MULTISCALE INVESTIGATION OF NEARSHORE HYDRODYNAMICS AND MORPHODYNAMICS IN SOUTHERN LAKE MICHIGAN

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Nearshore processes govern the transport of sediment and contaminants along the coast, influencing shoreline evolution and beach health. This thesis develops a holistic picture of the southern Lake Michigan nearshore through basin-scale and local investigations of the processes shaping the coastline using numerical model output, observational data, and satellite imagery. First, patterns of wind-driven alongshore circulation were examined using output from the Lake Michigan and Huron Operational Forecast System spanning 2021-2025. Model results were validated with field observations and analyzed for long-term, seasonal, and storm-driven patterns. Currents were generally stronger and more consistent during winter and storm periods, while summer currents were weaker and more variable. The dominant pattern explained 61.9% of the total current variability and showed a basin-scale reversal in transport direction between the eastern and western shorelines. The Indiana shoreline generally followed the western-shore pattern, while a zone of lower variability near the Indiana-Michigan border marked a potential deposition zone for sediment and contaminants.

At five sites along southeastern Lake Michigan, a one-dimensional, depth-averaged alongshore momentum balance was used to examine the sources of momentum driving alongshore currents in the region. Wind stress, bed stress, local acceleration, pressure gradient, and Coriolis forcing terms were compared to determine how their importance varied by site. The pressure gradient had the largest magnitude at every site, while wind stress was most strongly correlated with the combined response of the pressure gradient and bed stress. The dominant variability at shallow sites reflected a balance between the pressure gradient and bed stress, whereas deeper sites showed greater relative contributions from Coriolis forcing. Bottom friction became more important during energetic conditions, when wind stress also increased and critical bed stress thresholds were most frequently exceeded, indicating episodic sediment mobilization potential.

Finally, the response of Indiana nearshore morphology to rising lake levels (2013-2020) and subsequent decline (2020-2025) was examined using multispectral satellite imagery validated against LiDAR and field surveys. Shorelines expectedly receded landward as lake levels rose and advanced lakeward as levels declined. By 2025, 12 of 19 shoreline sub-reaches had not fully recovered from earlier recession, showing that water level change alone does not explain shoreline movement. Hardened shorelines were associated with reduced recovery. The nearshore was predominantly double-barred. The outer bar was more persistent, while the inner bar was narrower and more mobile. Both bars generally moved lakeward and became spaced farther from the shoreline as water levels fell after 2020. Altogether, this research contextualizes future investigations into sediment and contaminant transport in the region, supporting coastal management in southern Lake Michigan.