AVALANCHING ON AEOLIAN DUNES: KINEMATIC MODELING USING A DISCRETE ELEMENT FRAMEKWORK, WITH IMPLICATIONS FOR DUNE BEHAVIOR. S.L.F. Sutton and D.M. Burr, Earth and Planetary Sciences Department, University of Tennessee, Knoxville, TN, 37996 (ssteph34@utk.edu)

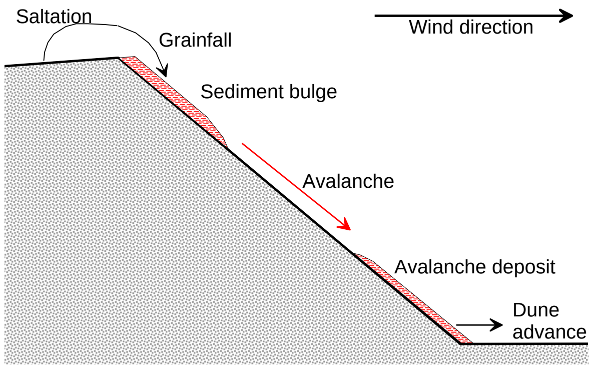

Figure 1: The aeolian avalanche system. Sediment is delivered to the slipface by saltation across the dune's brink, which collects in a sediment bulge until over steepening occurs. Following avalanche initiation on the sediment bulge sand flows to the slipface toe, causing the dune to move downwind. Discrete Element Modeling indicates that this process operates differently on different planetary bodies.

Introduction: Migrating aeolian dunes on Earth advance primarily through avalanching, and avalanche processes on aeolian dunes have received renewed attention in the last decade [1-8]. However, few models incorporate this important mechanism in a realistic fashion. Here a discrete element model of avalanching on aeolian dunes is developed. This modelling approach differs substantially from other past frameworks, and provides a more realistic representation of system behaviour by capturing characteristic length scales typically ignored. This advancement will allow for examination of changes in dune avalanche/ slipface behaviour on different planets, especially the minimum height of the slipface, and the impact on avalanche frequency and magnitude compared to transport rate.

*The avalanche process***:** The aeolian avalanche process is a manifestation of the sediment balance of the lee slipface (Fig. 1). Sediment saltates across the brink and is delivered to the slipface at the rate of the settling flux, Q_s (kg m^{-2} s^{-1}). This deposit on the upper slipface decreases with distance from the brink, resulting in a topographic bulge about 0.2 – 0.4 m downslope [9], this location is relatively constant on Earth and is also largely independent of dune height. The location of this bulge is tied primarily to the saltation trajectory length, and appears to be relatively insensitive to wind speed [1,2]. The bulge grows and increases the local slope angle until it reaches the angle of initial yield (θ_I), causing a localized failure and the release of sufficient sediment to relax the surface to the lower angle of repose (θ_R). Thus the avalanche volume is governed by the difference between these two angles, termed the "dilantancy angle" ($\delta\theta = \theta_I - \theta_R$) [1-3], and the distance from the brink downslope to the avalanche initiation point, which has also been referred to as the "accommodation space" [5].

Early modelling: Although early avalanche modelling accounted for this entire process [10,11], the models have never been used.

Most recent modelling of avalanching has occurred within dune system models, which simulate isolated dunes or entire dune fields [e.g. H, I, J] through Cellular Autonomous Modelling (CAM). CAM uses discrete uniform cells to represent sediments (Fig. 2A) and a set of simple rules to model system behaviour. The use of these models arises from their ability to form self-organizing systems with emergent behaviour, and follow the assumption that dune fields are a manifestation of self-organization. Although these models are useful to explore the behaviour of dunes on a large scale, they fail to model avalanches in sufficient detail to capture some important aspects of their behaviour, such as sediment bulge growth and failure cycles, or realistic depositional pathways.

Model design: In contrast to CAMs, our model is built on a horizontal discrete element framework, with dune height represented using continuous variables (Fig. 2). By switching from the discrete elevation change used in CAM modelling to this near-continuous level of precision the dilatancy angle ($\delta\theta$) is resolved, and thus *the sediment reservoir responsible for avalanche timing and magnitude may be modelled accurately*.

The model operates by volumetric addition of sediment to the upper slipface following expected sediment fallout distributions [e.g. 15-17] through Monte Carlo simulation. Comparisons between different planetary bodies is entirely dependent on the change in saltation trajectory and the resulting change in expected sediment settling distribution.

Preliminary model results: Preliminary results from the discrete element framework model show three interesting behaviours:

1) There is a required separation between sediment bulge and avalanche deposit. If the lower reach of the grainfall distribution overprints on the upper portion of a deposit from a prior avalanche the topographic growth of the sediment bulge is altered, interfering with the over-steepening and grain-flow initiation. Once large avalanches halt the model results in the loss of the slipface and the formation of a dome dune.
2) Due to the importance of the characteristic saltation trajectory in locating the topographic bulge, changing saltation properties from Earth's relatively short trajectories to Mars' much longer trajectories results in significantly taller dunes being required to develop a slipface due to the process described in 1, above. Further, the longer saltation trajectories also increase the volume of sediment contained in a typical primary avalanche.
3) On thick atmosphere bodies such as Venus and Titan sediment transport likely occurs with very short trajectories in comparison to Earth or Mars [18]. Sediment delivery to the slipface without the longer saltation trajectories result in changes in avalanche behaviour, specifically shortening the avalanche frequency and introducing larger variability in avalanche magnitude. By reducing the importance of the sediment reservoir, the sand dune system appears similar to that presented by Bak *et al.* [19] as the basis of their "self-organized criticality" concept. The significance of such different behaviour on landforms is entirely unknown.

Future work: Continued modelling is refining the predictions, conditions, and implications of these three behaviours through better characterization of saltation trajectories for different planetary conditions. The results, to be presented at the conference, will quantify processes and the relative importance of sand avalanching in dune behavior for different planetary bodies.

References:

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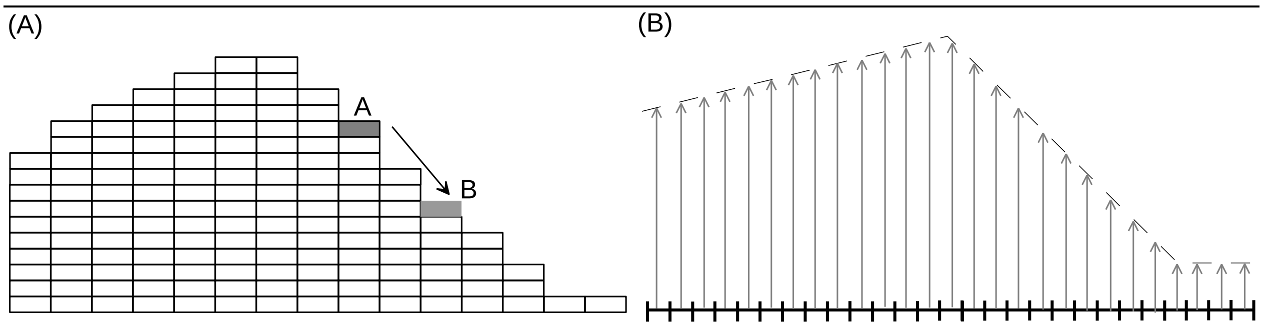

Figure 2: Comparison of CAM model (A) with the Discrete Element (B) framework. The CAM model considers the dune topography as a collection of regular cells, and uses simple rules to determine when the dune is oversteepened, and how to reposition any resulting grainflow (flow from A to B). The discrete element framework uses a discrete horizontal framework, but represents elevations with continuous variables.