GLACIAL FLOW MODELING OF MARTIAN LOBATE DEBRIS APRONS. A. Pathare[1], D. Winebrenner[2,3], M. Koutnik[3], and E. Waddington[3]. [1]Planetary Science Institute, 1700 E. Ft. Lowell Road, Suite 106, Tucson, AZ 85719 (pathare@psi.edu), [2]Applied Physics Lab, University of Washington (dpw@apl.washington.edu), [3]Dept. of Earth and Space Sciences, University of Washington (mkoutnik@u.washingotn.edu; edw@ess.washington.edu).

Introduction: Understanding the evolution of lobate debris aprons is of critical importance to Martian climatology because they likely represent the largest non-polar reservoir of bulk water ice on Mars. Lobate debris aprons (LDAs) are broad, thick accumulations of ice-rich material that are commonly found at the base of prominent topographic features such as massifs and valley/crater walls (Fig. 1d). Based on Shallow Radar (SHARAD) observations of LDAs across Mars, LDAs most likely correspond to debris-covered glaciers derived from atmospheric precipitation [1,2,3]. If LDAs consist of at least 90% ice, as strongly suggested by SHARAD observations, then the amount of water ice in LDA populations is equivalent to 10% of the volume of the North Polar Layered Deposits [4,5].

Given that the global distribution of LDAs is well known, and that SHARAD has firmly established their nearly pure ice composition, the key question regarding LDAs is no longer "Where?" or "What?" but rather "When?". Crater count studies suggest that LDA formation spanned a wide range of Amazonian ages, as inferred from the retention ages of the largest craters—however, the paucity of very small craters indicates recent resurfacing [6]. Parsons et al. [5] attempted to reproduce the crater retention ages of LDAs by modeling their rheology-dependent viscous relaxation, but could not find a single combination of grain size, temperature, and subsurface slope that could yield plausible ages for the full suite of observed LDA profiles, leading them to conclude that these properties must be spatially variable. However, the relaxation-only model of Parsons et al. [5] did not account for the effects of accumulation and ablation.

We will investigate whether a true glacial flow model of LDA evolution, incorporating spatial and temporal variations in the surface mass balance, is compatible with a self-consistent subsurface rheology. In other words, how uniform is the composition of martian LDAs?

Modeling Approach: We utilize the steady-state flowband model of Waddington et al. [7], which has been previously applied to the North Polar Layered Deposits (NPLD) by Koutnik et al. [8]. This "2.5-D" model incorporates variations in the widths of "flowbands", which are curvilinear slices of the glacier defined such that flow across boundaries between adjacent bands is negligible compared to flow in the direction along each band [7]. Winebrenner et al. [9] showed that flowband paths across much of Gemina Lingula (Fig. 1a) are consistent with an episode of glacial flow prior to trough formation. We employ the topographic gradient analysis techniques developed by [9] to calculate flowband widths in LDAs using Mars Orbiter Laser Altimeter (MOLA) data (Fig. 1e). Strain rates along the flowbands will be dependent upon the subsurface rheology. Following the approach of Pathare et al. [10], we will consider variations in the following rheological parameters: ice grain size, dust content, and subsurface thermal gradient. The driving stress is proportional to thickness, which we derive from MOLA and SHARAD data.

The other key input parameter is the surface mass balance profile, the choice of which can have important ramifications for flow. For example, Karlsson et al. [11] modeled NPLD ice flow using a "classic" mass balance pattern with constant values of accumulation and ablation in their respective zones, and concluded that the near-surface radar stratigraphy of Gemina Lingula is incompatible with past flow. However, Winebrenner et al. [12], using a slope-dependent ablation profile (Fig. 1b) more consistent with the NPLD sublimation model of Pathare and Paige [13], demonstrated that glacial flow of Gemina Lingula is indeed consistent with its near-surface stratigraphy (Fig. 1c).

Anticipated Results: We will apply our glacial flow model to mid-latitude LDAs (i.e., between 30°-60°) in three regions that exhibit a particularly high LDA density (Eastern Hellas, Deuteronilus Mensae, and Tempe Terra). We will investigate whether the most recently formed LDAs in these three regions (as inferred from crater counts) exhibit a mutually compatible flow history for a globally uniform LDA composition. We will also explore whether the flow history of Eastern Hellas LDAs, some of which date back ~3 Gyr [14], is consistent with multiple episodes of glaciation.

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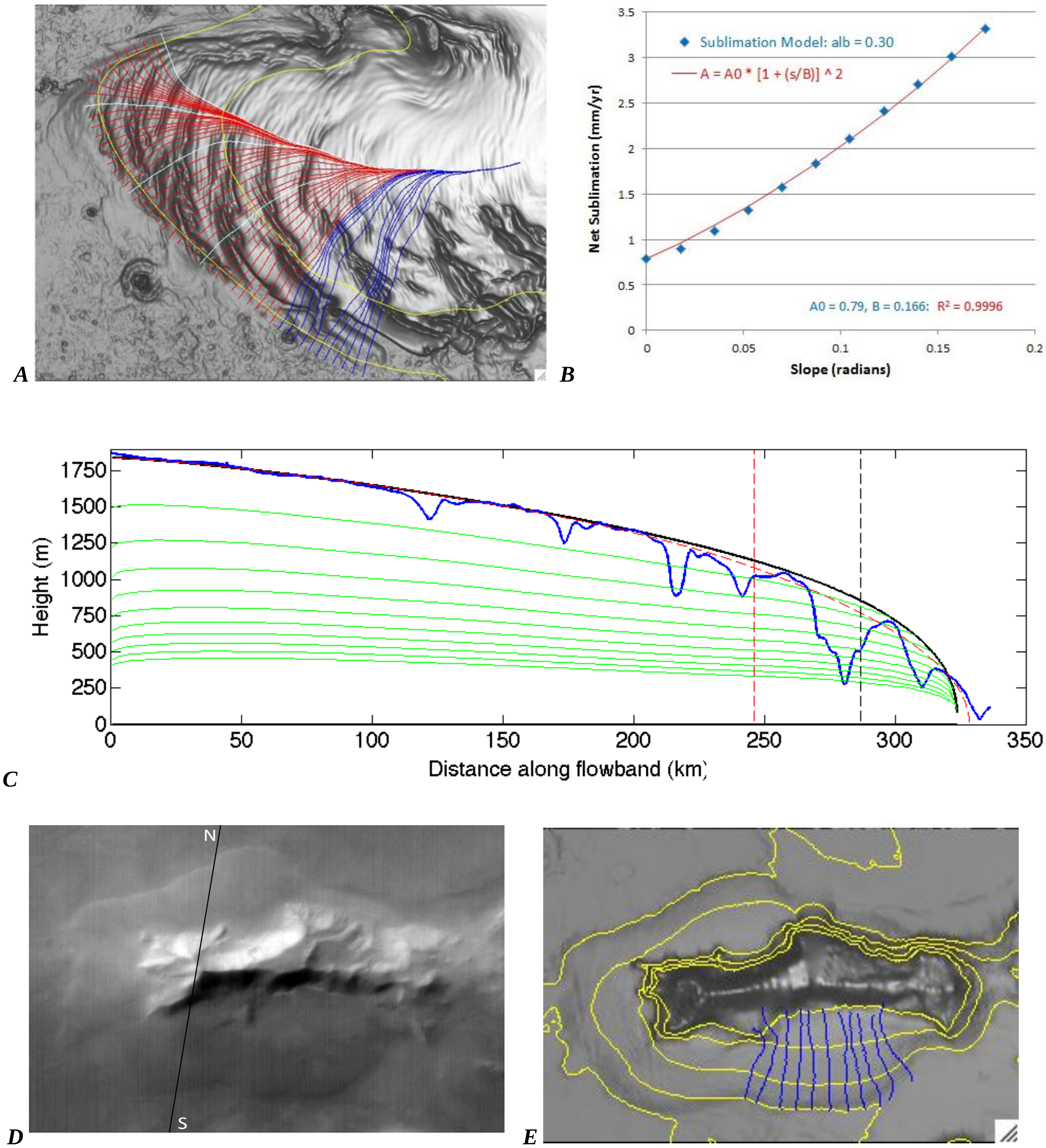

Figure 1: (A) Flowband paths in Gemina Lingula (GL) lobe of NPLD superimposed on MOLA Digital Elevation Model (DEM). Red and white paths are excellent fits to inter-trough elevation [9]. **(B)** Slope dependence of net NPLD ablation rate at 85°N, calculated using sublimation model of [13]. **(C)** Glacial flow model of GL flowband with increasing flowband width and slope-dependent sublimation (red best-fit formula in [B]). Solid black line is model-predicted surface, blue line is actual MOLA profile, and green lines are internal layers, which closely parallel SHARAD-detected near-surface layers (e.g., [11]). Vertical black dashed line represents equilibrium line. **(D)** MOC WA (Mars Orbiter Camera Wide Angle) image M0204416 of a debris apron complex surrounding a massif in Eastern Hellas at 45ºS, 255°W. **(E)** Calculated flowband paths (blue) for southern lobe of Eastern Hellas LDA shown in [D].