SIMULATING ABRASION UNDER TITAN-RELEVANT CONDITIONS. S. M. MacKenzie[1], K. D. Runyon[1], J.F. Kok[2], C.E. Newman[3], X. Yu[4] [1]Johns Hopkins Applied Physics Laboratory (shannon.mackenzie@jhuapl.edu), [2]UCLA, [3]Aeolis Research, [4]UCSC

Introduction: Wind is clearly an important player in Titan's sedimentary cycle. Cassini observed linear dunes 100s of kms long separated by sand-free interdunes, evidence that winds continue to transport sands enough to maintain these morphologies [1,2]. The vast dune fields almost circumscribe the moon in longitude but are confined within 30° latitude of the equator. It is therefore, perhaps, unsurprising that surface features have been put forward as putative yardangs [3,4]: if winds are sufficient for saltation to maintain duneforms, then they should be (or may have been) sufficient to erode bedrock into the long, linear yardang forms we see on Earth.

However, these yardang candidates are not found in or even near the sand seas. Rather, they are located in the midlatitude, where the comparative dearth of distinguishing radiometric and spectroscopic characteristics has given rise to the moniker "blandlands" [5]. The yardang candidates have similar radar properties to terrestrial yardangs [3] but the circumstances surrounding their formation are still unknown. A grand unified theory of yardang formation and evolution remains elusive, but several key factors of the process have been identified, including the kinetic energy of impactors [6], mechanical properties of the host lithology and the ablators [7-9], and sediment availability in the corridors [10]. It is difficult to constrain provenance when fundamental questions remain for the entire region: what materials are available to mobilize? What is the eroded bedrock? Do mobilizing winds blow sufficiently often? Could any/all of these factors explain why are there so few yardang candidates?

Given these unknowns, we set out to explore the possibilities for aeolian abrasion in the midlatitudes by considering endmember compositions of grains and target materials in combination with modeled wind profiles for these latitudes. We seek to elucidate how particle, target, and wind properties control the rate of abrasion under Titan conditions to provide new constraints on yardang formation on Titan.

Methods: While determining the exact composition of Titan's surface is beyond the reach of the *Cassini* dataset, water ice (the crustal bedrock) and organics (ultimately sourced from the photochemistry of the atmosphere) make a compelling set of endmembers [e.g. 11-13]. We assume grain and target material properties from values reported in the literature and/or bracketing sensible possibilities. For example, the particle densities for the organics come from those measured for laboratory analogs of Titan haze particles, "tholins" [14]: 400 and 1130 kg/m^3. Cohesive forces between sand grains considered, however, include not only that measured in the lab for tholins [15], but also 75% weaker and 75% stronger to account for the possibilities of Titan sand behaving more like terrestrial quartz or sintered snow, respectively. Other variables explored include grain diameter and target strength.

We model the kinetic energies of impactors and vertical flux profiles with COMSALT, a physics-based numerical model of steady state saltation [16] for a range of free stream velocities. The free stream velocities control the wind profile under which particle motion takes place and were chosen based on simulations of a Titan year with TitanWRF. This 3D general circulation model of Titan's atmosphere [17] allows us to determine the fraction of a Titan year during which conditions are sufficient to sustain grain motion along the bed (the fluid threshold).

It is generally agreed that the rate of abrasion depends on the kinetic energy of the impactor. [18] derived an expression for the rate of abrasion (R_z, m/s) at a height above the floor as a function of both the flux of impactor kinetic energy (KE_{flux}, J/m^{2}s) and the strength of the target rock (S_c, N/m^2):

$$R_z = k\frac{KE_{flux}}{S_c} \quad (1)$$

where k is a dimensionless empirical coefficient. The kinetic energy fluxes predicted by COMSALT can therefore be used to describe the rate of abrasion as a function of height.

Results: Equation 1 conveys that the abrasion rate decreases with the strength of the target material. Water ice, our strongest material at 200×10^6 N/m^2 [19, 20] is about an order of magnitude stronger than the weakest tholins measured in the lab (30 ×10^6 N/m^2) [15]. According to our model, then, softest targets abrade ~7 times faster under the same particle and wind conditions as the grain kinetic energies are sufficient to overcome the strength of the target material.

Cohesive forces between the grains play an important role in saltation [21] and thus influences the kinetic energy flux profile. The highest extents of abrasion for the largest particles we consider (1mm) are reached under low cohesion, low particle density scenarios (Figure 1c). This does not hold for the smaller

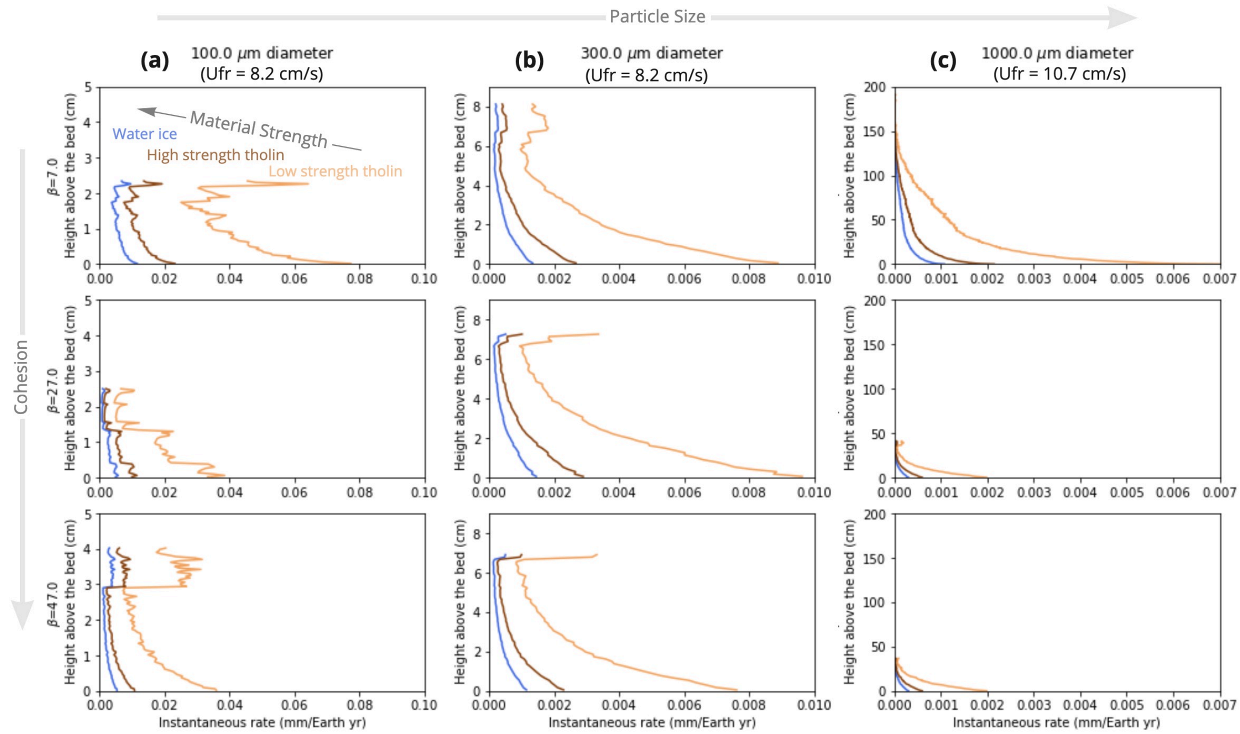

Figure 1. Abrasion rates as a function of height from the bed for three cases of particle sizes. A higher free stream velocity (Ufrs) condition is shown for 1 mm particles because these particles will not reach fluid threshold under the 8.2 cm/s regime.

particles investigated (100 µm, 300 µm). Figure 1a-b shows that maximum height above the bed is lowest for low cohesion, low density particles in this free stream velocity (8.2 cm/s), but other wind regimes do not demonstrate this trend. Peak abrasion rates happen just above the bed, regardless of target, particle, or wind properties. This arises from the fundamental assumptions of the COMSALT physics, namely that the system has unlimited sand supply. The wind stream saturates with grains, both saltators and reptators. This seems at odds with innumerable field observations showing maximum abrasion to be some distance above the bed [22] with limited sand supply, but whether conditions in these areas on Titan are supply limited or not remains unknown.

Conclusions and next steps: Abrasion rates along the bed for these Titan-like conditions are similar to those observed on Earth and at Mars. Weaker targets abrade faster and particle-particle cohesion plays a role in where kinetic energy gets deposited with height along a perpendicular target. Our next steps will incorporate the predictions of TitanWRF intermittency—how often winds blow above the fluid threshold—to determine the integrated rate of abrasion over a Titan year, as well as compare to recent investigations of sediment flux with other Titan GCMs [21]. These results will then be used to predict which scenarios are more likely at the midlatitudes where we see the yardang candidates and will be compared to the wind frequencies observed at the dune seas.

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