DAILY BEACH EVOLUTION WITH STEREO PHOTOGRAMMETRY AT AN UNDEVELOPED BARRIER ISLAND

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BACKGROUND

The subaerial beach – extending from the shoreline to the dune toe – is a critical, yet vulnerable, buffer that protects human development and coastal ecosystems from hydrodynamic forces. This region changes shape and position over multiple spatial and temporal scales. This includes seasonal oscillations in the beach and the punctuation of severe erosion caused by extreme storms with subsequent recovery towards an equilibrium beach profile (*e.g.,* Wright and Short, 1984; Stive et al*.,* 2002). Over longer time scales (years to decades), relative sea-level rise and human modifications to regional sediment budgets – through beach nourishment projects and post-storm recovery efforts – also exert controls on beach evolution.

Beaches on barrier islands can also change shape in response to storm impacts in ways that differ from other coastal settings, specifically through the processes of sand overwash, outwash (bay-to-ocean directed flows), and island breaching events (Matias and Masselink, 2017; Sherwood et al., 2014; 2022). Beach recovery following extreme events – over timescales influenced by hydrodynamic factors (*e.g.,* wave climate, storm sequencing) – can also exhibit significant alongshore variability associated with pre-existing beach morphology and human modifications to the regional sediment budgets (*e.g*., nourishments, jetties; Morton et al., 1994, Davidson et al., 2013). Over longer timescales, alongshore variability in beach dynamics and management could influence patterns of barrier migration with relative sea-level rise (Anarde et al., 2023).

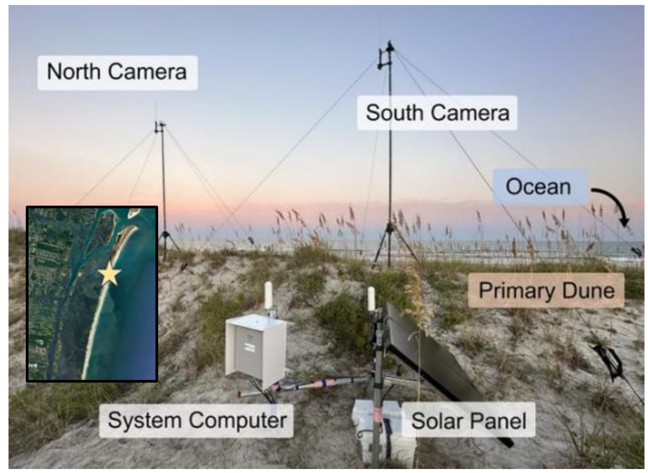

Fig. 1 – Masonboro Island field site (map inset) with two elevated cameras pointed southward along the coast.

While we know that beach evolution occurs over multiple spatial and temporal scales, we have limited observations connecting hydrodynamic processes and morphodynamic response across both scales (time and space). This is primarily attributed to a lack of long-term field observations, which are typically confined to a few cross-shore transects with low temporal resolution (*i.e.,* sampling frequencies from days to months). To address this, here we investigate the spatiotemporal evolution of subaerial beach morphology and the underlying processes responsible for these changes at an undeveloped barrier island with stereo photogrammetry.

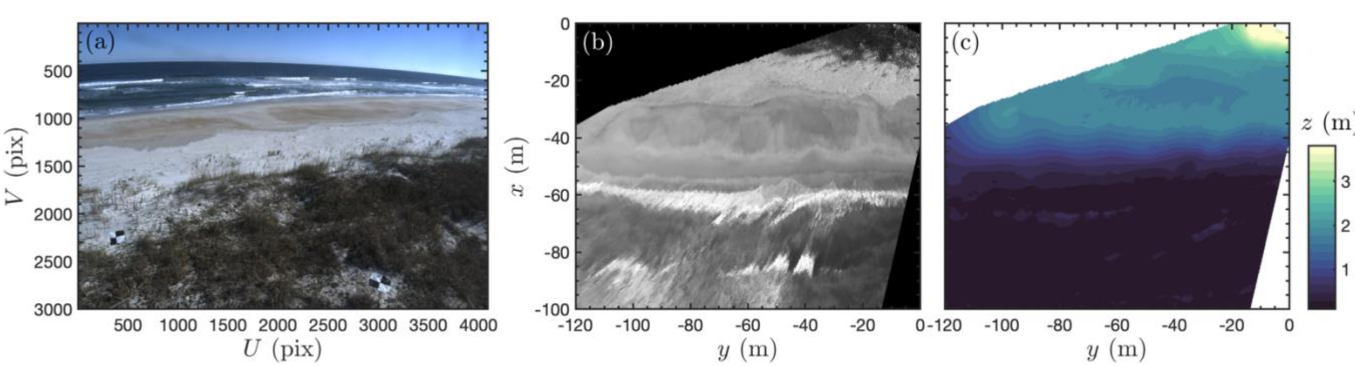

Fig. 2 – Example (a) oblique image (in pixel coordinates) and (b) rectified image (as a function of cross-, *x*, and alongshore, *y,* coordinates) from the southern camera on Masonboro Island. (c) A digital elevation map (*z,* color contours) created from both cameras with stereo photogrammetry.

FIELD SITE AND STEREO RECONSTRUCTIONS

Our study examines beach state changes on tidal to monthly time scales at Masonboro Island Reserve in southeast North Carolina (Figure 1). The region experiences high water levels during storms (tropical storms and nor'easters) and during seasonal high tides and persistent north winds (Sweet at al., 2022). Masonboro Island is positioned between two heavily developed barrier islands that alter regional sediment budgets through beach nourishment, dredging, and hard structures. Masonboro Island is undeveloped and serves as a wildlife refuge. However, the back barrier has historically been managed for natural resource preservation and sand has occasionally been placed on some portions of the beach as part of beneficial use dredging projects. Yet, the decision of sediment placement to optimize habitat resource benefits has not been informed by scientific research.

Two co-located visible-band cameras were elevated on 6-m masts above the established foredune and directed southward along the beach (Figure 1 and 2a). The system is powered by solar panels and images are collected and transmitted by a remotely accessible computer system. The overlapping camera field of view of the subaerial beach spans about 100 m in the alongshore (typically 1-3 cusp lengths) and 60 m in the cross-shore (from the shoreline to the dune face, Figure 2b).

The camera system was deployed in September 2023, with plans for continuous sampling for at least one year. The camera system collects 10 image pairs three times daily (capturing multiple stages of the tide) during quiescent conditions and at higher frequencies (2 Hz) during storms.

Digital elevation maps of the subaerial beach face are created from stereo photogrammetry applied to the co-located camera images (Figure 2b). Elevation maps along the beach range from <5-cm resolution near the dune toe to around 15-cm resolution at the shoreline. We evaluate the accuracy of stereo reconstructions by comparing them with elevations collected monthly at an overlapping RTK-sampled cross-shore transect and drone-surveyed lidar elevation maps. Stereo reconstructions are related to hydrodynamic and meteorological processes using wave buoy data directly offshore Masonboro Island and a local weather station (www.cormp.org).

BEACH EVOLUTION ANALYSIS

We examine beach morphology changes during high water level events (storms and high water levels from tides and wind) and subsequent beach recovery with the high spatiotemporal elevation maps. For example, high water levels (1.9 m above mean lower low water, MLLW) and large waves during Tropical Storm Ophelia on Sept. 22, 2023 resulted in wave runup reaching the incipient dune toe. During this event, the beach face and berm exhibited variability along the coast, altering the runup extent and subsequent sediment loss during storms. The berm was nearly alongshore uniform by the next high-high (perigean) tide event (2.1 above MLLW) that occurred a week later (Sept. 28, 2023).

For high water level events, the subaerial beach volume and shoreline position are extracted from stereo reconstructions at 0.5-m resolution along the beach to assess the temporal and alongshore variability in beach recovery stages. Through these dense spatiotemporal observations, we seek to improve and test existing models of storm impacts and subsequent beach recovery on subaerial beach volume that can be employed at other undeveloped barrier beaches exposed to high water levels.

REFERENCES

Anarde, K. A., Moore, L. J., Murray, B., & Reeves, I. R. (2023). The Future of Developed Barrier Systems-Part II: Alongshore Complexities and Emergent Climate Change Dynamics. *EarthArXiv.*

Davidson, M. A., Turner, I. L., Splinter, K. D., & Harley, M. D. (2017). Annual prediction of shoreline erosion and subsequent recovery. *Coastal Engineering*, 130, 14-25.

Matias, A., & Masselink, G. (2017). Overwash processes: lessons from fieldwork and laboratory experiments. *Coastal Storms: Processes and Impacts*, 175-194.

Morton, R. A., Paine, J. G., & Gibeaut, J. C. (1994). Stages and durations of post-storm beach recovery, southeastern Texas coast, USA. *Journal of Coastal Research*, 884-908.

Sherwood, C. R., Long, J. W., Dickhudt, P. J., Dalyander, P. S., Thompson, D. M., & Plant, N. G. (2014). Inundation of a barrier island (Chandeleur Islands, Louisiana, USA) during a hurricane: Observed water-level gradients and modeled seaward sand transport. *Journal of Geophysical Research: Earth Surface*, 119(7), 1498-1515.

Sherwood, C. R., Van Dongeren, A., Doyle, J., Hegermiller, C. A., Hsu, T. J., Kalra, T. S., ... & Warner, J. C. (2022). Modeling the morphodynamics of coastal responses to extreme events: What shape are we in?. *Annual review of marine science,* 14, 457-492.

Stive, M. J., Aarninkhof, S. G., Hamm, L., Hanson, H., Larson, M., Wijnberg, K. M., ... & Capobianco, M. (2002). Variability of shore and shoreline evolution. *Coastal engineering*, 47(2), 211-235.

Sweet, W. W. V., Dusek, G., Obeysekera, J. T. B., & Marra, J. J. (2018). Patterns and projections of high tide flooding along the US coastline using a common impact threshold.

Wright, L. D., & Short, A. D. (1984). Morphodynamic variability of surf zones and beaches: a synthesis. *Marine geology*, 56(1-4), 93-118