THE NAMIB SAND SEA AS AN ANALOGUE FOR THE BELET SAND SEA, TITAN: WINDS AND DUNE-FORMING PROCESSES.

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Introduction: The relationship between winds and resultant linear dune forms is the subject of considerable discussion [e.g.,1-6]. The newest arrival to the dialogue, the linear dunes of the surface of Titan, are valuable in that their development is not hindered by oceans or vegetation, and atmospheric circulation is generally simple [4]. However, there are not ongoing, in-situ measurements of winds to reveal current, sand-transporting wind directions and strengths. This means that correlation with model, typically higher-atmosphere winds with surface, sand-transporting winds has been elusive [e.g.,7]. Thus, terrestrial analogue studies can lead to a better understanding of linear dune-forming winds that can then be translated to the surface of Titan. We discuss the Namib Sand Sea as an analogue for the Belet Sand Sea of Titan and in particular discuss recent winds as a model for potential winds in the Belet Sand Sea.

The Namib and Belet Sand Seas: The Namib Sand Sea of Southwest Africa was considered an analogue for the sand seas of Titan from the time of discovery of dune on Titan [4,8,9]. It is a sand-rich region with N-S trending, large, linear dunes bounded by an elevated plateau on the east, a fluvial channel on the north and the Atlantic Ocean on the west [3]. Dunes here, as in most other terrestrial sand seas, are thought to have originated during the Last Glacial Maximum at least 20ka, since then reworked possibly minimally [3].

The Belet Sand Sea of Titan is also sand-rich, as apparent from Cassini Synthetic Aperture Radar (SAR) images that are dark in the center, indicating sandy conditions, similar to the Namib (Fig 1). Topographic data for the Belet Sand Sea from Cassini Radar altimetry and SARTopo, reprocessed to include the geoid (with incorporation of all data in progress), reveals the sand sea is bounded on the west and east by elevated, mountainous terrains and is low in elevation in the middle and on the northern margin [10].

Dunes in the Belet Sand Sea are wider at lower elevations, and are also wider the farther from the sand sea margins they are. Both trends indicate dunes at the center of the Belet Sand Sea are generally wider (Fig. 2) [10]. One conclusion is that sands collect at low elevations, causing dunes to grow larger. However, narrow dunes are found at low elevations along the northern margin of the sand sea (Fig. 2). Instead, perhaps the presence of more sand enables growth of wider dunes, or conditions at the margins preclude dune growth [10]. Dune widths in the Namib Sand Sea do not show strong trends with elevation; distance from margin is in progress [9].

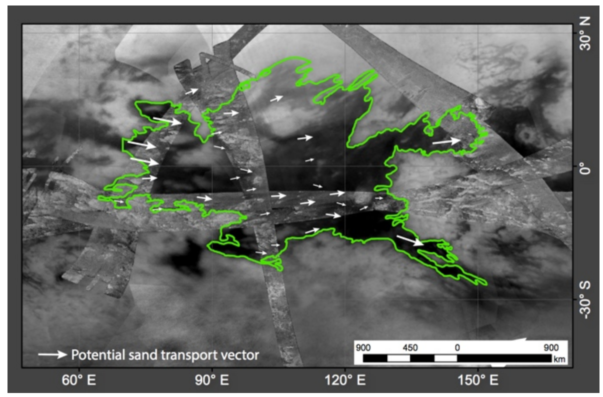

Fig. 1. The Belet Sand Sea, Titan. Outline is determined from combined SAR and ISS (Imaging Science Subsystem, visible camera) data [11].

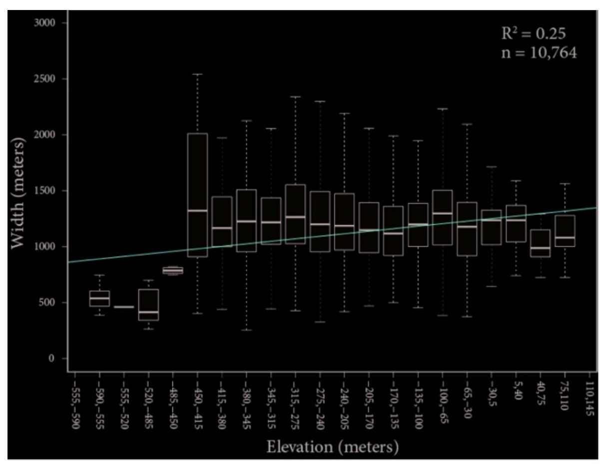

Fig. 2. Dune width vs. Elevation (increasing to R) in the Belet Sand Sea. Dunes are generally wider at lower elevations. Narrow dunes on the L correlate with low elevations at the northern margins of Belet [10].

The ERA-Interim Project for Winds on Earth: Integrating wind data obtained on Earth's surface over time with models for atmospheric circulation has produced the ERA-Interim Project wind model [12]. This has significantly improved resolution over other models and is enabling an understanding of wind directions in all locations on Earth [12]. We summarize the results for the ERA-Interim wind model in the Namib Sand Sea from 1 Jan 1979 to 31 Dec 2013 at 6 month intervals, visible as colored roses in Fig. 3. Winds can be used to find sand flux directions, using the method described in [13], the green roses in Fig. 2=3.

In the Namib, wind directions are roughly oriented N-S, aligned with the dunes, though they are slightly off-axis. The sand flux orientations derived from the winds correlate even more strongly with the orientations of dune crestlines. Furthermore, these orientations are roughly similar to winds from 21ka, 2ka, 1ka and today from the Paleoclimate Modelling Intercomparison Project (PMIP) [14].

This alignment fits fairly well with the fingering mode of dune growth, which results in dune elongation [13]. In this case, dunes elongate in the direction of the resultant sand flux [14,15]. For the Namib Sand Sea, dunes are aligned nearly directly N-S, and the winds are NNE, also corroborated by snapshot versions of modern winds [3] and observations of a sharp edge to the sand sea at the northern, river-bounded edge, where sediments shed off the margin are transported to the ocean by the river [3].

Discussion. Dunes in the Namib Sand Sea have morphological and wind characteristics consistent with the fingering modes of [6,13], though the dunes are not exactly aligned with the winds and sand transport directions. In the Belet Sand Sea, based on the orientations of dunes, we may expect wind and sediment flux directions of roughly E, ranging across ESE or ENE, consistent with previous conclusions [16]. It would be instructive to overprint the wind roses of the Namib onto the Belet dunes to determine precise orientations, and to compare these results with similar studies of other linear dunes on Earth and their ERA-Interim and paleoclimate wind directions, which we plan to do.

These observations allow us to quantitatively reconstruct possible scenarios for the development of large, linear dunes on Earth according to the local climatic conditions and apply those results to the linear dunes of Titan, where surface wind data is sparse.

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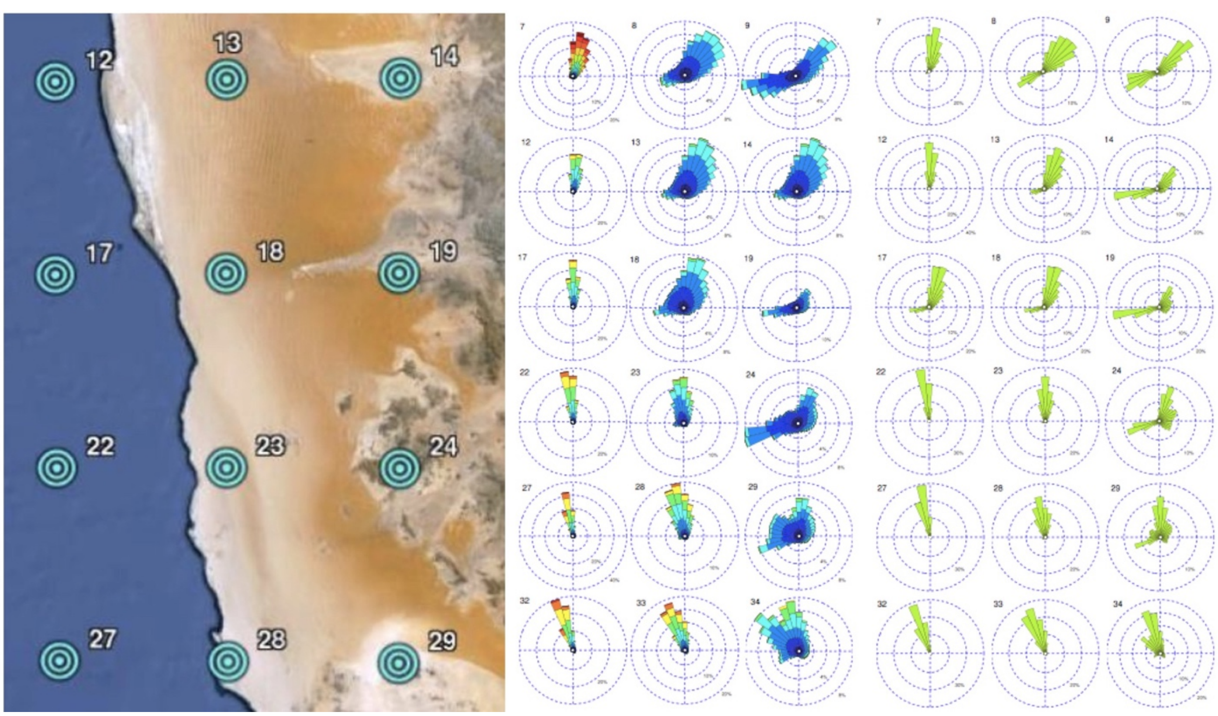

Fig. 3. ERA-Interim model locations (left) for the Namib Sand Sea and corresponding wind roses (middle) and sediment flux directions (right).