LINEAR DUNES ON TITAN AND REMOTE SENSING COMPARISONS WITH EARTH

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1. INTRODUCTION

The surface of Titan, the largest satellite around Saturn, currently under study by the Cassini spacecraft, has been found to have many Earth-like geomorphological features. River networks, carved by methane, erode mountainous terrains of mostly water ice bedrock and drain into lakes of hydrocarbons (Farr et al. 2009; Elachi et al. 2006; Lorenz et al. 2008; Barnes et al. 2007; Stofan et al. 2007; Tomasko et al. 2005; Radebaugh et al. 2007). Linear dunes, found in tens of thousands across nearly 15% of Titan's surface, are emerging as a dominant landform (Elachi et al. 2006; Lorenz et al. 2006; Radebaugh et al. 2008). These are similar in scale to linear dunes on Earth, at 1-2 km wide, 1-4 km apart, up to 150 m high, and more than 100 km in length (Radebaugh et al. 2008; Lorenz et al. 2006). They are likely composed of particles of primarily organic materials and some water ice (Soderblom et al. 2007) and nearly encircle the equatorial area, dominantly within ±30° of the equator.

This paper discusses the benefits of studying terrestrial dune regions with known wind data that are robust morphological analogues to features observed on Titan. In particular, we seek to understand how interactions of dunes with topographic obstacles reflect regional and global wind directions. Currently, the most puzzling aspect of Titan dune studies is the discord between mean wind directions inferred from sand transport indicated by dune/topography interactions (W to E, or westerly; Lorenz and Radebaugh 2009), and winds predicted by Global Circulation Models and from basic physics of angular momentum conservation (easterly; Newman et al., 2008). We hope to begin to resolve this problem through detailed studies of dune-topography interactions in regions of known wind regimes. In addition, this work highlights the utility of RADAR images for studies of dune morphology and compares RADAR and visible-near-infrared images of terrestrial dunes with Cassini Synthetic Aperture Radar (2.17 cm, hereafter Cassini SAR) images of dunes on Titan (Radebaugh et al. in press; Greeley et al. 1997.

2. RADAR/V-NIR AND DUNES

RADAR and V-NIR image data sets can be used to determine morphological, physical and compositional properties of the surface. Figure 1 shows a region in Egypt with linear dunes of quartz sand. The Landsat image (Fig. 1.a) clearly shows dunes, some sand-free substrate, and details on the dune surfaces, such as small, superimposed dunes. The X-SAR (3 cm; Fig. 1.b) image on the right differentiates clearly between the smooth and signal-absorbing sands and the sand-free substrate. Titan's dunes seen by Cassini SAR are also RADAR-dark features, and are affected by topographic obstacles (Fig. 1.c), seen here as bright to Cassini SAR. These affect the dune forms, as evidenced by piling up of dune sands and funneling around obstacles.

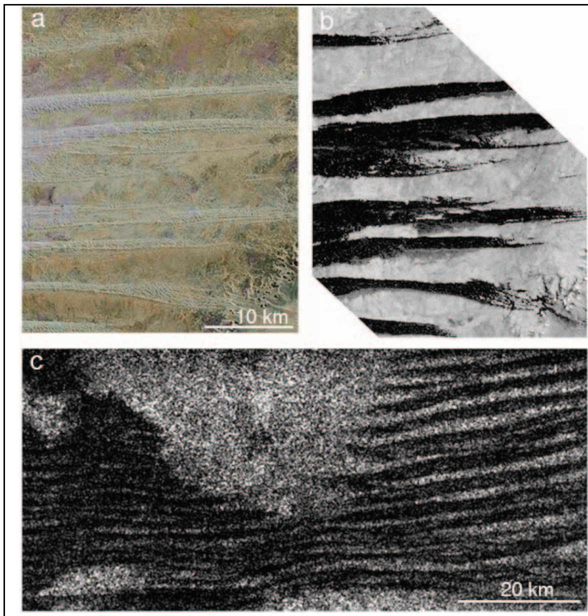

Figure 1.a Linear dune forms in SW Egypt are shown in V-NIR (Landsat) and X-SAR RADAR (**1.b**) images. Underlying bedrock can be seen in both images, but has a higher contrast in the radar image (**1.b.**), because dune sands are smooth or absorbing to the radar signal whereas the interdune area is rough. Images 32 km across, centered at 26.2° N, 26.9° E. North is left. 1.c. Dunes on Titan are also smooth or absorbing to Cassini SAR. Resolution of Cassini SAR image is 300 m.

3. WIND DIRECTIONS AND DUNE FORMS

We discuss wind directions and their effects on dune forms in the northeast Sahara to be able to determine wind directions from dune morphologies on Titan. Dunes in the Sahara have a variety of forms, but are dominantly linear and are parallel to sand transport pathways, which, for the Sahara, are controlled by trade winds (Fig. 2; Mainguet 1984). These pathways illustrate the transport of sand from northern mountains and rivers to the central and southern Sahara. Here, winds are fairly unidirectional and sediment bypassing dominates, occurring mainly over flat regions or through fluvial systems. However, locally, sand collects upwind of topographic obstacles, where winds decrease in strength and saltation is diminished (Bowen and Lindley 1977).

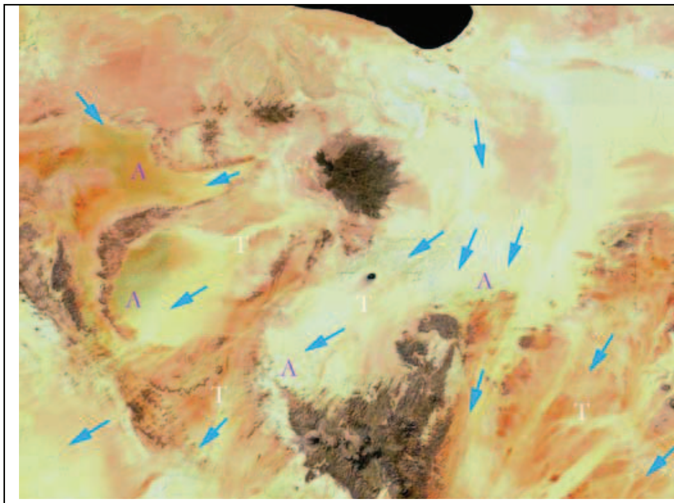

Figure 2. Sand transport pathways for the Libyan Sahara (from Mainguet 1984). Sand is yellow. Letters T indicate where transport dominates and A where accumulation is occurring. MODIS NIR image from NASA.

Once sand begins to collect ahead of obstacles, the process feeds back and leads to upwind migration of the wind velocity minimum (Mainguet 1984; Bowen and Lindley 1977). Thus, a local sand sink upwind of a topographic obstacle is established. The disruption of wind and collection of sand upwind of obstacles leads to a dearth of sand immediately downwind of obstacles and gradual regeneration of duneforms farther downwind. Results of these processes on landform morphologies – sand-rich vs. sand-sparse areas, obstacle-diverted dunes, and streaks indicating recent sand transport, can be seen clearly in a MODIS regional image (Fig. 2, marked A for accumulation areas) and ASTER close-up image (Fig. 3.a) (Radebaugh et al., in press).

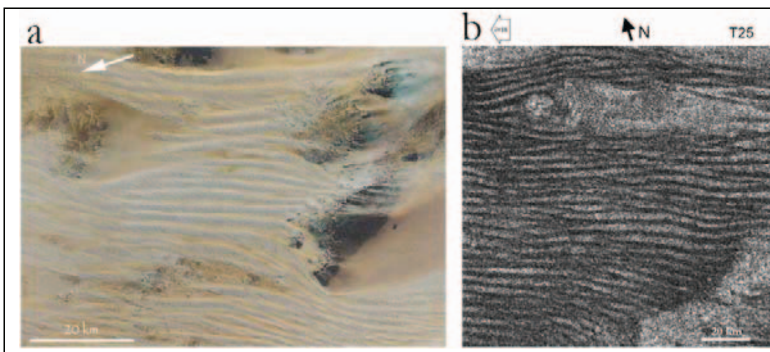

Fig. 3a. Closeup of dune forms in Libya seen in Fig. 2. Sand transport is from left to right. Similar morphologies seen in a Cassini SAR image of dune forms on Titan (**3b.**) indicate sand transport is to the east (left to right).

These relationships are also seen on Titan, albeit at lower resolutions. In locations such as in Figure 3.b, dunes are clearly separated from interdunes, and sands appear to be primarily undergoing transport. Morphological comparisons of these dune regions with those in Libya indicate the sand transport direction and related winds are uniformly from the west to the east.

4. CONCLUSIONS

Multi-instrument remote sensing studies of dunes on both Titan and Earth yield important insights into their formation and movement. Dune morphologies and their interactions with topographic obstacles indicate regional and global wind directions on Titan, information not obtainable elsewhere and valuable for atmospheric modeling. Morphologies of Saharan dunes that reflect unidirectional trade winds are also seen on Titan, indicating sediment bypassing is occurring and winds are westerly. These results are correlated with previous studies of wind directions based on dune morphologies (Radebaugh et al. 2008; Lorenz and Radebaugh 2009) but are anticorrelated with current GCM model wind directions (Newman et al. 2009).

5. REFERENCES

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