How altitude and latitude control dune morphometry on Titan

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Abstract

Dune fields are one of the dominant landforms and represent the largest known organic reservoir on Titan. SAR-derived topography show that Titan's dune terrains tend to occupy the lowest altitude areas in equatorial regions occurring at mean elevations between ~-400 and ~0 m. In elevated dune terrains, there is a definite trend towards a smaller dune to interdune ratio, interpreted as due to limited sediment availability. A similar linear correlation is observed with latitude, suggesting that the quantity of windblown sand in the dune fields tends to decrease as one moves farther north. These findings place important constraints on Titan's geology and climate.

1. Introduction

Vast fields of linear dunes cover at least 12% of Titan's surface, mainly confined to Equatorial regions [1,2]. They represent the largest reservoir of organics on the Saturn's moon [1].

On Earth and by extension Titan, several conditions must be met in order to develop dunes: a supply of sand-sized sediments, winds strong enough to transport these sediments from source zones, the absence of sediment removal or a trapping system and climatic and topographic conditions favourable to sand deposition (e.g. [1,3]). Furthermore, dune dimension and shape reflect the meteorological and geological boundary conditions in which they have formed and evolved. Regional contrasts in Titan's dune terrain thus hold important clues for Titan's climatic and geological history. They also set essential constraints for the carbon and methane cycles on the Saturn's moon.

Regional variations among Titan's dune terrains can be examined through their electromagnetic signatures using Cassini Radar passive and active real-aperture observations. Although these observations do not resolve individual dunes (the 3-dB radar beam footprint diameter is 5-10 km at closest approach while dunes are 1-2 km wide and spaced 1-4 km), they provide insight into dune field morphometry. Fig. 1 shows that both emissivity and backscatter of Titan's dune fields linearly vary with the interdune fraction i.e the proportion of interdune area in the radar footprint. To second order, we expect the radiometry and scatterometry data collected over dune terrains to depend on the level of brightness of the interdune corridors that is likely directly related to the thickness of the interdunal sand cover (T_i in Fig. 1).

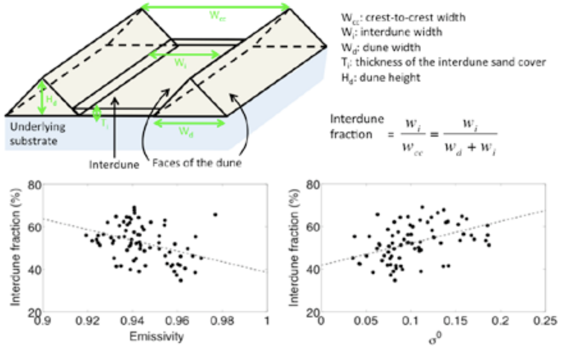

Figure 1: Emissivity and backscatter of Titan's dune fields as a function of the interdune fraction.

2. Elevation of Titan's dune fields

Topographic information presented in this paper are SAR-derived topography data also referred to as 'SARTopo' data [4]. The inferred surface height is biased towards the interdune height i.e. the local elevation. SARTopo data over Titan's dune terrains (see Fig. 2) show that most of the dune fields lie in relatively flat-floored regions, at elevation ranging between ~-400 m and ~200 m (relative to the geoid). Excluding Xanadu, they occur in the lowest regions of the Equatorial belt. Belet, Aztlan and dunes north of Senkyo, in particular, are hosted within topographic depressions that are a few hundred of meters lower than their surrounding.

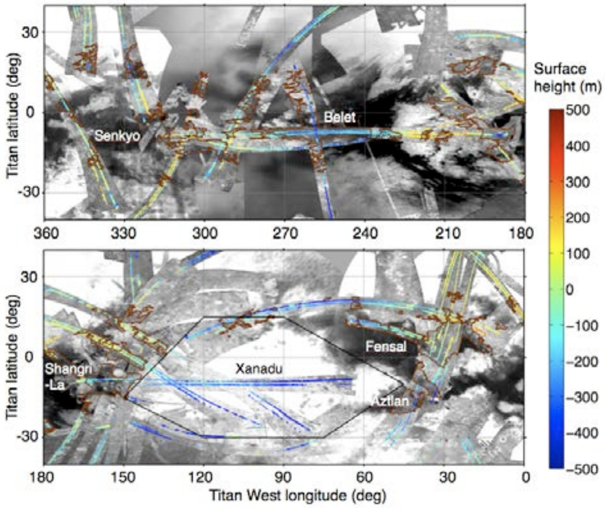

Figure 2: Global view of Titan's SAR-derived surface heights overlaid on SAR imagery and ISS base map. Dune regions are outlined in brown.

3. Variations of dune morphometry with altitude and latitude

Le Gall et al. [1] first demonstrated the existence of a latitudinal dependence in the dune field microwave signatures. Since northern tropic regions appear in general higher than southern ones (see Fig. 2), topography may be partially responsible for this trend. Using a Bayesian approach, we explore models that simultaneously account for latitudinal and altitudinal correlations. This statistical analysis shows that Titan's dune field emissivity linearly increases with both altitude and latitude while their backscatter decreases. This is interpreted as due to an increasing fraction of the interdune areas with altitude and latitude owing to either the thinning of the dunes, the broadening of the interdune areas or both. The brightening of the interdune corridors due to the waning of the sand cover may also contribute to the observed trends.

4. Implications for Titan's geology and climate

The potential thinning of the dunes and broadening and brightening of the interdune areas suggest less available sand-sized sediment both in more elevated and higher latitude dune-covered regions.

4.1 Altitudinal control

On Earth, dune fields commonly emerge within topographic basins where flow entering the basin expands, decelerates and results in the deposition of sediment. This same aerodynamic condition appears to control the location of dune field development on Titan as well as illustrated by the morphometrically generous Belet and Aztlan dune fields. The increase in interdune fraction with elevation is consistent with the idea that sediment source zones most probably occur in lowlands on Titan.

4.2 Latitudinal control

The latitudinal preference could result from a gradual increase in dampness with latitude due to the asymmetric seasonal forcing associated with Titan's current orbital configuration. This was advanced to explain lake distribution dichotomy on Titan [5]. Much like the Croll-Milankovitch cycles on Earth, the asymmetry in Titan's hemispherical seasons is expected to reverse as orbital parameters vary with periods of tens of thousands of years (~32 kyrs).

Alternatively, a latitudinal dependence in the sand source distribution or in the wind transport capacity (sediment-carrying capacity of the wind) may also be responsible for the observed latitudinal asymmetry.

Acknowledgements

This work was supported by the Cassini/Huygens mission, which is a joint endeavor of NASA, the European Space Agency (ESA), and the Italian Space Agency (ASI) and is managed by JPL/Caltech under a contract with NASA. A. Le Gall is supported by the NASA Postdoctoral Program, administrated by Oak Ridge Associated Universities (ORAU).

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