

The Impacts of Three Autumn Storms on a Lake Michigan Foredune

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Abstract

Although studies have analyzed the effects of storms on sand transport and foredune development, few studies have targeted Great Lakes dunes. We investigated how autumn storms affected a foredune in Hoffmaster State Park, Michigan. Our study objectives were to analyze the nature of several autumn storms, measure erosion and deposition on the foredune, and measure effects of wave run-up on the beach and foredune. We used sand traps and erosion pins to measure sand transport and surface changes. We mapped wave run-up and vegetation change with GPS. Wind measurements were recorded with an on-site anemometer tower. During a two-week period, we documented three different storms with varying wind speeds and precipitation. During one storm, winds reached up to 15 m/s, causing erosion on the upper windward face of the foredune. All three storms showed wave run-up onto the foredune, causing deposition in the first few rows of erosion pins. Wrack lines indicate wave run-up as much as twenty meters beyond the pre-storm shoreline. The combined effects of the three autumn storms suggest that storms are responsible for the majority of change to Great Lakes foredunes.

Introduction

Foredunes are key to buffer inland dunes from wind and waves. In recent studies, storm strength has been shown to be increasing [1]. Because of this, it is important to understand how a foredune interacts with storm conditions. In this study, we looked at autumn storms to see how they affected foredune shape as a result of wind, waves, and precipitation.

Objectives:

1. Quantify characteristics of each storm.
2. Measure change in the shape of the foredune.
3. Monitor wave run-up onto the beach/foredune.

Study Site

This study took place on the foredune in Hoffmaster State Park, Michigan (Fig 1). The study site included a portion of the foredune and recreational beach.

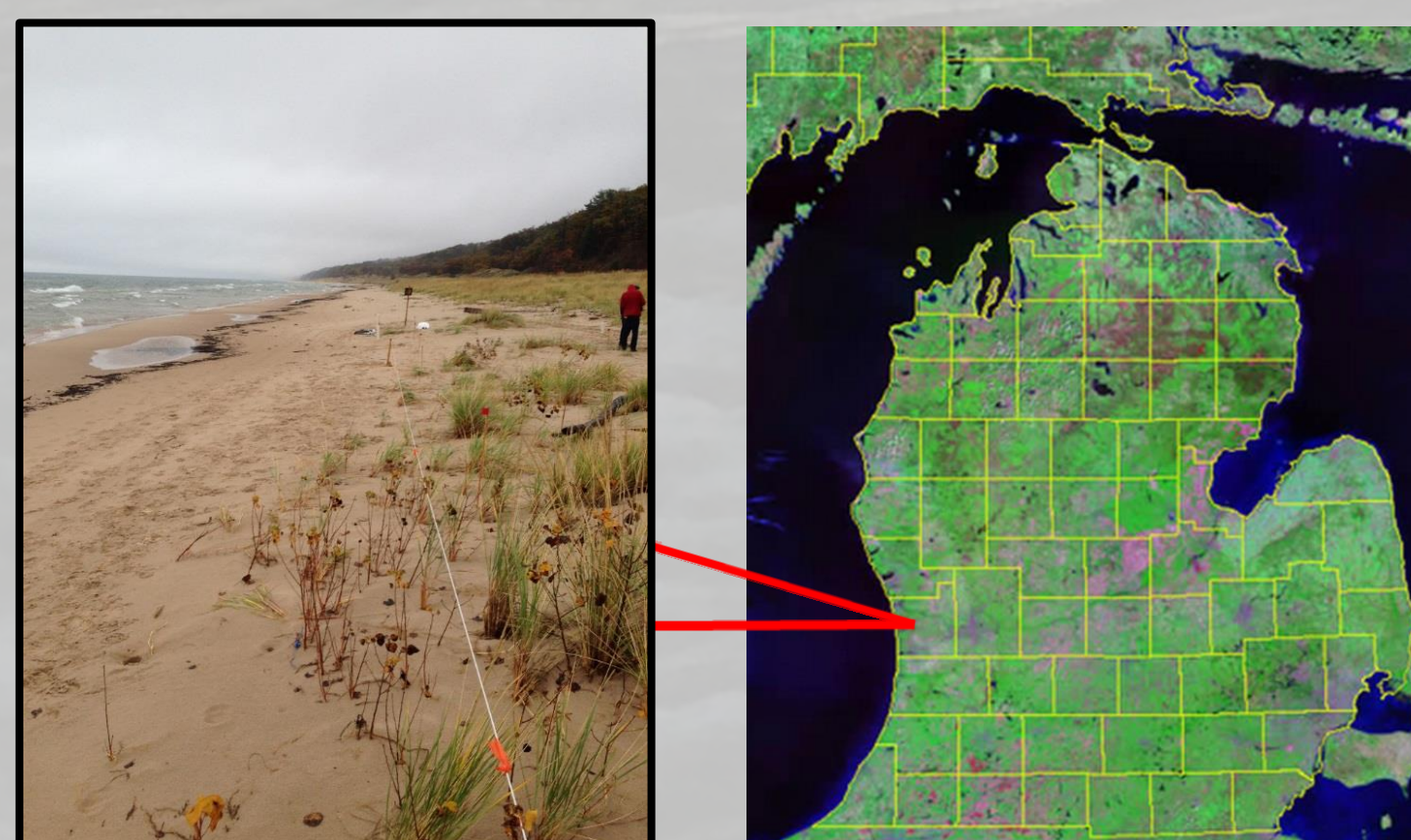


Fig 1: Photo and location of Hoffmaster State Park

Methods

The study was performed over a 2-week period in autumn 2013. To quantify storm conditions, an anemometer and wind vane were located at the site. Data on precipitation, pressure, and waves were obtained from regional sources weekly [2, 3]. Erosion pins were put into place on the beach/foredune and were measured weekly to look at changes in erosion or deposition. GPS units were used to measure vegetation limits and wracklines from wave run-up (Fig 2).



Fig 2: Researchers working at the study site

Results

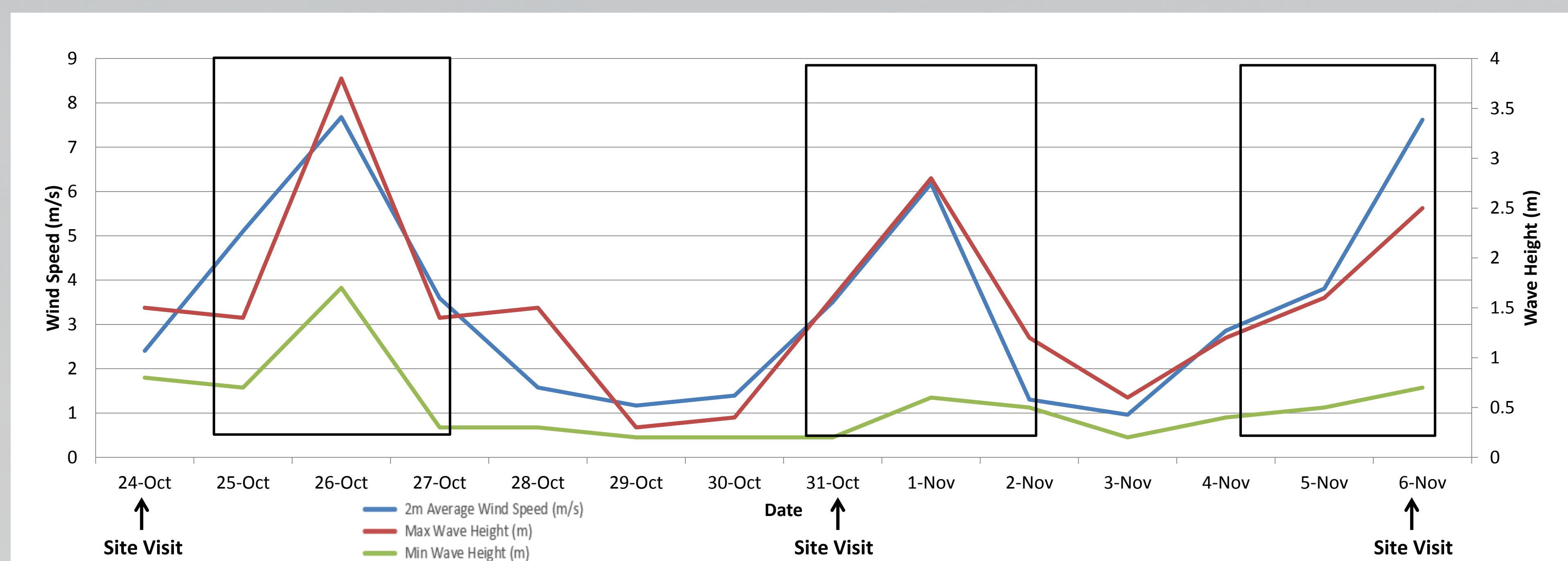
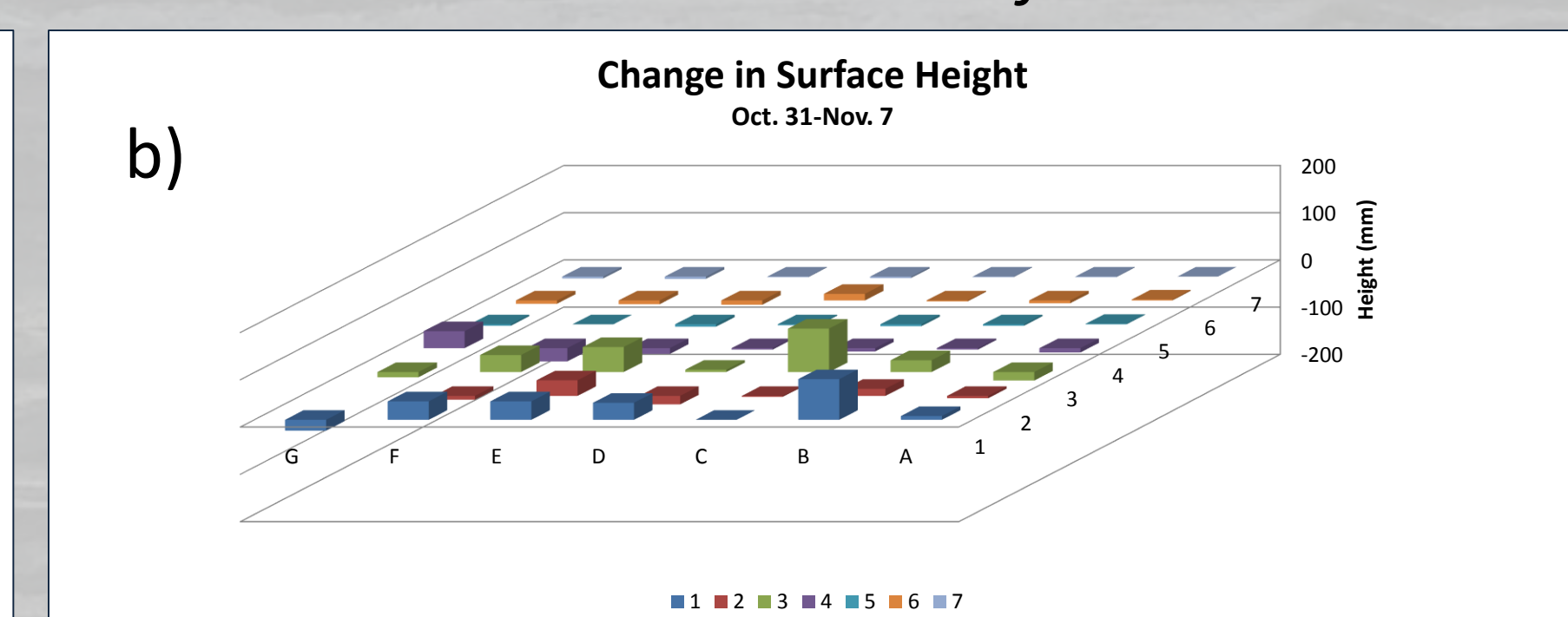
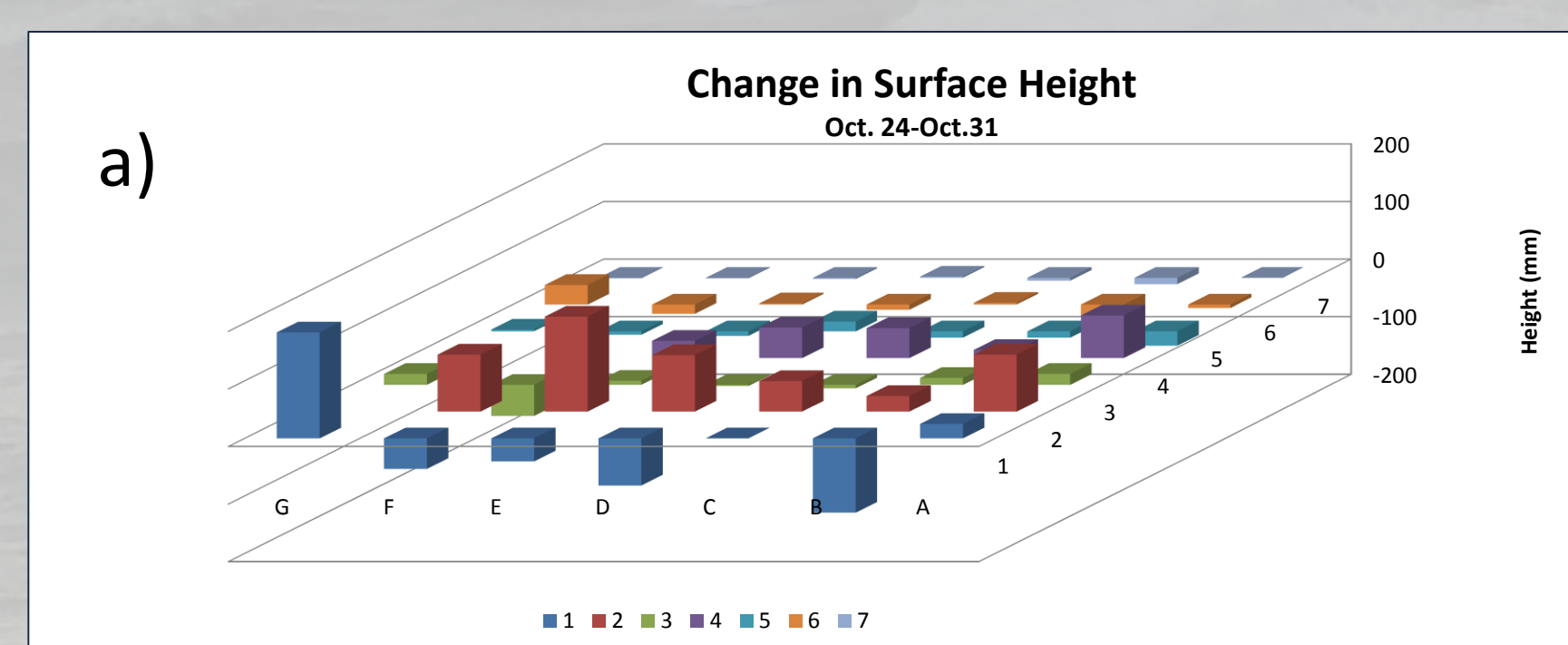


Fig 3: Wind speeds and wave heights during the 2 week study period

Three storms were observed during the study period (Fig 3) and their characteristics varied (Table 1). Storm 1 had the strongest wind and waves, but it also had the highest pressure and the lowest precipitation. Storm 2 had high precipitation and low pressure, but wind and waves were less substantial. Storm 3 had roughly the same wind and pressure as storm 1, but had much more precipitation.

	Storm 1 (10/25)	Storm 1 (10/26)	Storm 2 (10/31)	Storm 2 (11/1)	Storm 3 (11/5)	Storm 3 (11/6)
Average Wave Height [2]	2.8m	2.75m	1.8m	1.7m	1.5m	1.6m
Average Wind Speed	6.619m/s	9.67m/s	4.579m/s	8.07m/s	4.87m/s	9.7m/s
Precipitation Amount [3]	0.25mm	T mm	27.18mm	6.35mm	T mm	19.30mm
Range of Wind Direction	SW	SW-W-NW	NW	W-NW	SW-S	S-W-NW
Pressure [3]	1023 hPa	1011 hPa	997 hPa	999 hPa	1023 hPa	1012 hPa

Table 1: Storm characteristics from the three storms



Figs 4: Surface changes measured at the a) end of week 1 and b) end of week 2

The greatest change occurred on the portion of the foredune closest to the lake. Weeks 1 and 2 both show noticeable amounts of erosion and deposition. However, on the upper windward slope of the foredune, there is very little change in dune shape.



Different wracklines from recent storms were observed during our site visits on the beach and lower foredune (Fig 5). The most inland wrackline was observed during storm 3. The two wracklines observed on October 31 indicated two recent episodes of wave run-up.

Fig 5: Wrackline locations and dates, mapped with GPS units

Discussion

Storm 1 had the greatest effect on foredune change. It also had the highest wind speeds and wave heights, and the least precipitation. Of the two wracklines observed on October 31, the one further inland is interpreted to be from storm 1. Wave run-up to this position would have reduced the amount of sand available for aeolian transport. However, the amount of foredune change indicates that the high winds were still able to move sand to the foredune. Storms 2 and 3, with more precipitation, resulted in less erosion and deposition on the foredune.

Deposition patterns can be explained by the vegetation patterns on the lakeward portion of the foredune. The areas of least change are all stabilized by dune grass, and so there is not as much sediment movement by wind or waves. The area of most change has very little to no vegetation and is much more prone to aeolian or wave activity.

Conclusions

This study documented three storms and their characteristics in relation to foredune change. Wind speeds and wave run-up from storms were shown to have an effect on erosion and deposition of the foredune, which occurs mostly on the lakeward portion.

Acknowledgements

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Sources:

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