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Automated Feature Extraction of Foredune Morphology from Terrestrial Lidar Data

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ABSTRACT

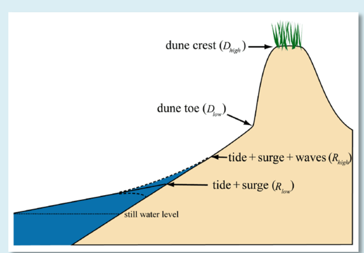
Foredune morphology is often described in storm impact prediction models using the elevation of the dune crest and dune toe and compared with maximum runup elevations to categorize the storm impact and predicted responses. However, these parameters do not account for other foredune features that may make them more or less erodible, such as alongshore variations in morphology, vegetation coverage, or compaction. The goal of this work is to identify other descriptive features that can be extracted from terrestrial lidar data that may affect the rate of dune erosion under wave attack. Daily, mobile-terrestrial lidar surveys were conducted during a 6-day nor'easter (Hs = 4 m in 6 m water depth) along 20km of coastline near Duck, North Carolina which encompassed a variety of foredune forms in close proximity to each other. This poster focuses on the tools developed for the automated extraction of the morphological features from terrestrial lidar data, while the response of the dune will be presented by Brodie and Spore as an accompanying abstract.

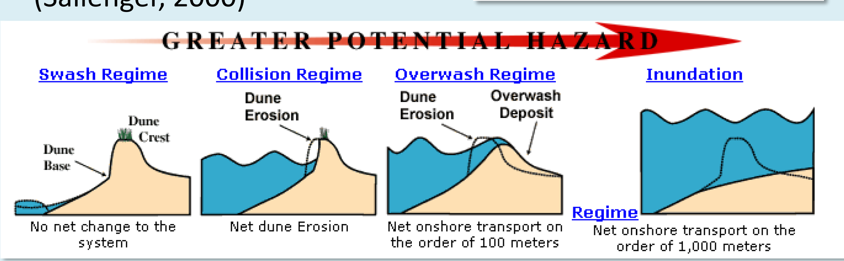
Raw point cloud data can be dense and is often under-utilized due to time and personnel constraints required for analysis, since many algorithms are not fully automated. In our approach, the point cloud is first projected into a local coordinate system aligned with the coastline, and then bare earth points are interpolated onto a rectilinear 0.5 m grid creating a high resolution digital elevation model. The surface is analyzed by identifying features along each cross-shore transect. Surface curvature is used to identify the position of the dune toe, and then beach and berm morphology is extracted shoreward of the dune toe, and foredune morphology is extracted landward of the dune toe. Changes in, and magnitudes of, cross-shore slope, curvature, and surface roughness are used to describe the foredune face and each cross-shore transect is then classified using its pre-storm morphology for storm-response analysis.

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. Lessons Learned from Hurricane Sandy

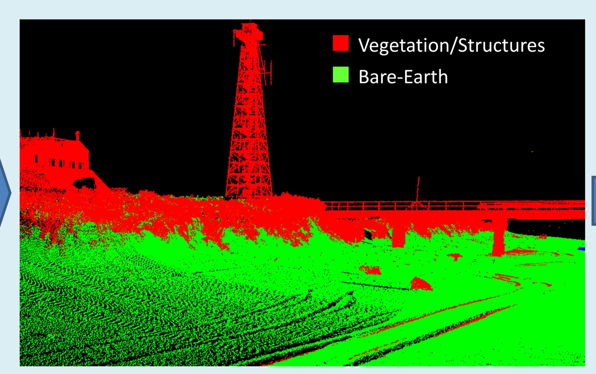
"Dunes can significantly contribute to the volumes of sediment available for redistribution along the shoreline during a storm, reducing the potential for undermining and exposure of land-based infrastructure, and impeding the landward reach of storm tides…Looking to the future, greater consideration of the multiple roles served by dunes, and the full suite of associated benefits that they provide should be required as part of delivering more comprehensive risk reduction along coastlines"

-US Army Corps of Engineers; *Hurricane Sandy Coastal Projects Performance Evaluation Study*, 2013

METHODOLOGY

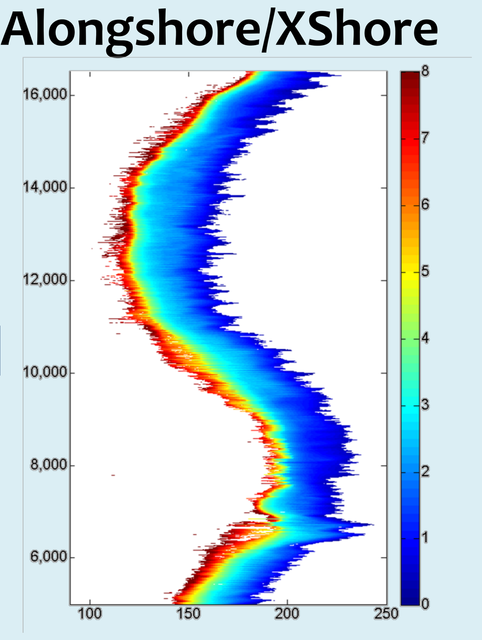
1. Data Collection: CLARIS Mobile Terrestrial Lidar

2. Data Processing: Point Cloud Rectification and Classification

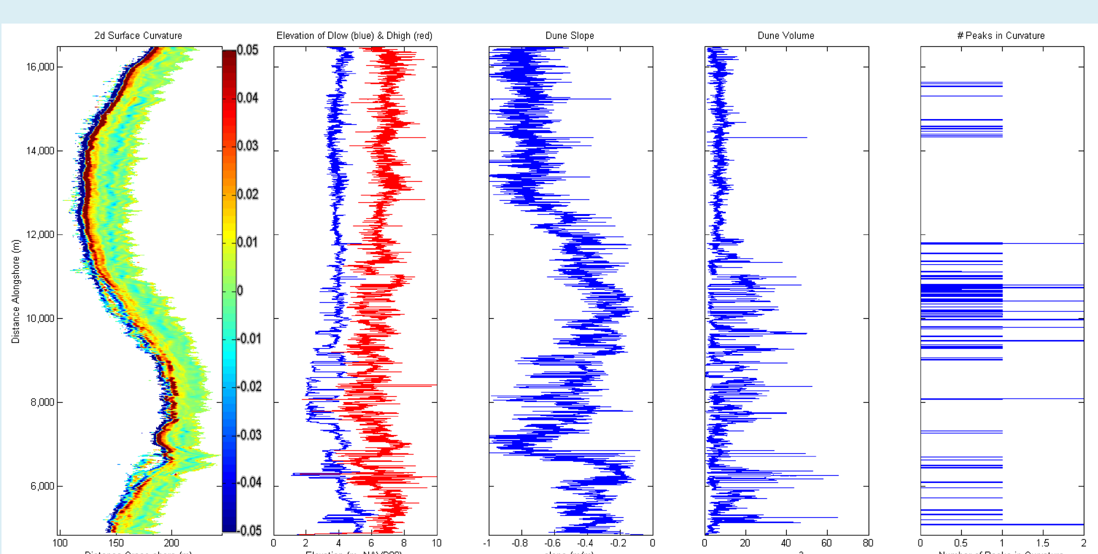


3. 50 cm Digital Elevation Model (DEM) QAQC: Global Coordinates

4. DEM Rotated & Translated into Local Alongshore/XShore



5. Feature Extraction and Analysis: 2D surface curvature, D_{High}, D_{Low}, dune slope, dune volume, and number of Xshore curvature maxima

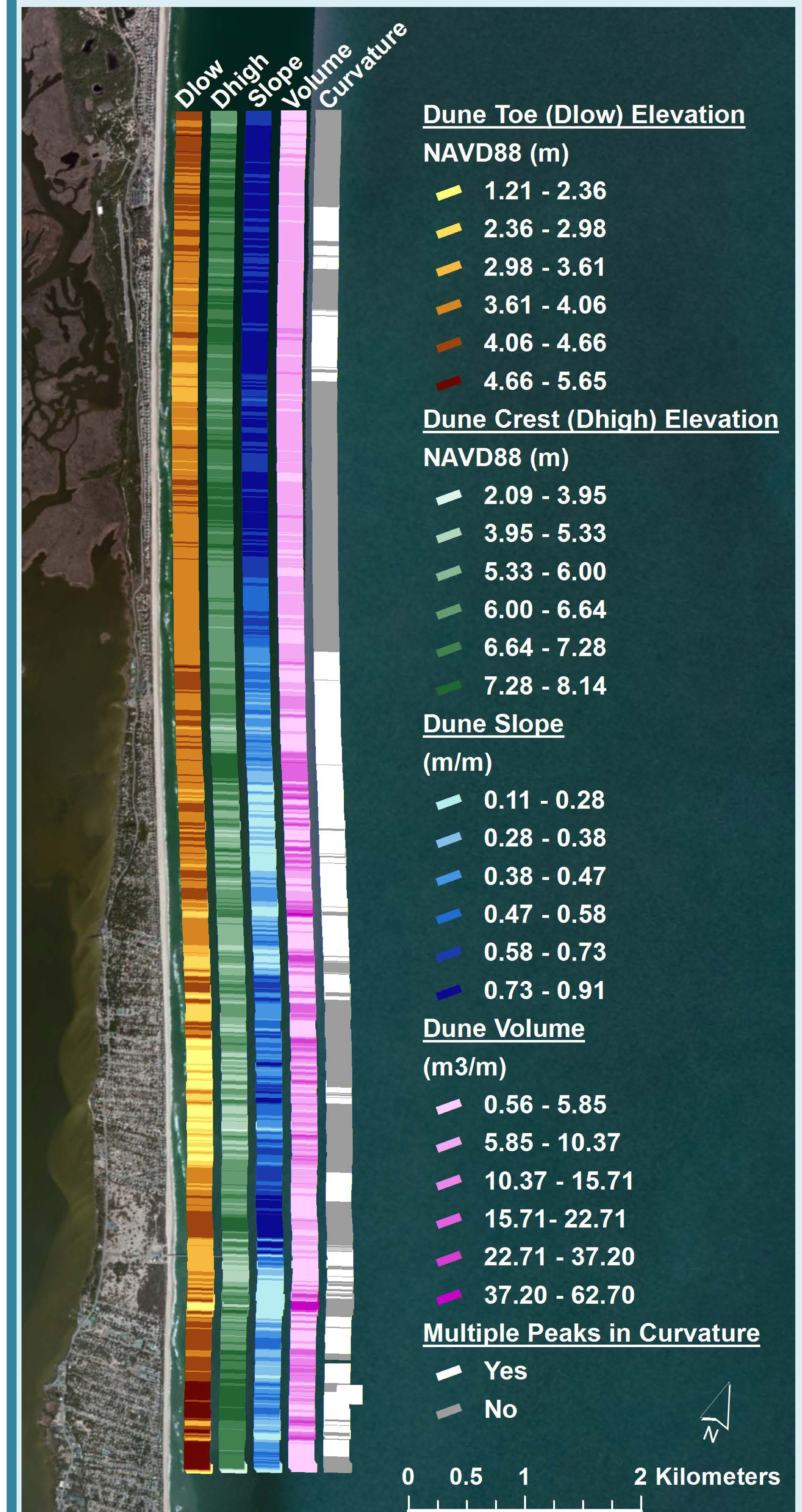


6. Parameter Definitions

- 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

RESULTS

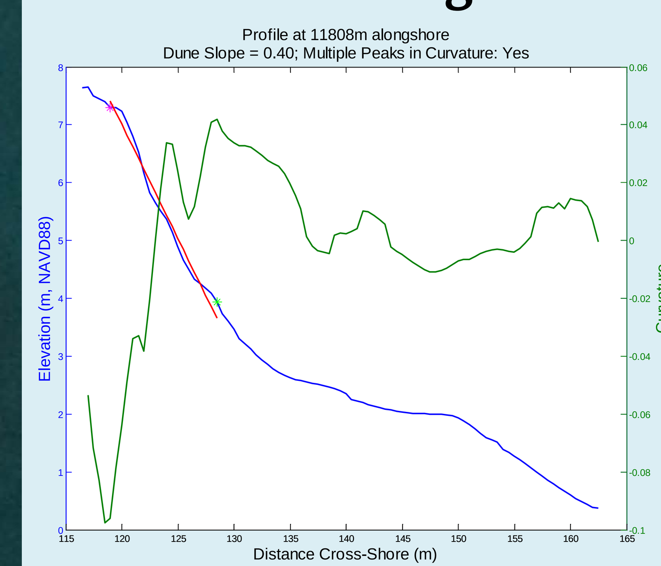
1. Dune Feature Parameterization



2. Feature Extraction Logic

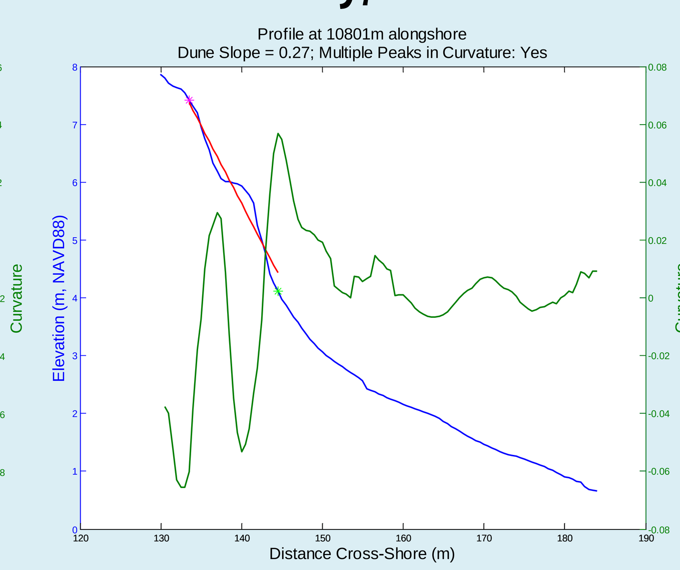
- Natural and anthropogenic processes impose change on the physical form of the foredune and are primarily reflected in the magnitude of dune slope and curvature
- Convex curvature present below the dune crest is indicative of active aeolian processes (Thom & Hall, 1991), resulting in increased volume and multiple peaks in curvature between the dune crest (D_{high}) and toe (D_{low})

Recovering



Steeper slopes typically present due to recent wave attack but exhibit incipient dune formation

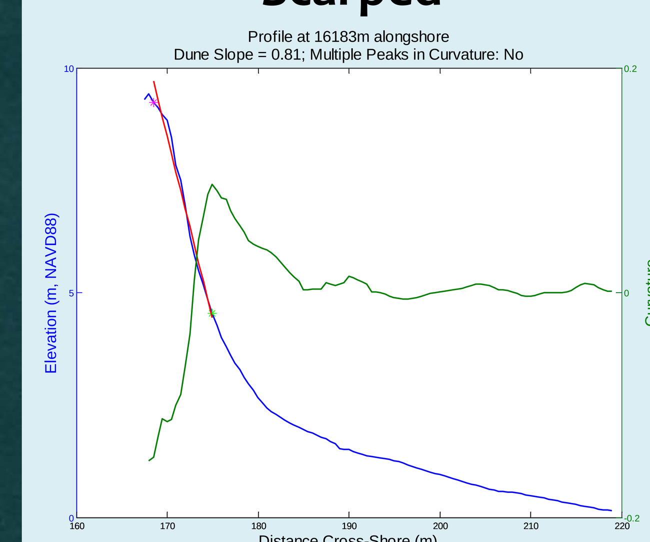
Healthy/Mature



Shallower slopes typically present due to active aeolian transport enlarging dune base

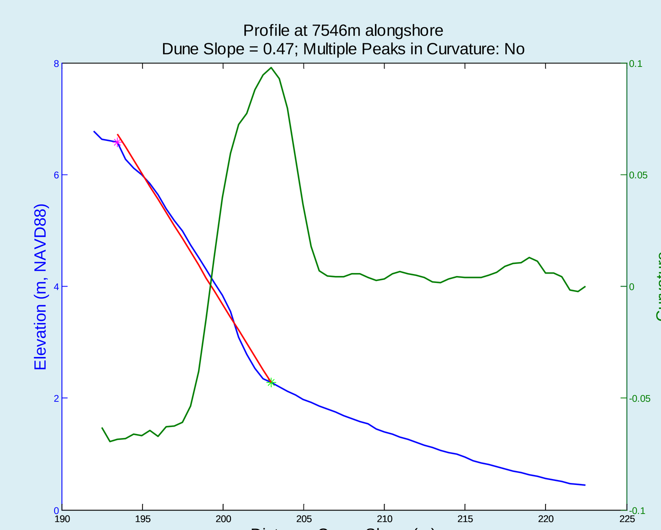
- Dunes without the multiple peaks in curvature signature have constant slopes between D_{high} and D_{low}

Scarped



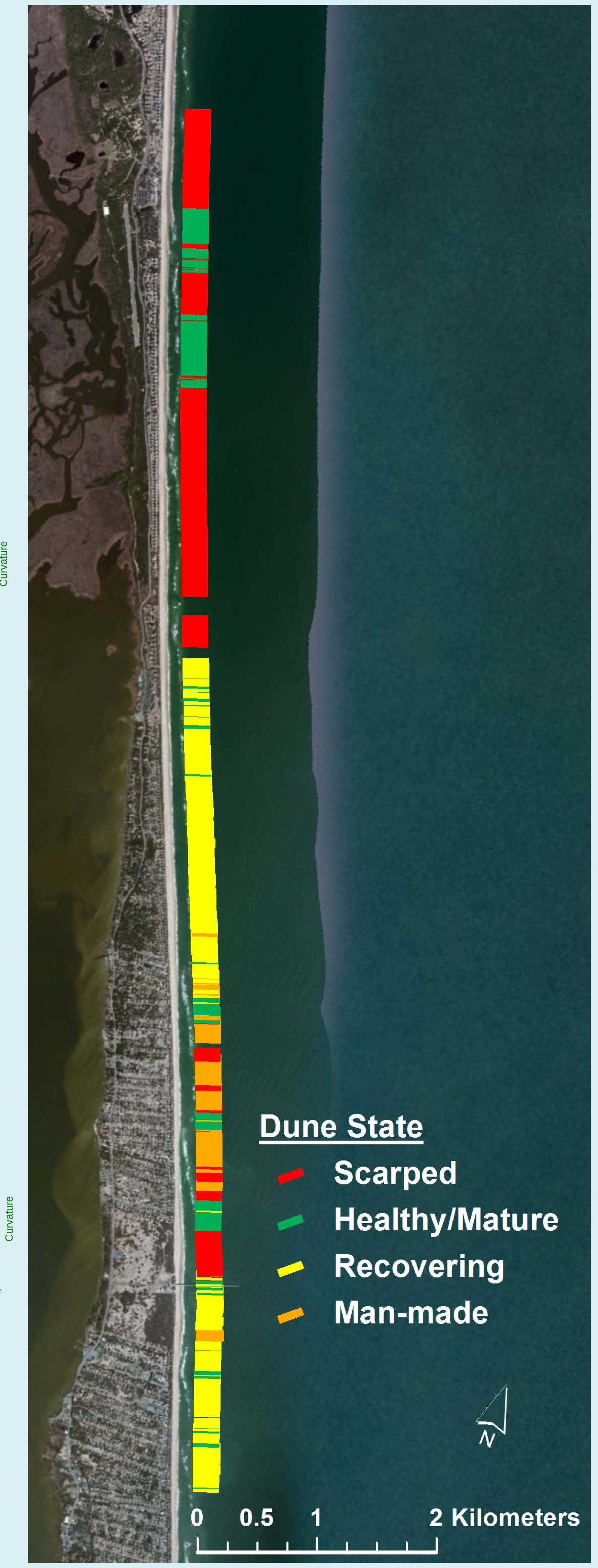
Very steep slopes present due to recent wave attack and scarped dunes typically have lower volumes

Man-made



Human activity (bulldozing) leads to slopes at or near angle of repose, higher volumes if sediment is outsourced, and lower D_{low} if sediment is pushed (Wells & McNinch, 1991)

3. Dune State Classification



CONCLUSIONS/FUTURE WORK

- Preliminary code was developed to extract dune morphologic features from DEMs generated from terrestrial lidar data. D_{low} is an important first parameter to extract, but is occasionally miss-identified, which can greatly alter subsequent parameter definitions. Future work will aim to improve the robustness of the feature extraction code, incorporate uncertainty and include feature extraction from the classified point cloud data.
- Preliminary logic was developed to classify foredune "state" based on extracted parameters. Basic histograms were used to crudely define thresholds; future work will focus on incorporating a machine learning or Bayesian prediction algorithm to improve and assess classification.
- Improved understanding of dune state will help coastal managers and district engineers understand the performance of managed projects and the resiliency of the beach-dune system. Mitigation efforts can then be focused in regions not already recovering on their own .

ACKNOWLEDGEMENTS

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