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Quantification of Dune Response during a 6-Day Nor'easter, Outer Banks, NC

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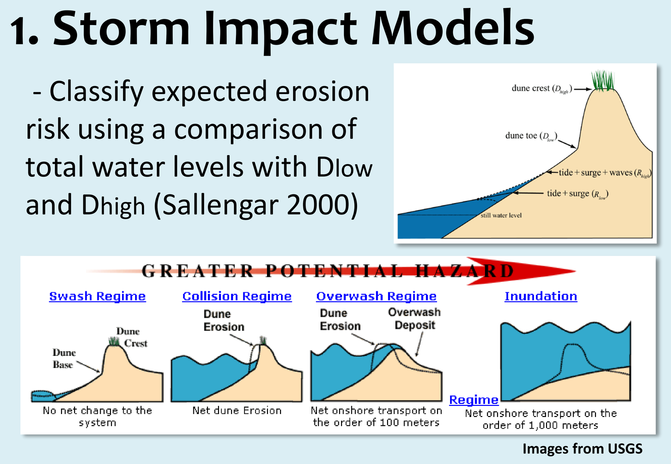
ABSTRACT

The amount and type of foredune morphologic change during a storm event primarily scales with the level of inundation of the system during that storm event. Specifically, external hydrodynamic forcing (total water level) can be compared with antecedent beach and foredune morphology to predict an impact regime that relates to the type of expected morphologic evolution of the system. For example, when total water levels are expected to be above the dune toe, but below the dune crest, the impact regime is classified as "collision" and the expected morphology response is slumping or scarping of the dune face. While the rate of dune retreat scales largely with the duration of wave attack to the dune face, other characteristics of the dune that are not described by its crest or toe elevation (compaction, vegetation type and density, initial slope) may also enhance or impede rates of morphologic change. The aftermath of Hurricane Sandy provided a unique opportunity to observe alongshore variations in dune type response to a 6-day Nor'Easter (Hs >4 m in 6 m depth), as a variety of dunes were constructed (or not) by individual home owners in preparation for the approaching winter storm season. Daily terrestrial lidar scans were conducted along 20 km of coastline in Duck, NC using Coastal Lidar And Imaging System (CLARIS) during the first dune collision event following Hurricane Sandy. Foredunes were grouped by their pre-storm form (e.g. vegetated, pushed, scarped, etc) using automated feature extraction tools based on surface curvature and slope, and daily rates of morphologic volume change were calculated. The highest dune retreat rates were focused along a 1.5 km region where cross-shore erosion of recently pushed, un-vegetated dunes reached 2 m/day. Variations in foredune response were analyzed in relation to their pre-storm morphology, with care taken to normalize for alongshore variations in hydrodynamic forcing. Ongoing research is focused on identifying specific properties, in addition to dune crest and toe elevation, that can be easily extracted from topographic DEMs and can help improve dune retreat predictions.

BACKGROUND

1. Storm Impact Models

- Classify expected erosion risk using a comparison of total water levels with D_{low} and D_{high} (Sallenger 2000)



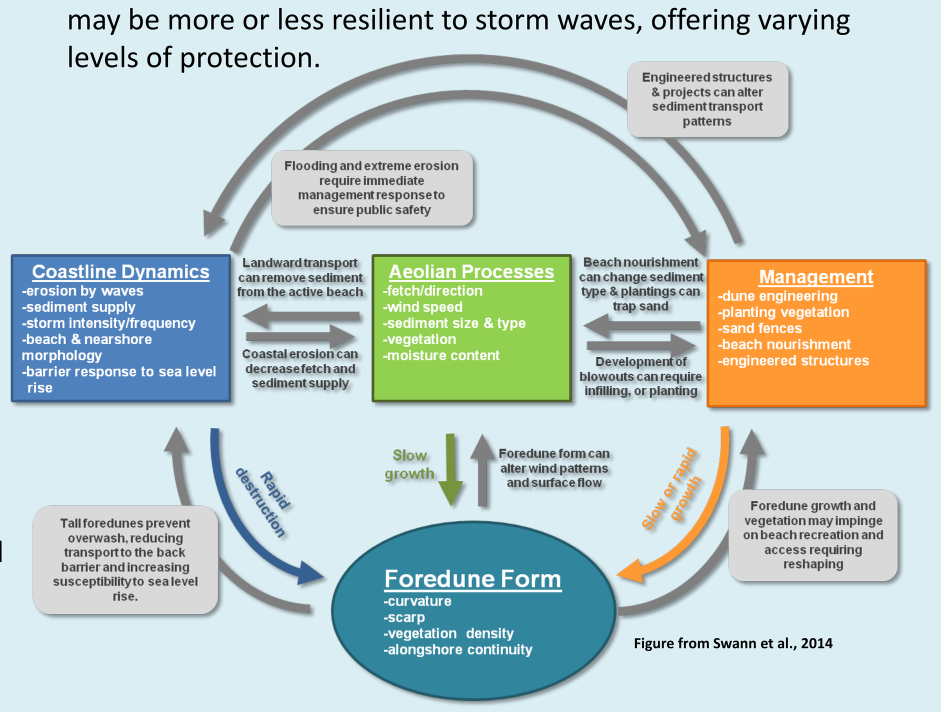
2. Simple Dune Erosion Models

- Relate volume of erosion through time to the momentum flux from wave impact (e.g. Larson et al., 2004; Palmsten & Holman, 2012)

- The Palmsten & Holman (2012) model has shown good results for both lab and field (Splinter and Palmsten 2012) predictions of dune toe retreat along a single profile, but has not been tested over a wide region.

3. Foredune Form

- Foredunes cycle through a variety of morphologic states depending upon the processes acting on them. Different forms may be more or less resilient to storm waves, offering varying levels of protection.

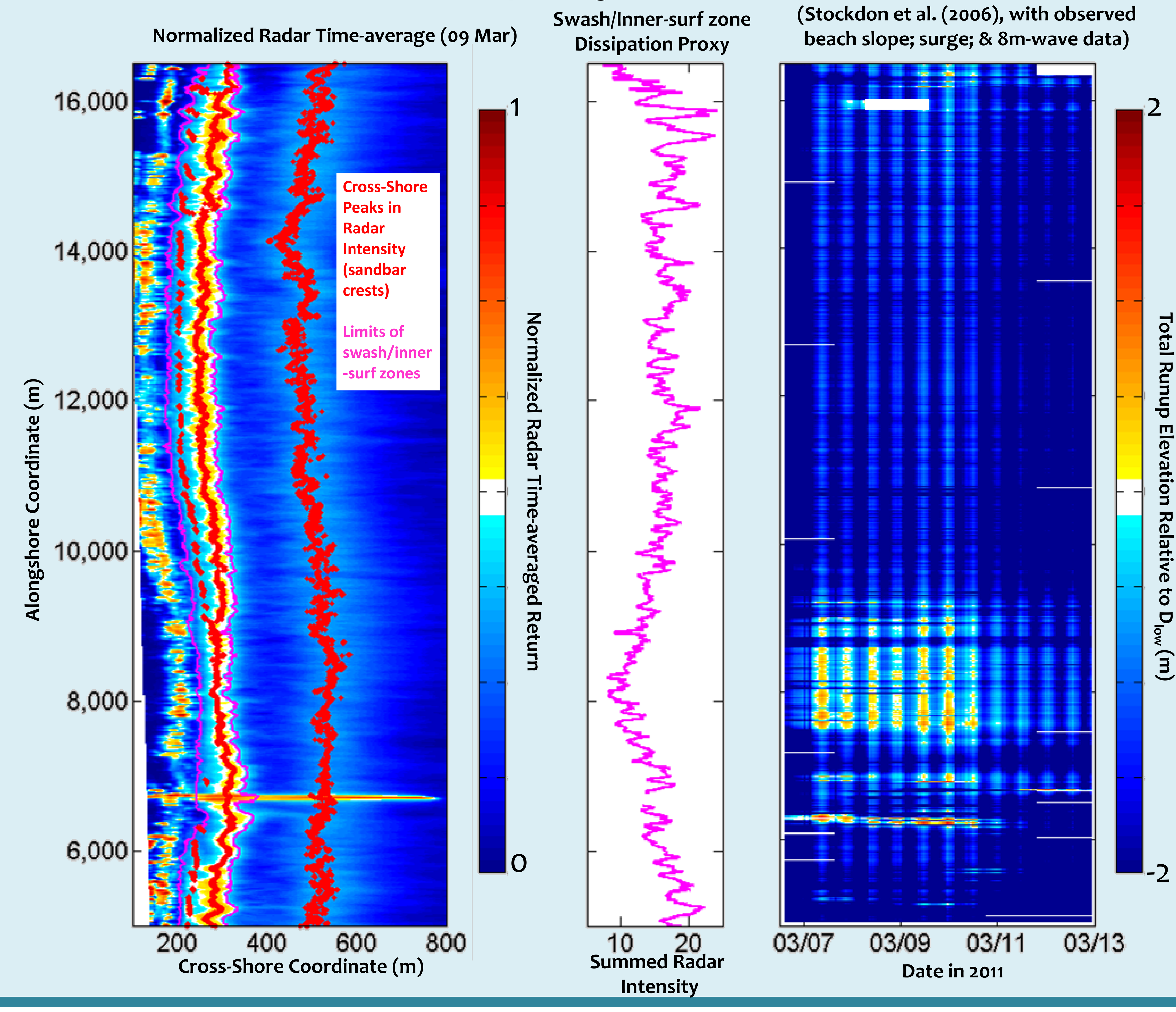


RESULTS: Alongshore variations in hydrodynamic forcing and beach/dune morphologic response

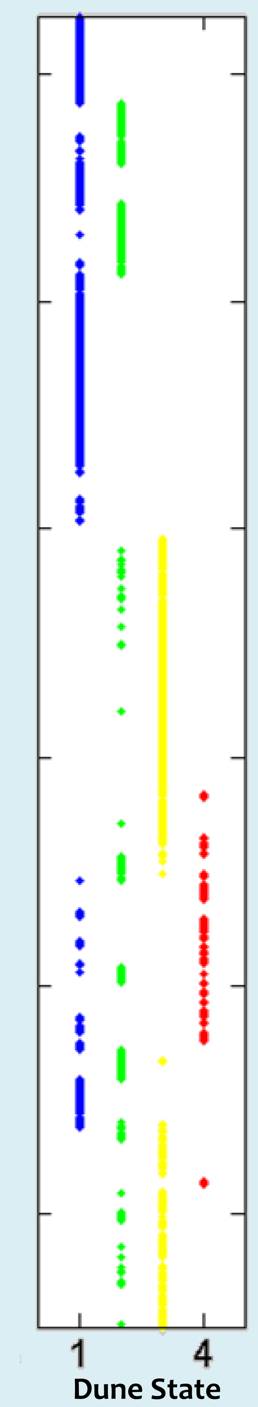
HYDRODYNAMIC FORCING

Surf-Zone Morphology

Predicted R2%



PRE-STORM DUNE STATE



Scarped (1)
- dunes with steep slopes

Recovering (2)
- dunes with steep slopes & multiple peaks in curvature

Healthy (3)
- dunes with high volumes and multiple peaks in curvature

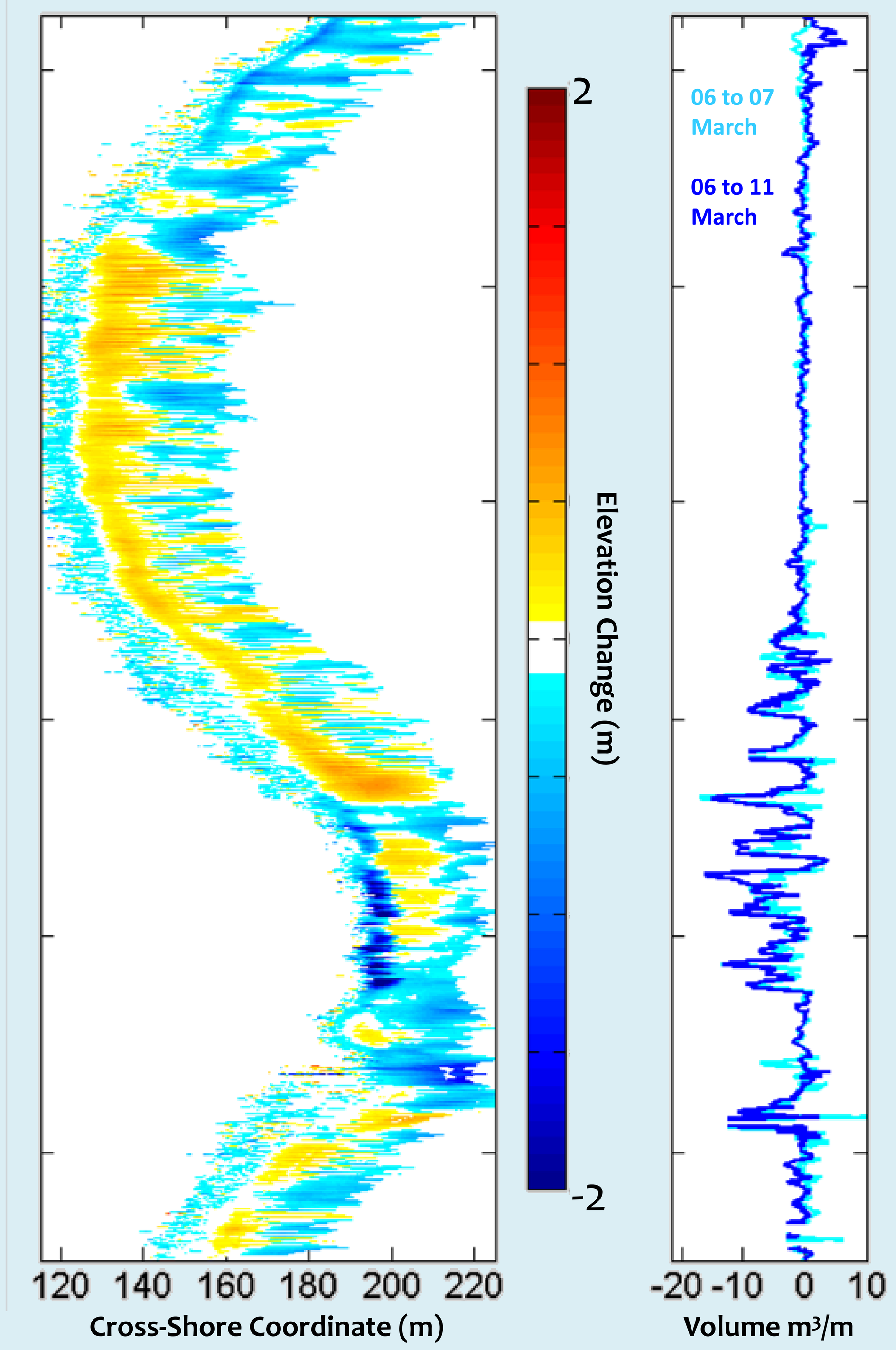
Man-made (4)
- dunes with low D_{low}, slopes near the angle of repose, and high volume

(see poster : EP31B-3558)

MORPHOLOGIC RESPONSE

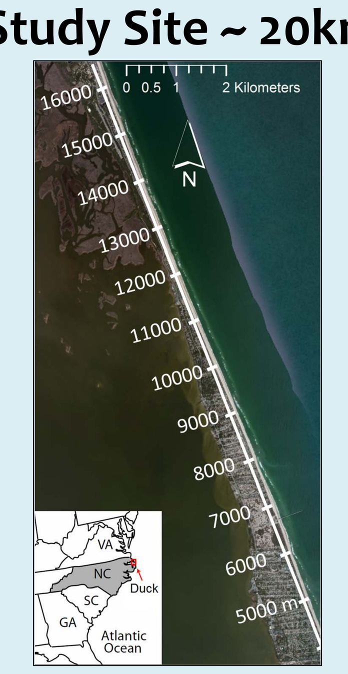
Pre to Post Elevation Change

Dune Volume Change



METHODOLOGY: DATA COLLECTION

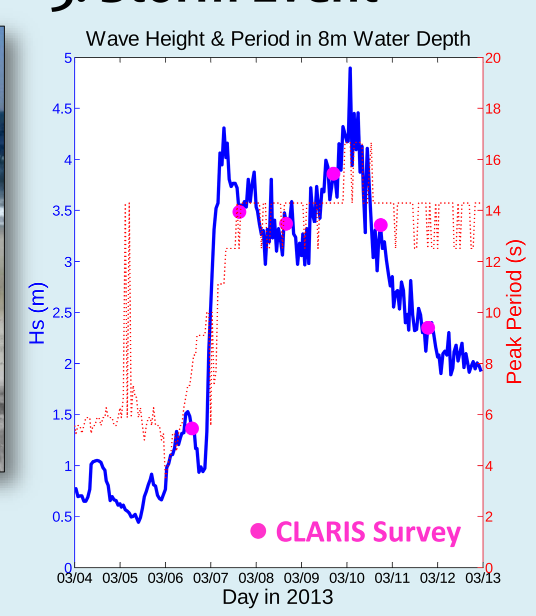
1. Study Site ~ 20km



2. CLARIS

Combines a Riegl terrestrial lidar scanner (VZ-1000), Applanix POS-LV, and X-Band Radar to map beach topography and surf-zone waves

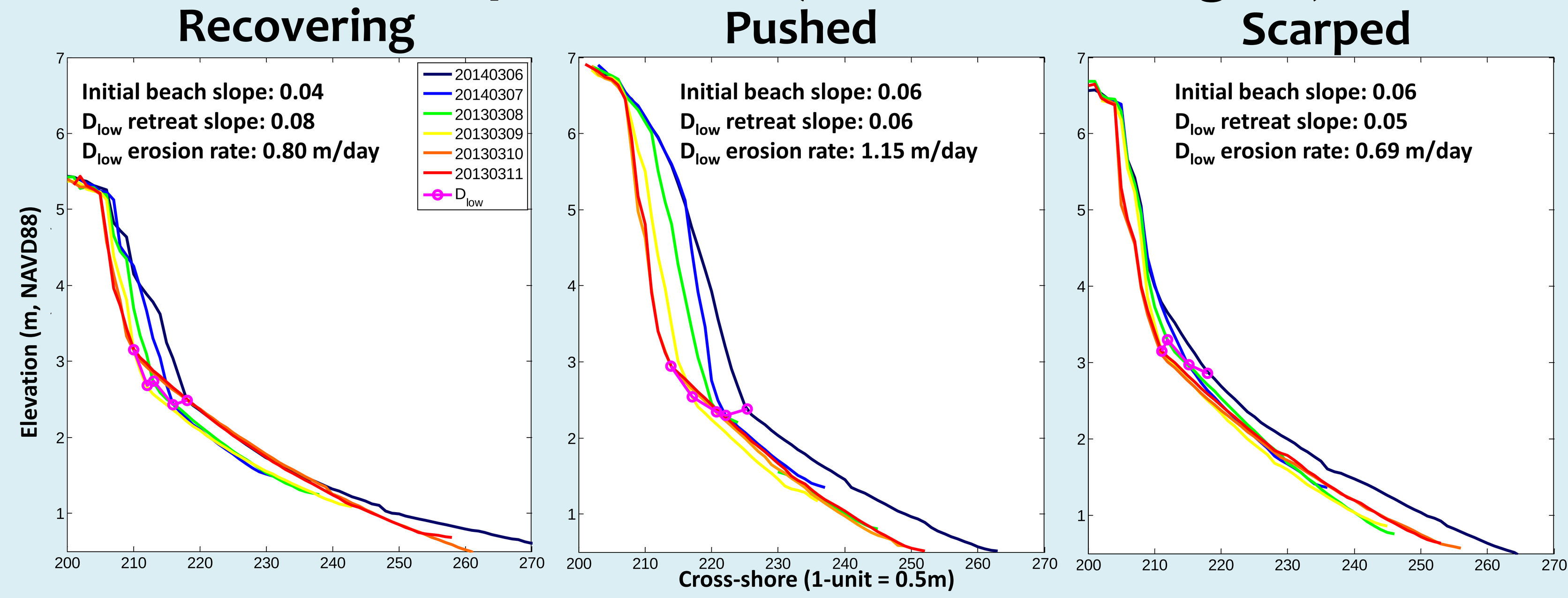
3. Storm Event



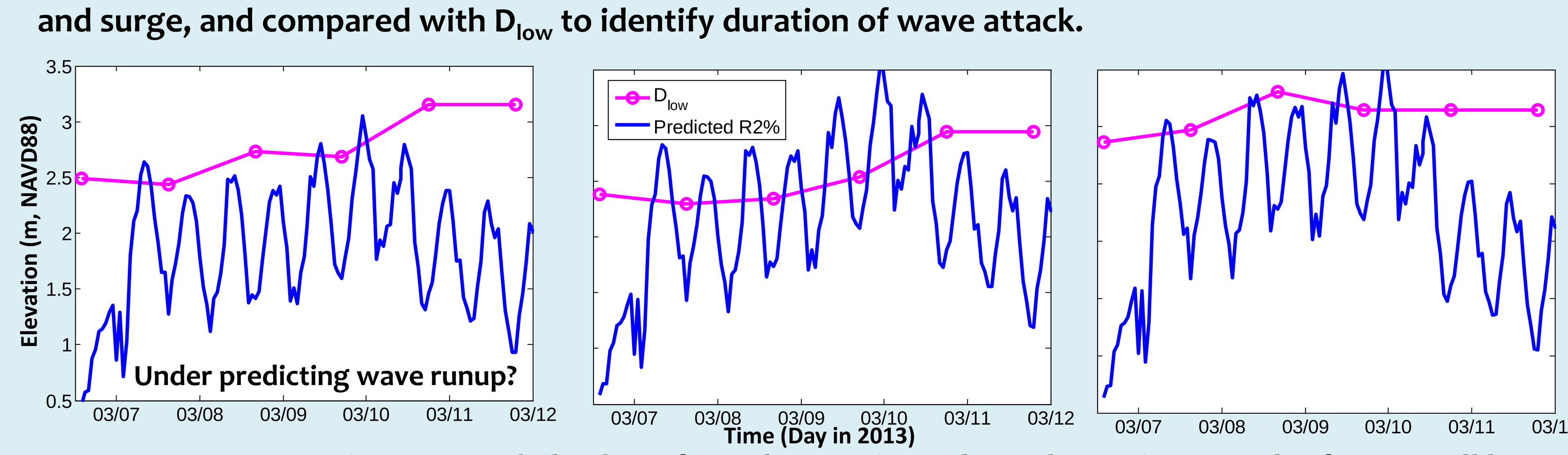
RESULTS: Dune Erosion Rates

Example Profiles (from erosive region)

Recovering | Pushed | Scarped



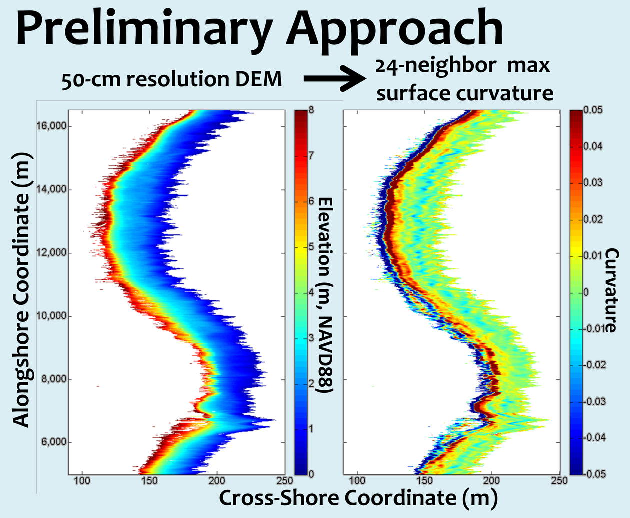
Wave runup was calculated using Stockdon et al. (2006), with measured beach slope, wave parameters, and surge, and compared with D_{low} to identify duration of wave attack.



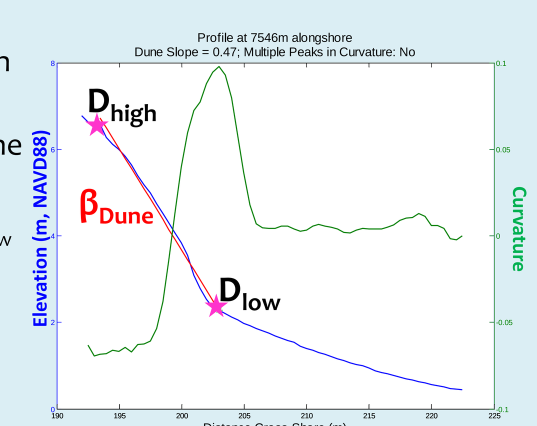
FUTURE WORK: During-storm, daily, dune-face observations along the entire stretch of coast will be compared with Palmsten & Homan (2012) & other models to identify model performance for a variety of dune types

METHODOLOGY: FEATURE EXTRACTION

Preliminary Approach



- D_{high}: max elevation of profile and min curvature landward of D_{low}
- D_{low}: max curvature between shoreline and D_{high}
- Slope: linear fit between D_{high} and D_{low}
- Volume: unit volume per trapezoidal area under dune profile
- Multiple Peaks in Curvature: counts number of peaks in curvature on dune profile



CONCLUSIONS & CONTINUING WORK

- A 2 kilometer stretch of beach (7700 to 8700 m alongshore) in Duck, NC experienced heightened beach and dune erosion during a Nor'easter. This region had only one offshore sandbar and a narrower inner-surf/swash zone compared to the rest the study site. Beach slope was also high in this region leading to higher predicted R2% compared to the rest of the study site, however, R2% appeared under-predicted, given the observed morphologic change at the dune. The upper beach between 8700 and 1100 m alongshore experienced significant net accretion during the storm.

-Pre-storm dune state within this region was a mixed of scarped and man-made dunes (placed following Hurricane Sandy). Man-made dunes lost considerably more volume than scarped dunes within the region, due either to lower D_{low} or high erodibility of unconsolidated sediment (or both).

-Man-made dunes retreated by up to 10 m in some locations at rates up to 2 m/day (landward movement of D_{low}). D_{low} retreat slopes varied from half the initial beach slope to twice the initial beach slope. At some locations D_{low} lowered significantly during the first two days of retreat, suggesting slumped sediment was removed from the system, whereas towards the end of the storm, D_{low} increased in elevation while retreating, suggesting slumped sediment was reworked into the upper beach profile (or transported alongshore).

- Future work will compare dune erosion predictions from the Palmsten & Holman (2012) model with observations within the highly erosive region to test the ability of the model to predict alongshore variations in dune response.

ACKNOWLEDGEMENTS

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