Linear Dune Formation in the Simpson Desert, Australia as a Planetary Analogue.

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Introduction: Linear dunes (sometimes referred to as longitudinal dunes) are common aeolian landforms and represent ~40% of all dunes found on Earth [1, 2]. These dunes are also found on all the planets and moons that have an appreciable atmosphere, having been observed on Titan, Venus, and Mars [e.g. 3–5]. Linear dunes can be a few tens of meters to several hundred meters wide, and their lengths commonly reach many tens to hundreds of kilometers with crest lines that vary from straight to irregularly sinuous. On Earth, linear dunes form in hyperarid, arid, and semiarid regions with moderate sand supply, typically in moderately variable or bimodal wind speeds and directions where there is moderate sand supply [6]. Despite their common occurrence, there is still considerable debate over how linear dunes form.

Part of the reason why a unique solution does not exist for the formation of linear dunes is because these features represent some of the largest dune forms on any planet or moon. It is difficult, for example, to place constraints on the age, composition, and stratigraphy of a large linear dune over its entire length, especially when this reaches tens or hundreds of kilometers. Consequently, additional research is needed to understand linear dune dynamics and to provide constraints on their physical properties (e.g., grain size and stratigraphy). All of the aforementioned observations are necessary for a comprehensive understanding of the nature of linear dunes, not only on Earth, but on other planets and moons.

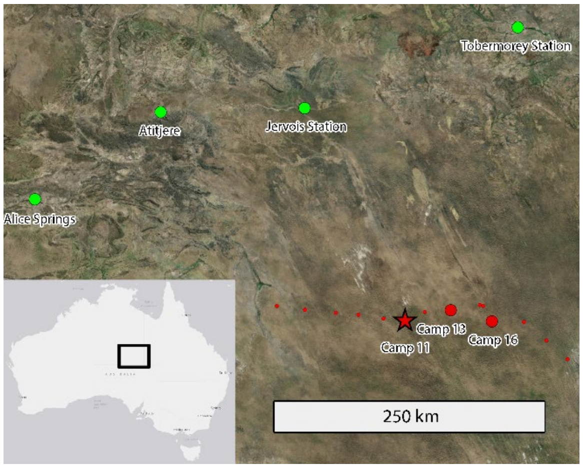

Figure 1 *Map showing location of Simpson Desert in Australia including the Madigan Camp locations used in this study. The Madigan track, used to access the sites, is shown by red dashed line.*

Dune monitoring studies provide a unique opportunity to decipher linear dune formation mechanisms and may provide key insights into the possible surface processes leading to linear dune formation on other planets. Here, we present preliminary results of a monitoring study of several linear dunes located in the Simpson Desert in central Australia (**Figure 1**). Our observations were collected during two field campaigns in April 2017 and October 2018. The purpose of our study is to monitor and quantify changes in dune morphology over time, as well as test the relative importance of the different models proposed for linear dune formation, including linear extension [7, 8], vertical accretion (i.e., "wind rift") [9–11], and lateral migration [12–16]. Although this study represents observations over a short interval of geologic time, continued monitoring can provide insight into the dynamics of linear dunes on Earth and, therefore, help decipher surface processes leading to linear dune formation on other planets and moons.

Field Location: The Simpson Desert in central Australia covers a vast area of ~170,000 km^2, occurring primarily within the Northern Territory and extending into western Queensland and the northern portion of the state of South Australia (**Figure 1**). Originally known as the Arunta Desert and referred to as "Australia's dead heart" in literature [e.g. 17], it is dominated by northwest to north-northwest oriented parallel linear dunes ranging from 10 to 40 meters in height and up to several hundred kilometers in length. Inter-dune spacing is typically between 100 meters and 1.5 kilometers and tends to vary as a function of dune height.

Methods: During each field campaign, unmanned aerial systems (UAS) were used to acquire stereophotogrammetry data sets for point cloud, digital surface model (DSM), and orthomosaic generation. A DJI Phantom 4 Pro UAS was used for the image acquisition, and Agisoft Photoscan was used for processing of the photogrammetry data into point clouds, DSMs, and orthomosaics. Georeferencing was accomplished with ground control points placed in the field during data acquisition, and marked with centimeter-scale DGNSS. Due to varying quality in the DGNSS units from 2017–2018, comparisons between surveys are made by co-registering point clouds using Cloud Compare™ point cloud editing and comparison software. Stable features in each point cloud, such as clay pans, and terrain adjacent to easily identifiable bushes and trees were used to co-register

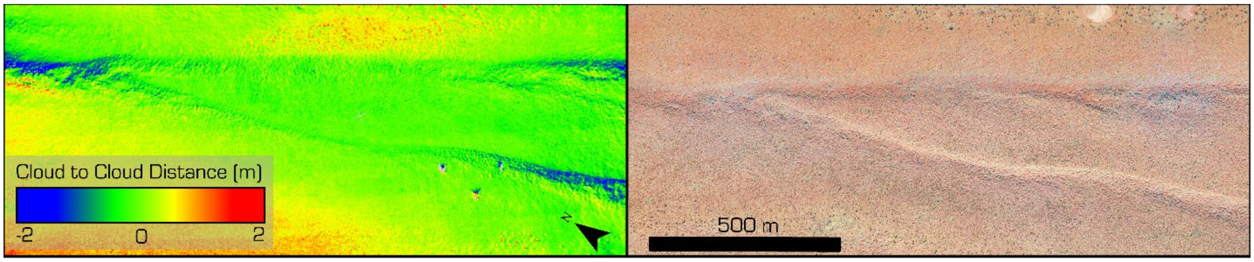

Figure 2 *Left: Difference map from Cloud Compare showing elevation difference between 2017 and 2018 point clouds. Green represents little to minimal to no change, while blue is removal of material and red is addition of material. Right: Orthomosaic generated from 2017 UAS imagery to reference for difference map.*

the data. Vertical distances between the 2017 and 2018 clouds were then computed within Cloud Compare™. **Figure 2** shows the resulting difference point cloud from a linear dune Y-junction at one of the field sites, Madigan Camp 11. Additional dunes were surveyed at Madigan Camps 13 and 16.

Observations: **Figure 2** shows Madigan Camp 11, a Y-junction between two linear dunes. Point cloud differencing illustrates that inter-dune regions have little to no change between 2017 and 2018 (blue color). The crests and the intersection point of the two linear dunes show the most change, represented by red and yellow coloring. The elevation changes between 2017 and 2018 tend to vary between -1 and 1 meter, while some values reach -2 and 2 meters on the lee sides of the dunes. The Y-junction appears to stabilize the two contributing linear dunes as they approach the junction point (represented by green, minimal change). The Y-junction seems to have the most sediment transport in the study area between 2017 and 2018, both on the east and west side of the coalesced dune. Observed differences in the northwest may be the result of co-registration artifacts (red in **Figure 2**). These artifacts can be negated by co-registering more points and minimizing the RMS error between the two clouds before differencing them.

Planetary Implications: Previous long-term monitoring of a single linear dune noted dramatic changes of ~1 m on the dune crest over periods of just 1-2 years [16]. There may be differences in the wind regimes or surface dynamics between locations, but our observations suggest that linear dunes are extremely complex aeolian systems where sediment erosion and deposition occur throughout the entire length of the dune with variable rates and intensities. This variability may be a function of changing wind regimes and surface dynamics. This may imply that unlike other dune forms, that represent transport of sediment, linear dunes represent ways of storing sediment. The linear dunes observed on other planetary surfaces, such as Titan, may reflect the presence of large sediment deposits (i.e., ergs).

Conclusions: We present the short-term evolution of linear dunes in the Simpson Desert, Australia from point cloud comparison methods. These results help to further our understanding of dunes on other planets by showing how dunes of this scale migrate over time, which can indicate prevailing wind directions and sediment transport response. Continued monitoring of dune changes will further influence the conclusions made here and help guide interpretation of linear dunes on other planetary surfaces.

References: [1] Lancaster, N. (1982), *Progress in Physical Geography*, 6, 475–503. [2] Bristow, C. S., S.D. Bailey, and N. Lancaster (2000), *Nature*, 406, 56–59. [3] Lorenz, R.D., et al., (2006), *Science*, 312, 724-727. [4] Bourke, M.C., et al., (2010), *Geomorphology*, 121(1), 1-14. [5] Craddock, R.A., (2012), *Progress in Physical Geography*, 36(1), 110-124. [6] Wasson, R.J. and R. Hyde (1983), *Nature*, 304: 337-339. [7] Tsoar, H., (1989), *Progress in Physical Geography*, 13, 507-528. [8] Tefler, M. W. (2011), *Earth Surf. Processes Landforms*, 36(8), 1125–1135. [9] King, D. (1960), *Transactions of the Royal Society of South Australia,* 83, 99-109. [10] Pell, S. D., et al., (2000), *Sedimentary Geology*, 130, 107-130. [11] Hollands C.B., et al., (2006), *Australia Quaternary Science Reviews*, 25, 142-162. [12] Hesp et al., 1989 [13] Rubin, D.M., and P.A. Hesp (2009), *Nature Geoscience*, 2(9), 653-658 [14] Nanson G. C., et al., (1992), *Earth Surf. Proc. Landforms*, 17, 807-819. [15] Bristow, C.S., et al., (2007a), *Geology*, 35, 555-558. [16] Craddock, R. A., et al., (2015), *J. Geophys. Res. Planets*, 120, 1736–1750. [17] Madigan, C. (1946), Crossing the Dead Heart, Georgian House, Melbourne.