CONNECTING AEOLIAN AND NIVEAN PROCESSES WITH MARTIAN POLAR DUNE MORPHOLOGY. S. Diniega1,*, S. Byrne2, K. Glasner1, *Program in Applied Mathematics, The University of Arizona, 617 N. Santa Rita Ave., P.O. Box 210089, Tucson, AZ 85721-0089 (serina@math.arizona.edu), 2Program in Applied Mathematics, The University of Arizona, 2Dept. of Planetary Sciences, The University of Arizona.

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].

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 (~ length²/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 of repose as calculations include smoothing at the top and bottom of the slope.

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 Antarctica (Fig. 5) and on Mars. We are exploring the effects of a location-dependent diffusion and/or cementation depth in creating this shape.