DUNES ON TITAN FROM CASSINI RADAR. J. Radebaugh[1], R. Lorenz[2], J. Lunine[3], S. Wall[4], G. Boubin[3], E. Reffet[3], R. Kirk[5], R. Lopes[4], E. Stofan[6], L. Soderblom[5], M. Allison[7], P. Callahan[4] and the Cassini Radar Team, [1]Brigham Young University, Dept. of Geological Sciences, Provo, UT 84602 *jani.radebaugh@byu.edu* [2]Johns Hopkins Univ. Applied Physics Lab, Laurel, MD [3]Lunar and Planetary Lab, Univ. of Arizona, Tucson, AZ 85721. [4]Jet Propulsion Laboratory, 4800 Oak Grove Dr., Pasadena, CA 91109 [5]US Geol. Survey Astrobiology Institute, Flagstaff, AZ [6]Proxemy Research Inc., Laystonsville, MD [7]Goddard Institute for Space Studies, New York, NY.

Introduction: Cassini Radar discovered, in addition to many other Earth-like geological features, thousands of dunes on Titan [1,2]. These are (W-E) in orientation, 1-2 km wide, 1-2 km apart, ~100 m high, and 10 - >100 km in length [1-4]. They are likely comprised of particulates of hydrocarbons and/or water ice and are found mostly near equatorial regions [2,5]. We present information about dune morphologies, extents, locations, orientations, and implications for global and local atmospheric wind patterns as determined from Cassini Radar observations in the first half of the Cassini tour.

Cat Scratches and Sand Seas: Dunes on Titan are considered belonging to two major categories. 'Cat scratches' are thin, radar-dark lines, clumped together in patches. They sit atop base materials having more subtle radar brightness variations (Fig. 1).

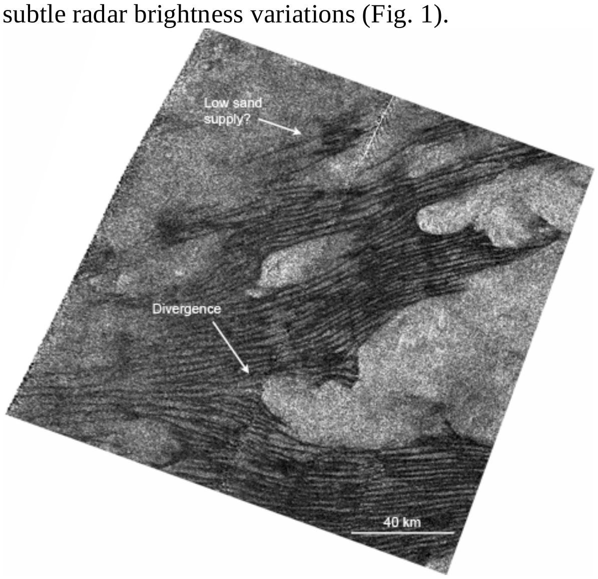

Fig. 1. Dunes (radar-dark) lie atop and diverge around basement materials (radar-bright) including elevated regions. Image obtained during T21 (12/06), ~10 N, 280 W, ~175 m px^{-1}, radar illumination from the left (NW).

The second category includes all dunes found in regionally extensive, densely populated, radar-dark areas called 'sand seas' (Fig. 2). These are often more nearly parallel and closely spaced than cat scratch dunes.

Dunes in both categories sit atop and interact with underlying basement materials, although in parts of the sand seas the underlying materials are not as visible at Cassini Radar wavelengths (2.17 cm) and resolutions (~175 m px^{-1}) as in other regions.

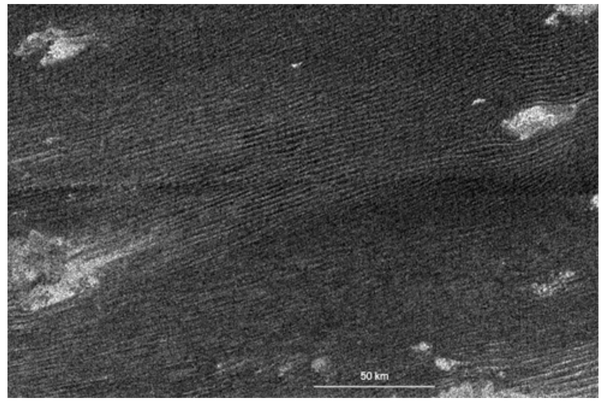

Fig. 2. A portion of the Belet sand sea, which extends nearly 2000 km. Dunes densely cover the underlying basement here, yet still divert around topographic highs. Image obtained during T8 (10/05), ~ 5 S, 250 W, ~175 m px^{-1}, radar illumination from the top (N).

As dunes interact with features of high topography, such as mountains of just a few hundred meters, they divert around the obstacle and resume their form and direction on the lee side of the feature. They sometimes locally become transverse dunes; both likely the result of topography-controlled wind variations.

Dunes in sand seas grade into cat scratch dunes at the margins of the sand seas (e.g., dunes in Fig. 1 are immediately north of the Belet sand sea). It could be that cat scratch dunes are present where there is a smaller sand supply than in the massive sand seas.

Longitudinal dunes: Dunes on Titan viewed at the Cassini Radar resolutions (and in some VIMS observations) appear to be almost entirely of the same type – longitudinal, or linear. These dunes form in Earth's deserts when winds are steady along a single direction parallel to the long axis of the dunes, with minor off-axis wind components that act to "shepherd" the dune particles [6,7]. Titan's dunes are morphologically similar to longitudinal dunes in the African Namib, Saharan, Arabian, and Australian Simpson deserts, and are often at the same scale. Dunes exhibit stronger radar reflection on their uprange slopes; observations yield slopes of ~10° and heights of ~100 m [3]. Repeat imaging shows these uprange glints to be dependent on view azimuth, supporting their interpretation as slopes. In addition, echo widths from radar altimetry compared to waveform simulations over dunes correspond to heights of 100-200 m and spacings >~10 times the height [8].

Dune Orientations and Wind Direction: Orientations reveal interesting things about the local, regional and global wind directions. Orientations obtained for over 8,000 dunes thus far on Titan have a mean azimuth (measured clockwise from N) of nearly 90°, with slight variations by region. This is likely a direct reflection of the long-term mean wind direction, which as mentioned above is parallel to the dune axis for this dune type. Regional wind variations from this dominant wind direction are evident in differences in mean dune orientations in some areas. These could be due to localized and broad diversions of wind by topography. For example, the radar and optically bright region Xanadu in Titan's leading hemisphere is thought to be slightly elevated above the surrounding terrains. Dunes in the T3 swath, north of Xanadu, and in the T13 swath, west of Xanadu, show marked deviation from the mean orientation as they attempt to divert around Xanadu.

To observe changes in wind patterns on a more local scale, dunes were analyzed in 5°x5° latitude-longitude boxes across Titan (Fig. 3). This kind of analysis demonstrates the general W-E trend of most dunes, especially those in the sand seas regions, as well as revealing regional variations due to topography, such as the diversion of dunes around Xanadu.

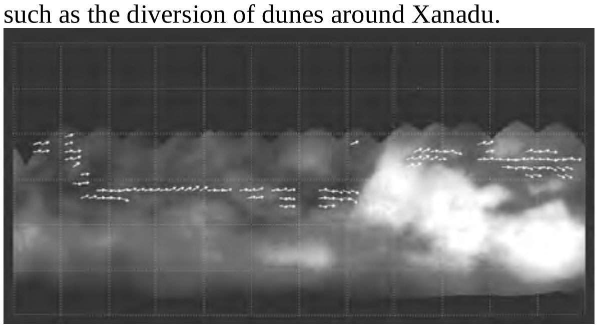

Fig. 3. Mean dune orientation vectors in 5°x5° boxes for all dunes seen on Titan through T19 (10/06). Dunes indicate a general W-E wind direction, but also show evidence of diverging around Xanadu (bright underlying region).

Global Distribution and Climate: Dunes on Titan are found only within ±30° of the equator, and the sand seas only within ±10°. We crudely estimate the coverage of Titan's surface by dunes by calculating the area covered by these 5°x5° boxes and comparing with the area covered by Cassini Radar. While nearly 7% of Titan's surface has been observed to be covered in dunes, less than 20% of Titan's surface has actually been observed. In fact, of the terrain observed by Cassini Radar within 30° of the equator, ~40% of the area observed has some dunes (Fig. 4). We can thus estimate that it is likely that 20% of the surface of Titan, organized into 5°x5° boxes (which can include other kinds of terrain as well, such as mountains, river valleys, and craters) has some dunes.

While dunes are found at Titan's equatorial regions, lakes are found near the poles (primarily >70°) [9]. A rough picture of Titan's climate emerges from these observations: that usually arid conditions prevail at the equatorial regions and wet conditions (perhaps with methane rainfall) at the poles. This fits with GCM models [10] with similar humidity distributions, although there are probably seasonal variations to this pattern [11]. It should also be remembered that Huygens, which landed near the equator, measured 50% humidity in the "soils" in a region within eyeshot of dunes [12]. Thus, the three major factors of generally low humidity, adequate sediment supply, and absence of sediment trapping (in the form of rivers washing away sediments, regional low basins containing fluids, etc.) must be considered together to explain the presence or absence of dunes on Titan.

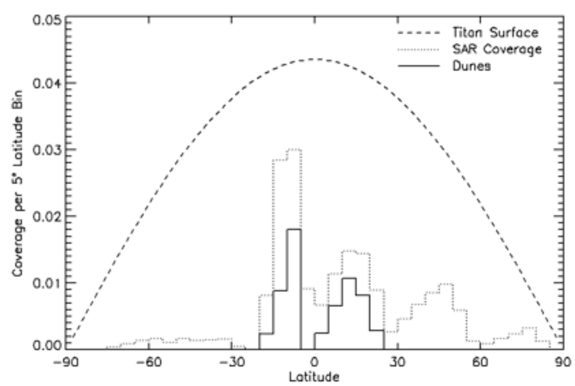

Fig. 4. Distribution of dunes and SAR coverage. The dashed line indicates complete coverage. Peaks in the SAR coverage (dotted line) include all passes through T18 (9/06) (figures in text are modified to include later passes). Solid line shows areas containing dunes, all are found between ±30°.

Given the nearly invariant dune type on Titan regardless of sand supply and topographic interactions, winds on Titan must have a prevailing direction, strength, and persistence over time to create and maintain the observed duneforms.

References: [1] Elachi C. e.a. (2006) *Nature* 441,709-713. [2] Lorenz R.D. e.a. (2006) *Science* 312,724-727. [3] Kirk R.D. e.a. (2005) *LPS XXXVI*, Abst #2227. [4] Boubin G.M. e.a. (2005) *AAS DPS 37*, Abst #46.04. [5] Radebaugh J. e.a. (2006) *AGU FM* Abst #P12A-03. [6] Fryberger S.G. and Dean G. (1979) *USGS Spec. Pap.* 1052. [7] Lancaster N. (1995). [8] Callahan P. e.a. (2006) *AGU FM* Abst #P13A-0165. [9] Stofan E.R. e.a. (2007) *Nature 445*. [10] Rannou P. e.a. (2006) *Science* 311, 201-205. [11] Hourdin e.a. (1995). [12] Tomasko M.G. e.a. (2005) *Nature* 438, 765-778.