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Reorientation Timescales and Pattern Dynamics for Titan's Dunes: Does the Tail Wag the Dog or the Dragon?

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Fields of bedform patterns persist across many orders of magnitude, from cm-scale sub-aqueous current ripples to km-scale aeolian dunes, and form with surprisingly little difference in expression despite a range of formative environments. Because of the remarkable similarity among bedform patterns, extracting information about climate and environment from these patterns is a challenge. For example, crestline orientation is not diagnostic of a particular flow regime; similar patterns form under many different flow configurations. On Titan, these challenges have played out with many attempts to reconcile dune crestline orientation with modeled and expected wind regimes. We propose that thinking about the time-scale of the change in dune orientation, rather than the orientation itself, can provide new insights on the long-term stability of the dune-field patterns and the formative wind regime.

In this work, we apply the crestline re-orientation model developed by Werner and Kocurek [Geology, 1997] to the equatorial dune fields of Titan. We use Cassini Synthetic Aperture Radar images processed through a de-noising algorithm recently developed by Lucas et al. [LPSC, 2012] to measure variations in pattern parameters (crest spacing, crest length and defect density, which is the number of defect pairs per total crest length) both within and between Titan's dune fields to describe pattern maturity and identify areas where changes in dune orientation are likely to occur (or may already be occurring). Measured defect densities are similar to Earth's largest linear dune fields, such as the Namib Sand Sea and the Simpson Desert. We use measured defect densities in the Werner and Kocurek model to estimate crestline reorientation rates. We find reorientation timescales varying from ten to a hundred thousand times the average migration timescale (time to migrate a bedform one meter, $\sim$1 Titan year according to Tokano (Aeolian Research, 2010)). Well-organized patterns have the longest reorientation time scales ($\sim 10^5$ migration timescales), while the topographically or spatially isolated patches of dunes show the shortest reorientation times ($\sim 10^3$ migration timescales). In addition, comparisons between spacing and defect density reveal that the well-organized patterns plot along an expected trend with Earth and Mars' largest, well-organized fields. Patterns on Earth and Mars that have been degraded and broken by environmental change fall off this trend and similarly, so do the isolated dune patterns on Titan fall suggesting changing environmental conditions such as wind regime and/or sediment availability have influenced the dunes on Titan. Crestline orientations in these areas suggest star and crescentic (barchans) morphologies in addition to linear dunes.

Our results suggest that Titan's dunes may react to gross bedform transport averaged over orbital timescales, relaxing the requirement that a single modern wind regime is necessary to produce the observed well-organized dune patterns. We find signals of environmental change within the smallest patterns suggesting that the dunes may be recently reoriented or are reorienting to one component of a longer timescale wind regime with a duty cycle that persists over many seasonal cycles.