LENGTH COMPARISON OF LINEAR SAND DUNES FROM LONG AXIS TRACES ACROSS THE SHANGRI LA, BELET, AND FENSAL/AZTLAN SAND SEAS OF TITAN. M. Wright[1], J. Radebaugh[1], D. Rose[1] and E.H Christiansen[1]. [1]Department of Geological Sciences, Brigham Young University, Provo, UT. anldsme@gmail.com

Introduction: As NASA's *Cassini* spacecraft made its tour of the Saturn system, Synthetic Aperture Radar (SAR) images taken of its moon Titan revealed dark regions near the equator were vast sand seas populated with primarily linear or longitudinal sand dunes [1, 2, 3]. These dunes share similarities with those found on Earth and throughout the solar system, and the ability to draw comparisons with better known dune fields presented us with an opportunity to learn more about the surface and history of Titan.

Tens of thousands of individual dunes are present across five distinct but connected sand seas, with variations in lengths and orientations on local and regional scales [4, 5, 6, 7]. Measurements of individual dune long axes would reveal dune orientations, which are indicative of sand transport directions [8], and relatedly wind directions [4, 5]. Thus, a global map of dune traces is valuable.

Thus far long axes of dunes in four of the Titan sand seas have been traced and mapped: the Shangri La, Belet (half), and Fensal/Aztlan sand seas, covering more than 70% of the dune regions that have significant image coverage (Fig. 5). This study focuses on images of the dune long axes measured and compares the lengths of dunes between these four sand seas and across different latitudes.

Methods: The dunes were traced from SAR images, which were obtained in strips (Fig. 1) and assembled into an image mosaic in ArcGIS. This map enabled creation of individual traces of every visible dune on Titan's surface, now nearly complete for the SAR data that exists, which is approximately 60% at the equator. The dunes were traced by creating line shapefiles in ArcGIS. Those shapefiles were then analyzed for length and orientation using ArcGIS tools. From these measurements, physical characteristics of the dunes can be extracted and analyzed to determine patterns and relationships across the sand sea regions. The lengths for each measured sand dune were calculated in ArcGIS from which the maximum, minimum, and average for each region and for the sand seas as a whole were calculated.

Length by Region: Dunes varied in overall length across the sand seas (also a proxy for longitude), with a maximum length of 404 km and a minimum of 2.2 km (Table 1). The longest and shortest dunes both come from the Shangri La sand sea, which also has the highest number of dunes measured and the lowest average length of 36.4 kilometers.

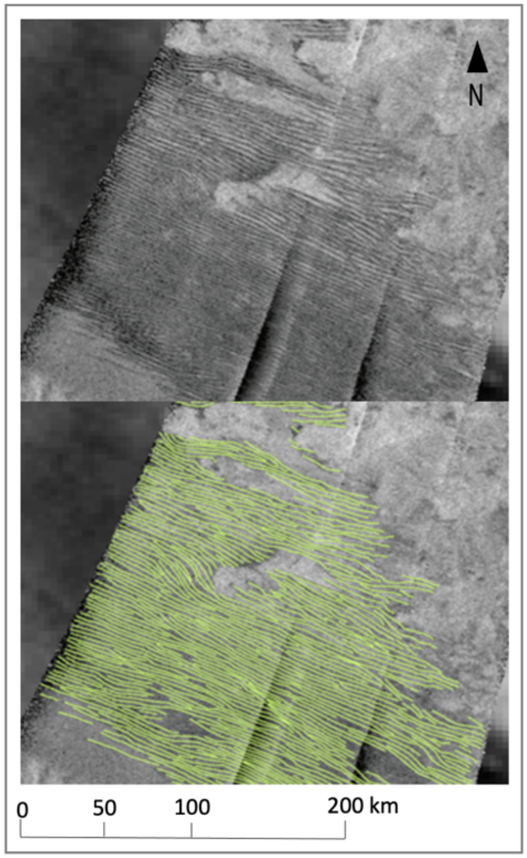

Figure 1. Upper: Close up of SAR imagery of linear dunes in the Fensal/Aztlan sand sea. Lower: Corresponding dune tracings done in ArcGIS.

Thus far, the Belet sand sea has the lowest number of measured dunes (it is about 50% completed of the measurable area) and in contrast with Shangri La, it has the highest average length of 58.9 kilometers (Fig. 2). Across the four regions, the average length is 41.5 kilometers, which is closest to that of the Fensal/Aztlan sand sea with 40.7 kilometers.

	Shangri La	Belet	Fensal/ Aztlan	Total
Dunes Traced	11164	3538	5412	20114
Maximum	404 km	361 km	354 km	404 km
Minimum	2.2 km	3.7 km	3.6 km	2.2 km
Average	36.4 km	58.9 km	40.7 km	41.5 km

Table 1. Number of dunes traced and maximum, minimum, and average dune lengths.

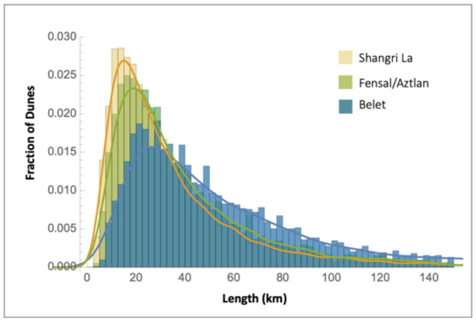

Figure 2. Distributions of dune lengths in each sand sea. Actual values are included, such that the most dunes have been measured in the Shangri La sand sea so far. Note the average length is higher in Belet (blue).

Length by Latitude: Once the dunes were traced, they were examined for their lengths by location, in particular by latitude. Dunes on Titan were previously known to be found roughly between 30° degrees north or south of the equator [1, 2]. This study reveals that individual dunes traceable in SAR are found between 23° N to 35° S (Fig. 3). The majority of dunes are found between 6° S and 8° N, which correlates with the most densely collected dunes in Belet and Shangri La (Fig. 3).

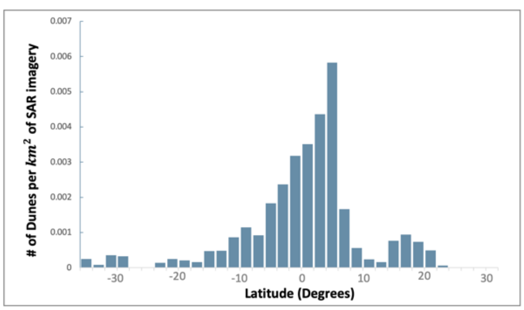

Figure 3. Number of dunes per square kilometer of SAR imagery coverage o by latitude.

The extracted dune lengths were complied into a single set and sorted by latitude in 10 degree increments. The resulting length distributions from each set showed consistancy across latitude and with the net distribution (Fig. 4).

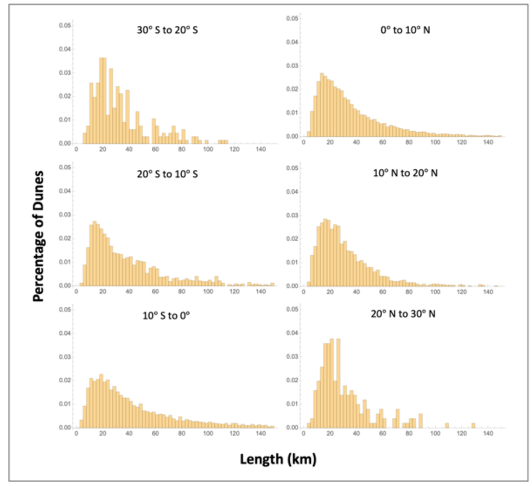

Figure 4. Distributions of dune lengths at different latitudes.

Discussion/Conclusions: This work follows on that of [7] and reveals that dune lengths across Titan have roughly similar distributions. Short dunes may be controlled by topographic obstacles that deflect the wind [9,10] but dunes can grow to hundreds of kilometers where unobstructed, especially in Belet (Fig. 2), where these obstacles are more rare. This is in contrast to dunes on Earth, where oceans and regional climate often preclude growth of linear/longitudinal dunes. Future studies will include more detailed analyses of these data by region and orientations as in [7] to reveal sand transport directions across Titan.

These studies reveal sand sea properties and histories, especially in Shangri La, where the *Dragonfly* mission will land among the dunes.

References: [1] Lorenz, R. D. (2006) *Science*. 312: 724-727. [2] Radebaugh et al. (2008) *Icarus 194,* 690-703. [3] Barnes, J. et al. (2008) *Icarus 195*, 400-414. [4] Lorenz, R. and J. Radebaugh (2009) GRL 36. [5] Malaska, M. J., et al. (2016) *Icarus* 183-196. [6] Telfer, M.W. et al. (2019) *JGR 124*, 2369-2381. [7] Rose [8] Lucas et al. (2015) *Geology, 43*, 1027-1030. [9] Radebaugh et al. (2010) *Geomorph. 212*, 122-132. [10] Ewing, R.C. et al. (2006) *ESPL 31*, 1176-1191.

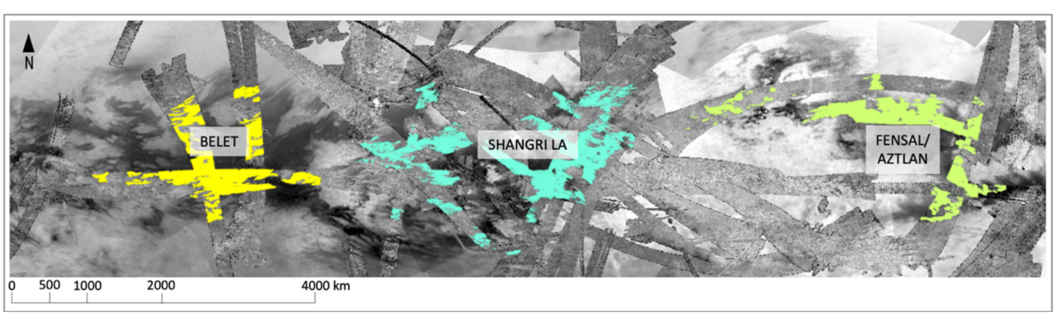

Figure 5. Mapped dune traces (colored lines) on SAR strips and an ISS basemap of Titan. Dunes are traced in SAR images only.