Evidence of Topographic Steering in a Small Saucer Blowout on Lake Michigan

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Abstract

Understanding how wind and topography interact to form and develop blowouts is an important topic for both research and management. This study was conducted on a small saucer blowout on the coast of Lake Michigan to understand whether topographic steering of wind occurs and how the blowout responds. The objectives and methods of the study were to 1) Map the topography of the blowout with a total station survey, 2) Measure wind direction and speed inside and outside of the blowout using anemometers and wind vanes, and 3) Measure erosion within the blowout using erosion pins. The saucer blowout has a relief of ten meters and deposition lobes extend to the NNE and ENE. WSW winds within the blowout contrasted with winds measured outside the blowout from the WNW, which suggests topographic steering is likely occurring. Erosion measured in the blowout corresponds with several events recorded in the wind data. While other studies have shown topographic steering occurs on large blowouts, our results indicate topographic steering is also possible on small blowouts.

Introduction

The study of wind flow patterns on dunes is important for understanding the dune system and for management efforts in dune stabilization. When dunes become destabilized, they are blown landward by the wind, posing a threat to anthropogenic structures [1].

Most research to date on topographic steering has been conducted on large blowouts [2,3,4] but the initial development of blowouts in relation to topographic steering has been relatively unexplored. For this research, we investigated whether topographic steering occurs in a small blowout (Fig. 1).

Figure 1) *Can the topography of this small blowout influence wind direction?*

The objectives of the study were to:

1) Map the topography of the blowout with a total station survey.
2) Measure wind direction and speed inside and outside of the blowout using anemometers and wind vanes.
3) Measure erosion within the blowout using erosion pins.

Study Area

The study was conducted on the eastern shore of Lake Michigan in Ottawa County (Fig. 2). The study focused on a small saucer blowout located on a dune ridge within the large parabolic dune system in Hoffmaster State Park. In 2017, the saucer blowout was situated 70 metres from Lake Michigan.

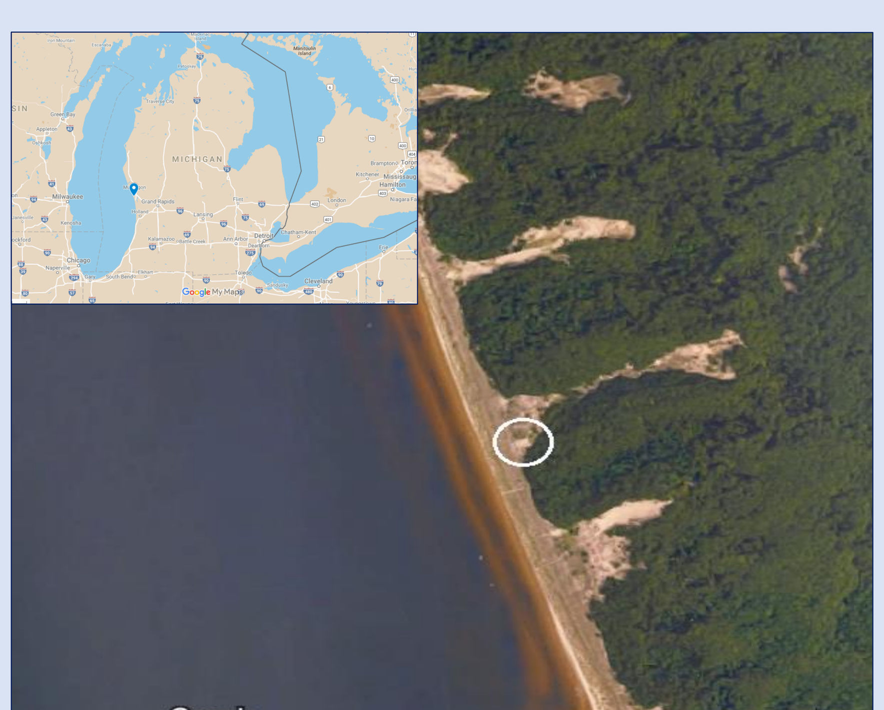

Figure 2) *Study site location in Michigan and within a large parabolic dune system.*

Methods

We measured topography, erosion/deposition and wind speed and direction (Table 1) on the blowout (Fig. 3). The study was split roughly into two measurement periods, one from Oct. 26-Nov. 2 and Nov. 2-Nov. 9, 2017.

Study Objective	Methods	Equipment
Survey the topography	• We surveyed from the opening of the deflation zone to the slipface and just beyond the arms of the blowout. • Benchmarks provided a way to georeference survey data into ESRI's ArcMap (Fig. 3).	• Sokkia Total Station
Measure wind direction and speed inside and outside of the blowout	• Week 1, we set up the wind equipment in a line oriented NE-SW (Fig. 3). • Week 2, we oriented the anemometers in a line facing NW-SE. • The wind vane remained in the deflation zone for both weeks. • A reference wind tower array was set up on the foredune.	• Cup anemometers (3) • Cup anemometer with wind vane. • Wind tower
Measure erosion within the blowout	• We placed erosion pins every 5 metres along transects A and B from the foredune to the bottom of the slipface (Fig. 4). • A grid of erosion pins were placed in the deflation zone at 2.5 metre intervals.	• Erosion pins

Table 1) *Methods and equipment related to objectives.*

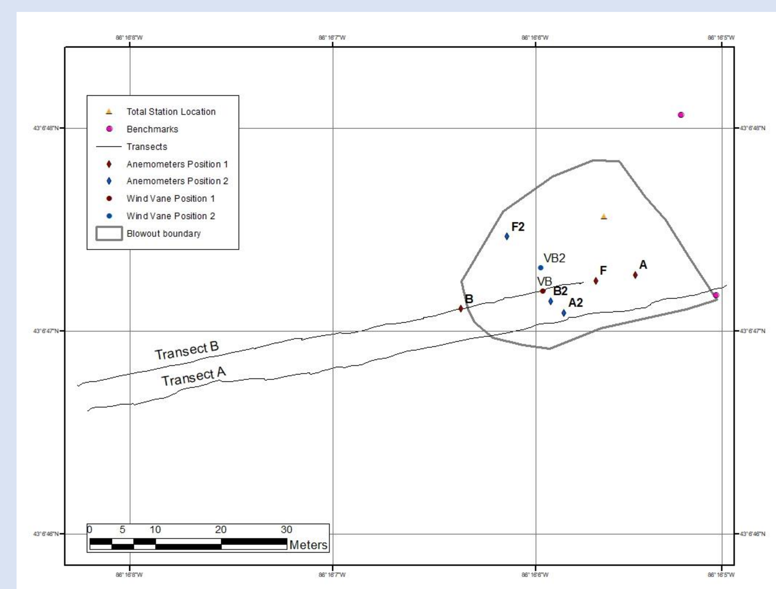

Figure 3) *Measurement locations in study area, including wind measurements, survey locations and lines of erosion pins.*

Figure 4) *Numbered erosion pin locations on aerial view of study area.*

Results

The blowout is small with dimensions of 23m by 16m and a relief of ten metres (Fig. 5). Dense vegetation occurs on the slipface of the blowout and sparse vegetation occurs near the windward opening of the blowout towards the shore. The topography indicates the main axis of the blowout is oriented NE-SW.

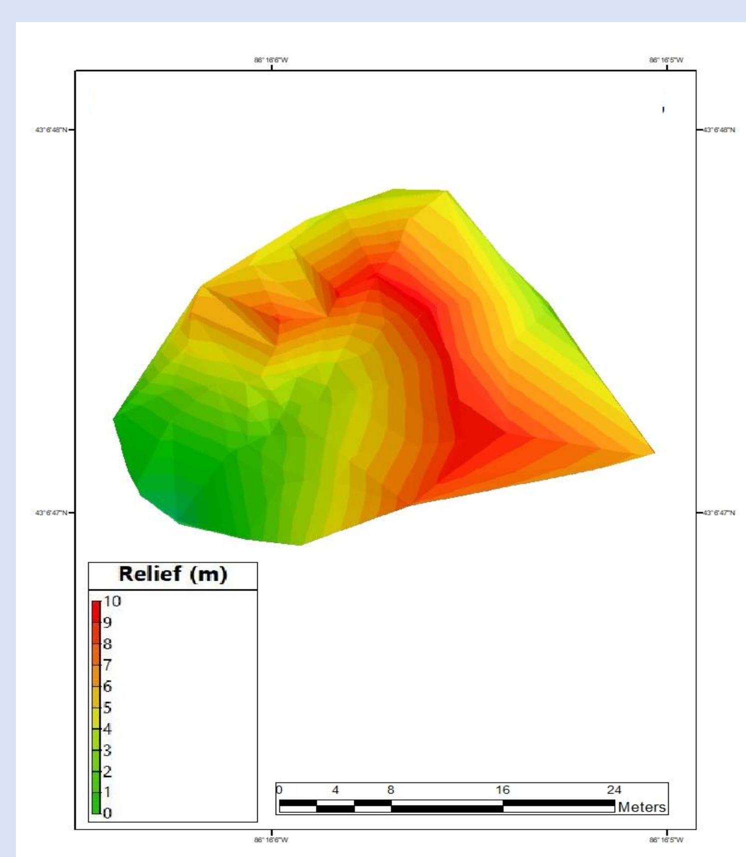

Figure 5) *Blowout topography. Two depositional lobes extend from the blowout crest to the NNE and E.*

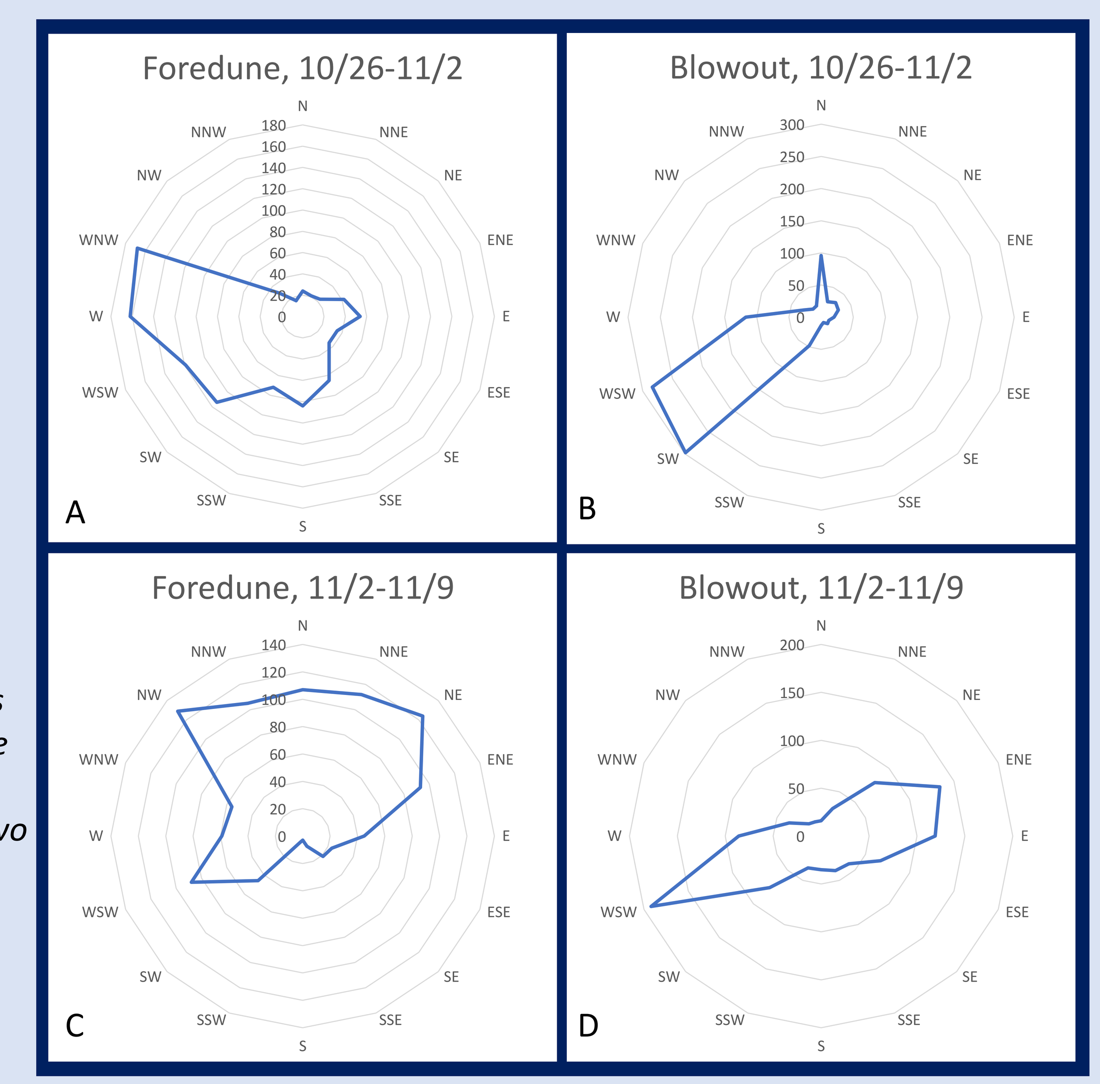

Figure 6) *Wind roses show frequency of wind directions at the foredune and blowout locations for two study weeks.*

Some of the strongest winds occur in the deflation zone towards the NNE which suggests the blowout is progressing NNE. When wind over the foredune approaches from the WNW, W and WSW, the wind is redirected to the ENE and NE in the deflation zone (Fig. 6).

The greatest erosion occurs in the deflation zone along the NNE/SSW axis (Fig. 7). Erosion occurs on topographic highs and windward facing slopes while deposition occurs in low areas and leeward facing slopes.

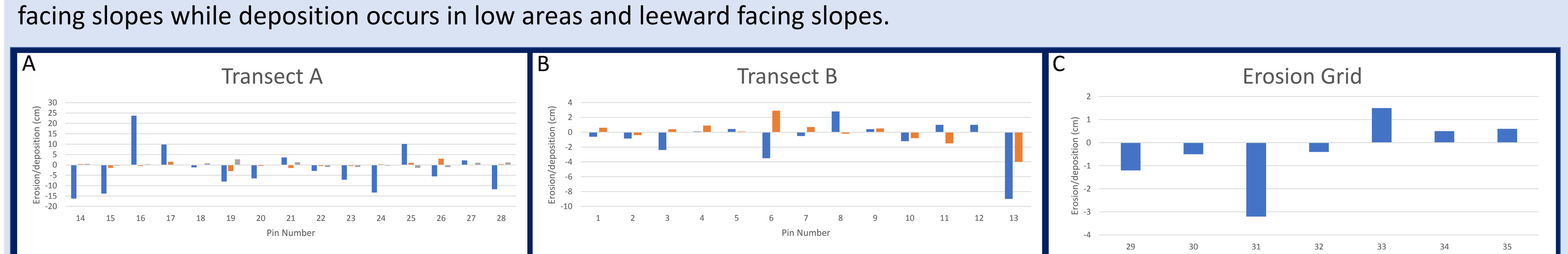

Figure 7) *Erosion and deposition measured at pin locations along two transects and within deflation area (See Fig. 4 for pin numbering).*

Discussion

Winds on the foredune had many directions while in the blowout, the winds had few directions which indicates topographic steering [4]. Topographic data shows the deflation zone oriented in the same direction as the predominant winds occur in the deflation zone.

Erosion occurs on the windward slope and deposition occurs on the leeward facing slopes, which matches wind flow acceleration [2,5] (Fig. 8). Deposition occurs on the arms of the blowout where vegetation slows wind velocity [6]. Based on the topographic data, the saucer blowout appears to be in transition to a trough shape.

Figure 8) *View inside the blowout indicates erosion beginning on upper windward slope beyond vegetation.*

Understanding wind patterns in active dune environments is an important topic since dune landscapes can change quickly with dunes moving up to 22 metres per year [7]. It is important for dune managers to know the direction of movement to better manage the dune (Fig 9).

Figure 9) *Leeward slope of the blowout is vegetated but the pictured deposition lobe is advancing NNE <5cm/year.*

Conclusions

Our results show topographic steering occurs in a small blowout. Measured erosion and deposition matches the locations where the topography accelerates or decelerates wind velocity.

Acknowledgements

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Works Cited

[1] Fraser G. S., S. W. Bennett, G. A. Olyphant, N. J. Bauch, V. Ferguson, C. A. Gellasch, C. L. Millard, B. Mueller, P. J. O'Malley, J. N. Way, M. C. Woodfield. 1998. "Wind flow circulation patterns in a coastal dune blowout, south coast of Lake Michigan." *Journal of Coastal Research*, Vol. 14 No. 2 pp. 451-462.

[2] Gares, P. A. and P. Pease. 2015. "Influence of topography on wind speed over a coastal dune and blowout system at Jockey's Ridge, NC, USA." *Earth Surface Processes and Landforms*, Vol. 40, pp. 853-863.

[3] Smyth, T. A. G., D. Jackson and A. Cooper. 2014. "Airflow and aeolian sediment transport patterns within a coastal trough blowout during lateral wind conditions." *Earth Surface Processes and Landforms*, Vol. 39, pp. 1847–1854.

[4] Pease, P. and P. Gares. 2013. "The influence of topography and approach angles on local deflections of airflow within a coastal blowout." *Earth Surface Processes and Landforms*, Vol. 38, pp. 1160–1169.

[5] Hansen E., S. DeVries-Zimmerman, D. van Dijk and B. Yurk. 2009. "Patterns of wind flow and aeolian deposition on a parabolic dune on the southeastern shore of Lake Michigan." *Geomorphology*, Vol. 105, pp. 147-157.

[6] Swineford, J. T., J. K. DeVries, N. DeVries, J. D. Gorter, J. Santucci, and J. T. Spykman. 2014. "The impacts of three autumn storms on a Lake Michigan foredune." FYRES: Dunes Research Report #10. Grand Rapids (MI): Department of Geology, Geography and Environmental Studies, Calvin College.

[7] Ranwell, D. 1958. "Movement of vegetated sand dunes at Newborough Warren, Anglesey." *Journal of Ecology*, Vol. 46, No. 10, pp. 83-100.