VARIABLE WIND REGIMES AND DUNE DEVELOPMENT AT GREAT SAND DUNES, COLORADO, USA.
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Introduction: Great Sand Dunes is a relatively small aeolian system contained within the Alamosa Basin of the San Luis Valley, Colorado. It is a useful site to study conditions that lead to the formation of aeolian deposits as there is a 30 km stretch on the eastern margin of the Alamosa Basin that acts as deflation, migration, and deposition zones for Great Sand Dunes [1]. Conditions vary across this topographic profile and a variety of deposits and dune types have developed (Fig. 1).

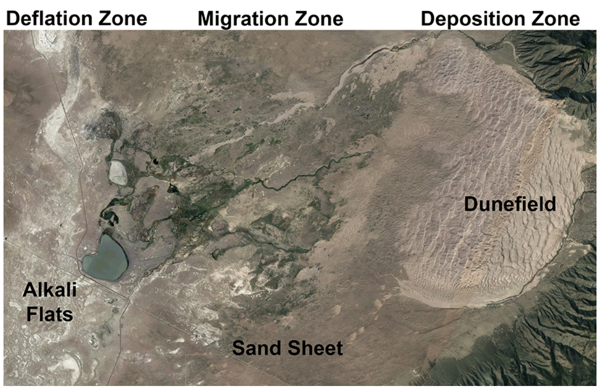

Figure 1 Great Sand Dunes Aeolian System. Image dimensions approximately 30x15 km and taken from Google Earth.

The National Park Service manages Great Sand Dunes and is interested in better understanding processes that influence the development of Great Sand Dunes. Of particular importance is wind regime and its influence on dune behavior. Questions to be answered include: Does wind regime vary spatially and over time? How does wind regime correlate with dune type and dune behavior? Can wind regime be used to predict future dunefield evolution?

Wind Regime and Dunes: The variety of dune types and dune configurations at Great Sand Dunes suggests that dune forming conditions/processes vary. Lunettes are common around playas of the alkali flats. Parabolic dunes form on the sand sheet. Reversing and star dunes are the most common type in the dunefield. This presentation will focus on wind data collected near the dunefield, on the sand sheet, but more recent efforts by the NPS include collecting wind data closer to the deflation zone.

Wind Data. Daily weather data at Great Sand Dunes begins in 1950, but digital wind measurements did not start until 2005 when a Remote Automated Weather Station (RAWS) was set up southeast of the dunefield. That was followed by and USGS (MET) station in 2007 west of the dunefield. In the past decade, 4 more weather stations have been set to measure winds at sites surrounding the dunefield (Fig. 2). The data from each site is processed to produce annual and longer-term sand roses [2].

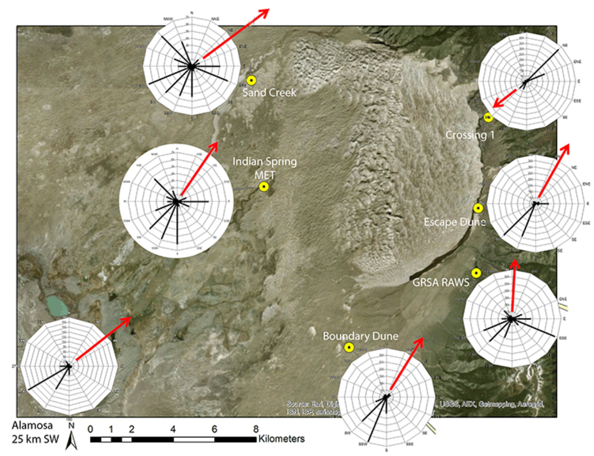

Figure 2 Variable wind regime at Great Sand Dunes. Examples of annual sand roses from weather stations near the dunefield (yellow dots) and Alamosa (off map). Modified from [3]

The results indicate that wind regime does vary spatially but is consistent annually. The total wind energy at a given site can vary but the regime is consistent with most sites having a resultant trending to the northeast. Unimodal regimes occur at Alamosa, the boundary dune, and escape dune. Bimodal regimes are at the RAWS and likely the crossing 1 site. Large dunes west of crossing 1 may reduce ground level winds from the southwest. Complex regimes exist at the Indian Springs and the Sand Creek [3].

Dune Data. The location of selected 'index dunes' are measured annually with mapping grade gps (Fig 3). The index dunes that are star dunes are also mapped using survey grade gps to obtain elevations. The mapping effort is an adventure. These dunes also have their location digitized from 1m aerial imagery produced by the National Agriculture Imagery Program that is shot every odd year. The dune locations and elevations provide data to track dune migration and changes in height.

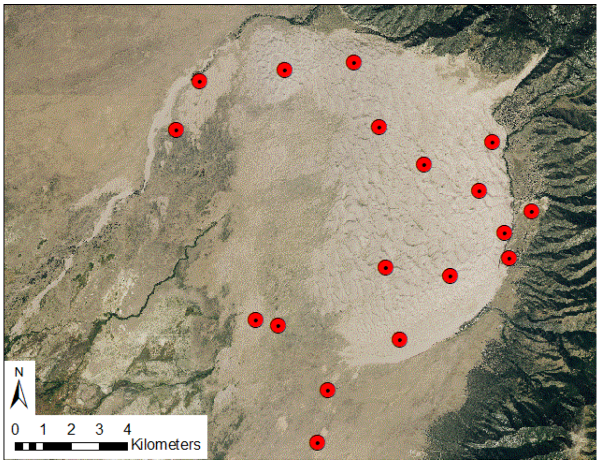

Figure 3 Index Dunes at Great Sand Dunes. Red dots indicate location of sand dunes measured annually.

Wind Regime/Dune Correlation. Each station's wind regime accurately predicts the form and behavior of nearby dunes. The boundary dune site, with its unimodal winds, is where parabolic dunes form that are constantly migrating toward the northeast, matching the resultant. The MET station correlates well with the star dune west of it. The complex wind regime results in a nonlinear dune migration, but with a north-northeast trend. It's also been discovered that NE migration results in a decrease in dune height while the opposite is true when migrating is to the SW. Near the mountain front, wind may be more bimodal, especially near Medano Pass as dunes near there migrate across a smaller area with little net displacement [3].

Conclusions: Using dune form appears to be an accurate way to predict wind regime, especially with when studying remote areas that lack data, such as Mars. When possible, there is a benefit to collecting wind data near dunes. It can document variations in total wind energy and overtime, become baseline monitoring data to quantify environmental changes. Wind data is especially valuable at Great Sand Dunes. Sand dunes are a product of the climate where a balance between, wind energy, temperature, and precipitation all play a role in the growth of vegetation on sand and therefore how mobile the sand is and whether dunes develop. Climate change also has potential to alter wind regimes and baseline data along with the dune measurements can document that.

Serving NPS clients. Repeat visitors to Great Sand Dunes sometime comment that they visited as a child, and the dunes still look the same. Thanks to regular measurements, we can assure them that while the overall appearance is similar when viewed from a distance, they are moving. We do not fully understand how long it takes for megadunes to change in a noticeable manner, but we hope to learn that. As for the future, if conditions remain constant, the dunefield should contract toward the mountains with the dunes getting taller. Few things are constant, but monitoring is always useful because it can provide a better sense of scale then memories and document conditions especially when a natural system functions in a cyclical pattern, which may be the case here. In addition, providing visitors with a detailed description of how the dunes formed and what they are doing often increases their interest in the area.

Expanding the Effort. This project can be expanded by including atmospheric modeling. An existing, one meter, lidar derived, digital elevation model of Great Sand Dunes NP&P can provide accurate topography and the weather stations can serve as calibration points for near surface winds. Creating a local model that ties into a global model would be useful in predicting how potential climate changes would affect wind regime at Great Sand Dunes. It would also be useful to do repeat airborne lidar mapping of the dunefield. The current dataset was done in 2011. Lidar mapping of the dunes on a decadal scale will help resolve what the entire dune form is doing. Current mapping only represents the behavior of the ridgetops.

References:

[1] Fryberger S. G. (1990) *Ch. 6, Modern and Ancient Eolian Deposits. SEPM* 6-5. [2] Fryberger S. G. (1979) *U. S. Geol. Survey prof. Paper 1052*. 137-169 [3] Valdez A. V. and Zimbelman J. R. (2020) *Inland Dunes of North America* 239-282