PATTERN RECOGNITION FROM INLAND DUNES USING TERRAIN ANALYSIS

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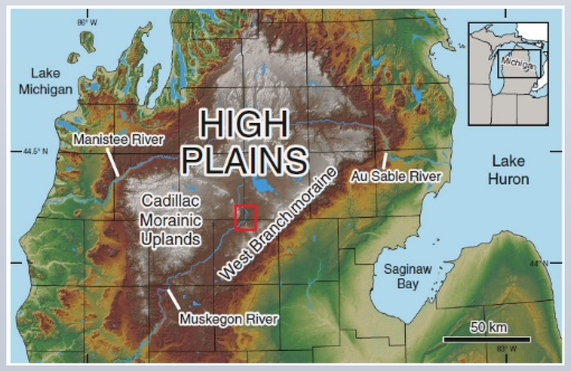
ABSTRACT

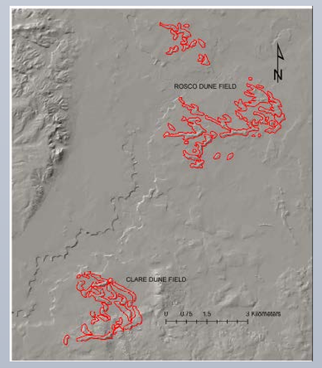
Pattern analysis of dune fields from dune spacing and crest orientation has been seen as a potential source of information for dating of the dunes and determining the wind regimes which formed them. While these techniques have found application in active dune fields they have found less application to smaller, stabilized dune fields found across formerly glaciated terrain. In North America many of these inland dune fields have been dated to dry periods occurring since the end of the last extensive glaciation of the continent. They are often characterized by parabolic forms derived from progressive stabilization of fields of barchan dunes which invert into parabolic forms. The mapping of the dune fields studied here used a Geographic Information System based approach that implements digital elevation model (DEM) terrain analysis for characterization of terrain surfaces. The parameters that describe the terrain surfaces include derivatives such as slope, aspect, convergence indices and anisotropic coefficient values. Exploratory data analysis (EDA) was used to evaluate morphometric characteristics of two dune fields. Here we illustrate the systematic characterization of the degree of directional symmetry and employ wavelet analysis to evaluate periodicity exhibited by the fields.

STUDY AREA

The study area is in north-central lower Michigan in an area known as the "High Plains", one of the State's major physiographic regions. The dune field region is highlighted in red in the map immediately below (adapted from Schaetzl et al., 2013). Most of the study area is on the Houghton Lake Basin with a small section extending onto the West Branch Moraine. The area is bordered to the west by the Muskegon River. A 1/3 arc second resolution DEM from the USGS was the data source. (USGS-NED-n42w087).

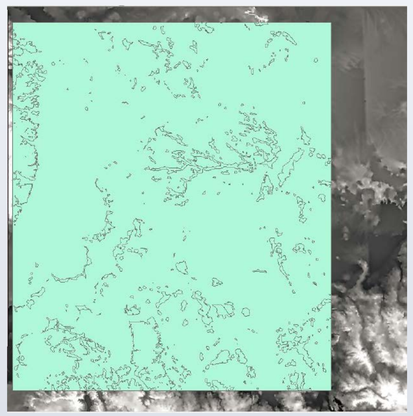


There are two dune fields in the study area, the more northerly Rosco Dune Field covering about 10 km^2 and Clare Dune Field covering about 6 km^2. The Rosco Dune Field has been dated to the late Pleistocene. The Clare Dune Field has not been previously described in the literature. The Clare Dunes lie on both the the Houghton Lake Sandy Flats and Ridges and the West Branch Moraine.

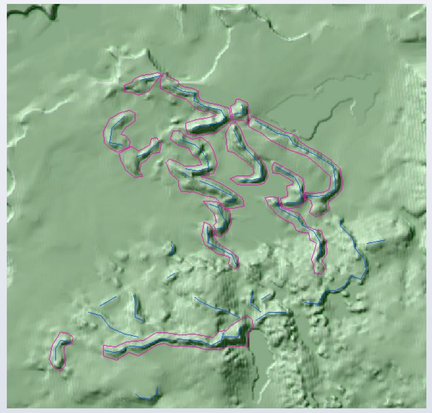


DUNE IDENTIFICATION AND DELINEATION

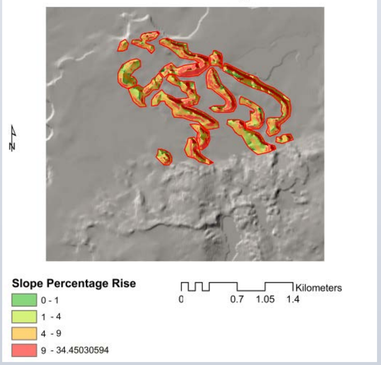
Shapefiles were derived from wind exposition.



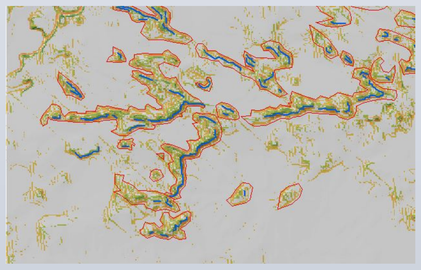
Clare Dune Field partially delineated by shapefiles.



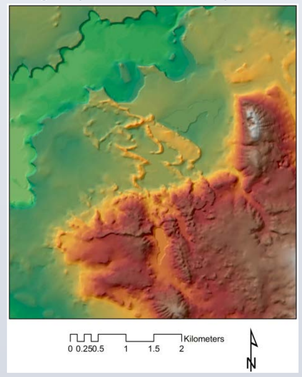
Lower Clare Dune Field Slope Distribution



Locating likely slip faces in the Clare Dune Field was complicated by the field extending onto the West Branch Moraine seen above and to the right. The dune field was divided between lower and upper fields as shown to the left.

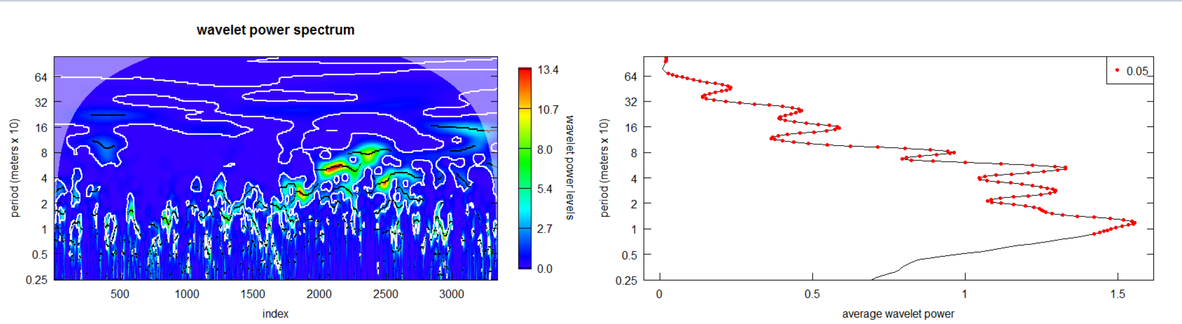


The dune fields were initially identified and shape files corresponding roughly to the dunes generated using wind exposition. Comparison with hill shades, here combined elevation keyed color shading, was used to eliminate elevated nondune features and to identify dunes on the moraine. Shapefiles were manually adjusted using slope and curvature products.



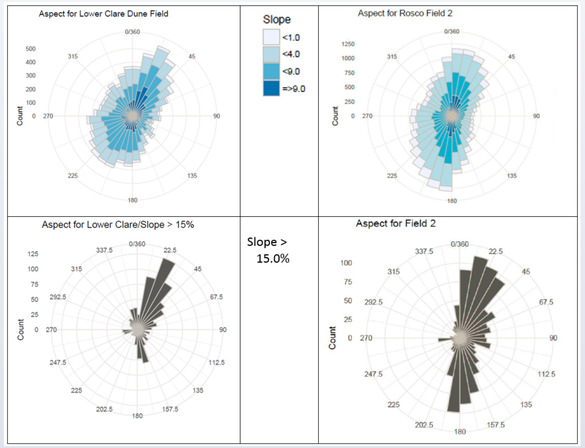
The location of crests from a portion of the Rosco Dune Field is illustrated to the left. Crests (shown in blue) were hand digitized to track either profile curvatures or the smallest change in anisotropic coefficient value. Crest and dune shape files were used to extract elevation sub-rasters for subsequent analyses.

DUNE PERIODICITY WITH DOWNWIND RANGE



When analyzed against downwind range, slip face orientation from dunes in the Rosco Dune Field appeared to exhibit periodicity. Here slopes exceeding 9% are used as a proxy for slip faces. Easting range is used as a proxy for downwind range. The horizontal axis in a wavelet plot depicts a transect associated with the easting detection, while the vertical axis shows a period the aspect direction associated with slip face slopes. The covariations of the easting and aspect dune indicators are expressed as a distance analog to a time series by warmer and colder colors. The warmer colors (red) represent regions with significant interdependence while colder colors (blue) represent non-significant dependence between the time series. Lower frequencies on the vertical axis represent scale intervals of larger geographic scale. The periodicity of slip faces is higher at smaller spatial distances. Wavelet power decreases with increasing period.

DUNE FIELD SYMMETRY



For the Lower Clare and southern portion of the Rosco Dune Fields most slip face like slopes were binned in orientations orthogonal to the dominant wind direction, that is, to the NNE and S. For both fields there were more slope segments binned in the north oriented bins than in the south oriented bins, particularly from Lower Clare. Clear results like these were not repeated for the northern portion of Rosco. There were a substantial number of upwind oriented slopes > 9% for the Upper Clare field, a result attributed to its location on a moraine. This largely disappeared for slopes exceeding 15%.

RESULTS

The regular periodicity of the dunes may suggest that the wind regime was stable over the period during which the dune field formed. The asymmetry exhibited by the fields is more consistent with models based on progressive stabilization of barchan dunes beginning at the horns of the dunes. The asymmetry could stem from reduced insolation protecting snow or favoring wetter conditions supporting vegetation. This forced inversion of the dunes into parabolas. Models based on blowouts or stabilization that began on the crests are disfavored. Additionally, mathematical approaches are demonstrated, such as wavelet analysis, which have the potential to greatly expand upon, and to render less subjective, statistical descriptions of dunes such as dune defect analysis.

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