

MACHINE LEARNING AND REMOTE SENSING APPLICATIONS FOR LAKE MICHIGAN COASTAL PROCESSES

by

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ABSTRACT

The recent surge in water levels within the Great Lakes has laid bare the vulnerability of the surrounding coastal areas. Over the past few years, communities along the Great Lakes coast have struggled with widespread coastal transformations, witnessing phenomena such as shoreline retreat, alterations in habitat, significant recession of bluffs and dunes, infrastructure and property damage, coastal flooding, and the failure of coastal protection structures. Unlike the ocean coasts, the Great Lakes coastal regions experience a unique confluence of large interannual water level fluctuations, coastal storms, and ice cover dynamics, which complicates the ongoing coastal management endeavors. To address this multifaceted challenge, the interplay between all these factors and their impact on coastal changes should be understood and applied to improve the resilience of Great Lakes coastal areas.

In this dissertation, several steps were taken to improve knowledge of coastal processes in the Great Lakes, spanning from the initial use of remote sensing for quantifying coastal changes to the subsequent stages of modeling and predicting shoreline changes as well as leveraging machine learning techniques to simulate and forecast influential factors like waves and ice cover. First, a fully automated shoreline detection algorithm was developed to quantify the shoreline changes in Lake Michigan, detecting the most vulnerable areas, and determining the main factors responsible for the spatial variability in the shoreline changes. Additionally, a reduced complexity model was designed to simulate the shoreline changes in Lake Michigan by considering both waves and water level fluctuations, which significantly improved the shoreline changes modeling and forecasting for Lake Michigan. Furthermore, new deep learning-based frameworks based on the Convolution Long Short-Term Memory (ConvLSTM) and Convolution Neural Network (CNN) were introduced to model and extend the current records of wave heights and ice cover datasets, adding 70% and 50% data to the existing waves and ice time series respectively. Finally, the extended

waves and ice time series were used to study the long-term trends and the correlation between the interannual water level and waves changes, revealing a statically significant decreasing trend in the ice cover over Lake Michigan of 0.6 days/year, and an increasing trend in the waves interannual variability at Chicago area.