US Coastal Research Program (USCRP) DUNE R&D

Estimating Potential Dune Vulnerability to Storm Sequences: A Pilot Study

Motivation and Community Need

In many coastal jurisdictions dunes are the preferred alternative to reduce erosion and storm surge flooding associated with hurricanes or seasonal storms. Depending on the environment, dune design guidance may specify ideal dune volume and crest elevation to resist relatively infrequent high magnitude events, such as the 100-year return interval storm. Current practice does not recognize the potential for substantial dune erosion by sequences of lesser storms at intervals that are short relative to natural dune recovery time. Consecutive storms can result in progressive erosion of the dune system before recovery from a previous event, leading to reduced erosion buffering capacity and flood protection.

The purpose of this study is to develop a methodology to assess the long term, regional storm sequence regime at any location using relative wave energy forcing. The new methodology will allow better appraisal of vulnerability associated with reduced dune integrity caused by smaller storms that occur over relatively short (seasonal scale) intervals, and provide a decision-making tool to guide dune remediation interventions and longer-term vulnerability mitigation strategies.

Figure 1: Dunes being bulldozed into place after a coastal storm, Kitty Hawk, NC.

Approach

We assessed the hazard regime of coastal storms for a region of the Outer Banks of North Carolina using reanalysis wave data from the European Centre for Medium-Range Weather Forecasts (ECMWF) at three hour intervals from 1901 to 2010, and extended the assessment to 2016 using wind data from the North American Regional Reanalysis (NARR) dataset. These data were used to identify discrete storm events, defined as having wave heights > 4 m for at least 18 hours, which translates to a summed event energy (wave height squared) > 96 m^2. The magnitude and frequency regime of events was assessed using the Gumbel extreme value distribution. Dune response was assessed using a rich, nearby topographic profile dataset collected by the US Army Corps of Engineers Field Research Facility (FRF) at Duck, North Carolina from 1980 to 2016.

Findings/Benefits

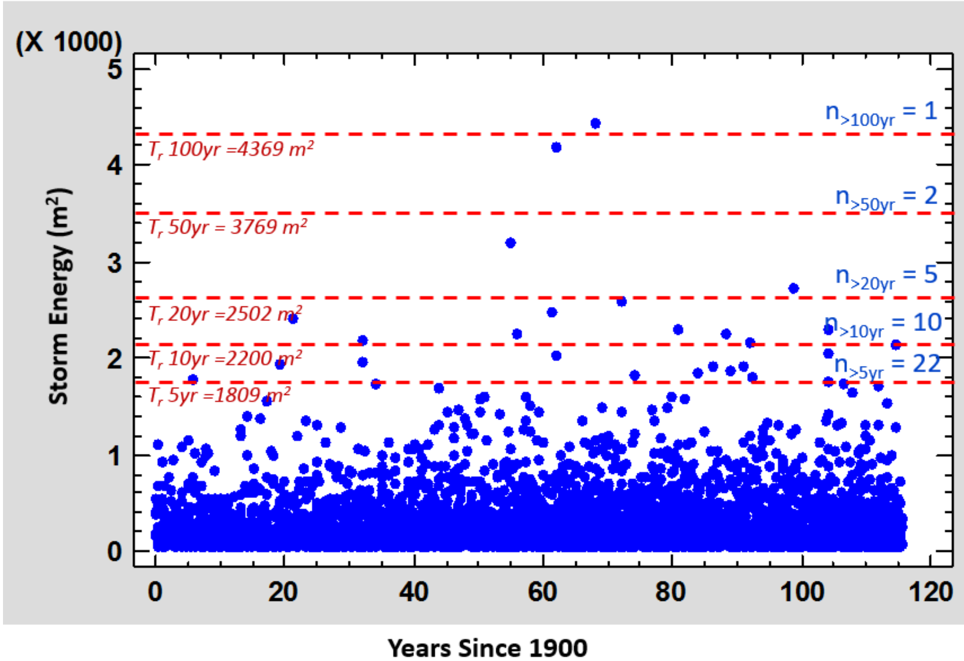

Figure 2: Time series of storms and associated storm energy exceedance thresholds for the Outer Banks

Figure 2 is a time series of storm events and storm-energy thresholds for different recurrence intervals for the Outer Banks, NC. Comparing storm sequencing to overall magnitude, we found that the energy of the 100-year storm is similar to that of a 50-year plus a 1-year event sequence, or a 20- plus 5-year sequence, or a series of 4 1-year events, given that storm sequences occurred during a short time period relative to the dune recovery rate. These estimates do not include necessary threshold magnitudes (e.g., water level elevations) that must be exceeded before dune erosion occurs, and do not assume any timing. We found no relationship between storm magnitude and dune response, but a storm intensity index (wave energy divided by duration), did produce a weakly predictive model for the FRF dune response data, as depicted below.

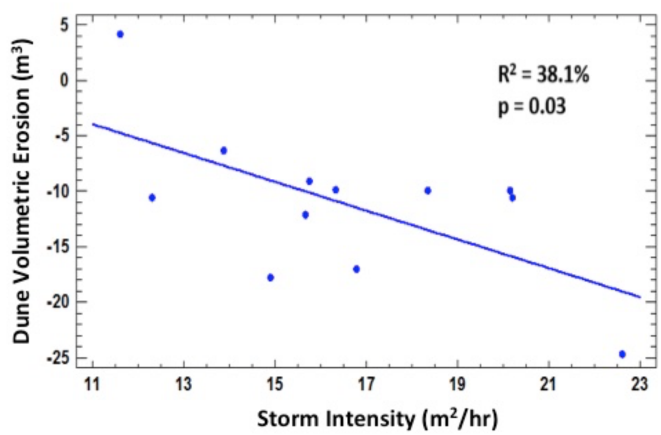

Figure 3: Relationship between storm intensity (energy/duration) and dune erosion rates as measured at the Field Research Facility, Duck, NC, 1980-2016

Status/Steps Moving Forward

We have demonstrated that utilizing storm intensity as a proxy for dune erosion is viable at a regional scale, but the availability of detailed dune response data, and the spatial variability in coastal storm response within a region, currently limits application of the model to a first-order erosion vulnerability assessment. It is likely that the relationship depicted above is site specific, for example, and model performance might improve over time and/or with increasing availability of dune response datasets. Our remaining steps are to expand the coastal response dataset so that we can seek an improved relationship that spans the entire wave data period (back to 1901) rather than just the last 36 years.

More Information

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