale are not strong enough statistically to serve as a useful predictive model. The objective of this study is to develop a more robust marsh edge erosion model by characterizing the shear strength, wave power, and retreat rates in Terrebonne Bay, Louisiana.

METHODS

The methodology consists of synchronized field data for waves, soil properties, and retreat rates. The soil, moisture, resistivity, and temperature (SMRT) piezocone penetrometer test (CPTu) was used to quantify the geotechnical properties of wetlands, including tip resistant, soil dielectric constant, and soil resistivity. The tip resistance (q_c) is used to determine the undrained shear strength, $S_u = q_c/N_{kt}$, where the empirical factor N_{kt} is assumed 20. To perform a cone sounding, the cone is hand-pushed into the marsh at a rate of 2 cm/s. The data acquisition system records continuously with depth. The average shear strength of the soil below the vegetative mat is used for development of the marsh edge model. Land area change assessments are often conducted from satellite imagery at coarse scales (30 m). These assessments are inappropriate for quantifying fine-scale processes, such as marsh edge erosion. Therefore, a coast-wide spatial dataset was created, which enabled quantification of edge erosion at millions of locations, thereby resulting in edge erosion at 1-m resolution for three time intervals. Erosion rates were calculated by measuring the distance of shoreline retreat along vectors perpendicular to shoreline orientation at regular intervals. This dataset was used for marsh erosion model calibration and validation in Terrebonne Bay. In this study, SWAN was coupled with Delft3D-Flow, a coastal and estuarine circulation model to predict wind waves along the marsh edges. Delft3D provided water levels and currents for the SWAN model. Following Everett et al. (2017), the validated SWAN and Delft3D models were

employed in Terrebonne Bay to determine the wind-sea wave power generated by winds blowing over the shallow estuaries and the swell power from entering the estuaries from the Gulf of Mexico. The locations of wave power and retreat rates were correlated to shear strength for the development of marsh edge erosion model.

RESULTS

Based on the synchronization of soil shear strength and high-resolution wave power and retreat rates, the following model is proposed for Terrebonne Bay:

$$V = \bar{k} P \exp \left[-\gamma \left(\frac{S_u^*}{S_{xx}^*} - 1 \right) \right]$$

where V is the volumetric erosion rate, P is the wave power, S_{xx} is the radiation stress for a give wave energy field associated with P , $s_u^* = s_u/\bar{s}_u$ is the local shear strength normalized by the mean shear strength for the region, $S_{xx}^* = S_{xx}/\bar{S}_{xx}$ is the site-specific radiation stress normalized by the mean radiation stress of the data set, and \bar{k} is the slope relating V and P when these values are averaged over regular wave power bins, s_u is the site specific shear strength, and γ is a calibration parameter used to relate soil properties to erosion rates (Johnson 2016). For the Terrebonne Bay basin, the calibrated empirical constants are $\bar{k}=0.0516$ and $\gamma=1.95$ based on an existing soil shear strength dataset.

CONCLUSIONS

A new model is proposed relating erosion rates to mean wave power and radiation stress with the inclusion of soil shear strength. A new technique has been utilized to conduct field measurements of wetland soil properties. The proposed model scales the effects of incident wave power by considering the wave radiation stress relative to the shear strength of the marsh. High-resolution wave and marsh edge retreat data are being used to calibrate and validate the model.

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