CONNECTING AEOLIAN AND NIVEAN PROCESSES WITH MARTIAN POLAR DUNE MORPHOLOGY.

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We investigate the influence of reversing wind directions, diffusion, and ice cementation on dune slope evolution. The aim of this study is to quantitatively connect specific morphologies to processes and related parameters, which will aid in decoupling the effects of these processes in the interpretation of actual dune forms.

Martian dune morphology

Seasonally reversing wind directions will slow dune migration and create more symmetric dunes [1, 2]. Within polar regions, interbedded snow layers and ice cementation will perturb dune morphology and behavior [3, 4]. Such processes may be especially important in martian dune fields, as current dune evolution may occur over 10 000's of years [5], a timescale comparable to estimates for climate shifts and polar processes. Recent studies have shown that martian polar and mid-latitude dunes contain geomorphic markers of wind reversals (Fig. 1; [6]) and nivean processes [7].

Figure 1: An example of the break in slipface seen in many martian polar dunes. The ∼10m wide "bright ribbon" that runs along the crest-line is due to a lack of ripples and increased slope relative to the lower portion of the slipface. This type of slipface morphology forms on terrestrial dunes due to wind reversals [2]. On Mars it is found only in the mid-latitudes and polar regions, implying possible formation due to a niveo-aeolian process interaction. To see the full image (81.7N,133.6E) - http://hirise.lpl.arizona.edu/PSP_010269_2620.

Quantitative connections

This study utilized a standard two-dimensional continuum dune evolution model [8] to evaluate dune slope evolution. Parameters used for wind speeds and sand flux were taken from [5], with windspeed held constant (so results will need to be scaled relative to actual saltation rates). Simulations were initiated with a dune form with slipface to the left.

As observed within terrestrial dunes (e.g., [2]), a reversing wind slows dune migration and steepens the dune's slopes (Fig. 2). Simulations showed that the amount of steepening depends primarily on the frequency of wind reversal (Fig. 3), and only weakly on the period of wind cycling and the dune size.

Simulated dune mean slope values also depend on assumptions made about diffusion, as the dune shape results from a competion between saltation (which piles sand and increases slope) and diffusion (which decreases slope). In terrestrial desert dune systems, it generally can be assumed that diffusion is comparable in strength to saltation only within avalanches (when the slope exceeds the angle of repose). However, the effective diffusion on the dune can be increased through processes that preferentially transport material downslope, such as atmospheric turbulence, creep, freeze-thaw cycles, seismic shaking, or micro-meteorite impacts.

Additionally, if saltation does not occur for a large fraction of time (due to sediment or wind limits), then simulation results and model time need to be scaled via this fraction to yield real-time results. As the diffusion coefficient is inversely related to time (∼ length^2/time), this coefficient needs to be increased by the same multiplicative scale as time, to accurately reflect the effect of diffusion operating over the longer real-time period.

Certain measurables, such as the ratio of the length of the slipface to the total lee slope length (Fig. 4), may relate strongly to the relative rates of saltation vs. diffusion.

Preliminary results indicate that analysis of simulation results and comparison with observable dune morphologies will provide ways of decoupling the effects of

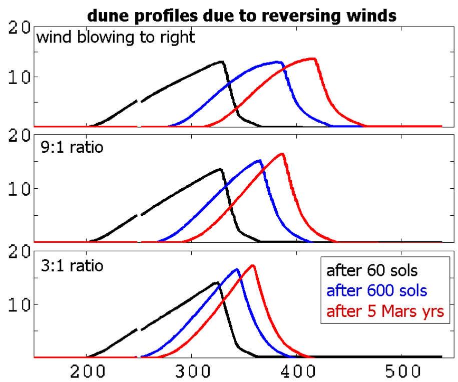

Figure 2: Under unidirectional winds, the dune migrates 97m; under 9:1 (9/10 of time wind blows to left, 1/10 to right) winds, 63m; and under 3:1 winds, 35m. The dune also grows in height, as its slopes steepen.

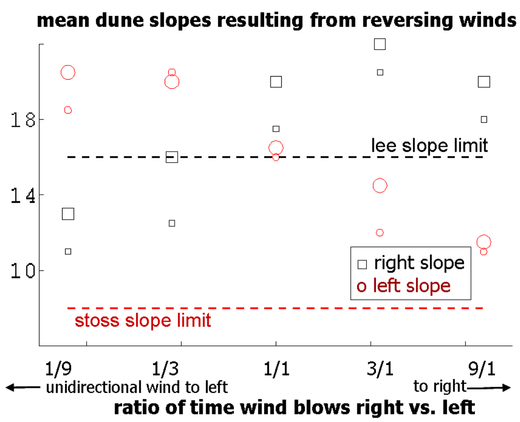

Figure 3: Both slopes adjust to a mean value that depends on the frequency of wind reversals, but is nearly independent of the period length (not shown) and dune size (indicated by marker size). Dashed lines show effect of unidirectional wind, which is consistent in stoss values with observations [2, 9]. The mean lee slope is lower than the angle or repose as calculations include smoothing at the top and bottom of the slope.

interacting contemporaneous processes. Future studies will also be aided by connection with climate, polar process, and sediment cementation studies, which can provide independent constraints of some process parameters. Additionally, we will compare dune morphologies located within the mid-latitudes vs. the polar regions to isolate the effects of polar processes.

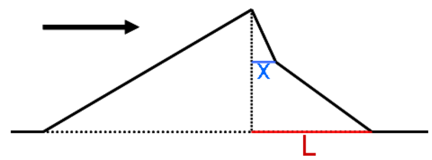

Figure 4: The ratio of the slipface length (x; the portion of the lee slope at the angle of repose) to lee slope (L) may be related to the relative rates of diffusion and saltation. Wind direction is indicated by the arrow.

Creating flat-topped dunes

Currently, simulation results have been used to replicate the general features of most martian dune forms. However, we have not yet created the flat-topped dunes found in Antartica (Fig. 5) and on Mars. We are exploring the effects of a location-dependent diffusion and/or cementation depth in creating this shape.

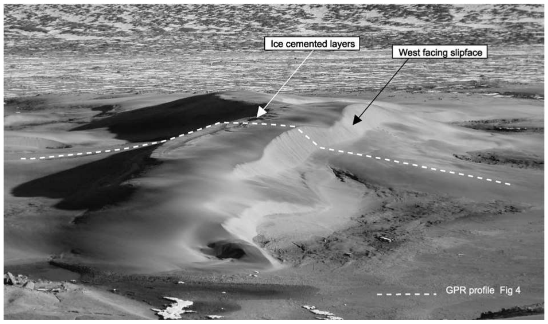

Figure 5: A flat topped Antarctic dune, similar in shape to some martian dunes. In Antarctica, these dunes appear to form due to ice cementation and reversing winds. Image is from [1].

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