Predicted Flow Rates for Martian Mid-latitude Ice Deposits

*Reid Parsons[1,2], Hideaki Miyamoto[1]

1. University of Tokyo, 2. Fitchburg State University

The origin of martian mid-latitude, debris-covered glaciers (DCGs) are hypothesized to have formed via precipitation and preservation of ice during one or more episodes of high obliquity during the Amazonian period [1]. DCGs can extend for 10s of kilometers and often border steep scarps in both N and S hemispheres. In order to investigate both the flow history and potential for ongoing ice deformation, we develop a numerical ice flow model using slope and ice thickness information extracted from the Mars Orbiting Laser Altimeter. The flow model consists of components which calculate or estimate surface slope, ice thickness, and the temperature and flow velocity at the surface and within ice deposits.

The magnitude (colored pixels) and direction (red arrows) of the surface slope for a study location in Deuteronilus Mensae (42°N,18°E) is given in Fig.(a) - overlain on a CTX image mosaic. The colored pixels give the distribution of DCGs mapped by Levy et al. [2] with the labeled white dots indicating the slope at the locations of vertical profiles (given by symbols in subsequent panels). X- and Y-axis tick marks indicate the number of pixels in the DTM/model. The model currently estimates the ice thickness (Fig.b) by comparing the minimum elevation within an approximately 10 km radius to the elevation of a given ice deposit pixel. This search radius corresponds to the length scale of most DCGs resulting in a basal topography which mimics the nearly flat surroundings. The exception is for DCGs longer than 10 km for which the model will produce thicknesses less than that associated with a flat base (light blue pixels in region surrounding x=150, y=100 in Fig.b, for example).

Next, the model estimates the surface temperature using latitude, slope, and obliquity inputs based on an insolation function derived by Ward [3]. This calculation adjusts the latitude of a DTM pixel by the N-S component of the surface slope to approximate the influence of solar incidence angle on temperature [4]. The subsurface temperature gradient is determined using a regolith porosity and thermal conductivity structure described in Parsons and Miyamoto [5]. These gradients assume an average geothermal gradient of 22 mW/m2 [6]. Flow in the ice layer is computed using the Goldsby and Kohlstedt [7] flow law in which the ice grain size is assumed to be 1 mm and accounts for the change in temperature and stress with depth.

The result is a velocity map in which ice flow is predicted to range over roughly eight orders of magnitude. The largest velocities are likely erroneous due to the large thicknesses estimated by the model along the steep scarps bordering the head of DCGs. These areas likely have a much shallower ice thickness associated with propagation of the scarp slope below the headward portion of the DCG. Based on our model assumptions, DCGs are likely currently flowing at rates reaching roughly a few hundred meters per million years. However, the flow history of these deposits and their relation to a debris mantling age of ~300 Myrs [e.g. 8, 9] remains a topic for future investigation. We will perform calculations over larger areas using different obliquities in order to investigate the influence of climate variations on the ice flow velocity with the ultimate goal of shedding light on the origin of the ice that make up mid-latitude DCGs.

References:

[1] Head, J.W., et al., 2006b. EPS Lett., 241, 663–671.

[2] Levy, J.S. et al., 2014. JGR, 119, 2188–2196.

[3] Ward, W., 1974. JGR, 79, 3375–3386.

[4] Aharonson, O., and N. Schorghofer (2006), JGR, 111, E11007.

[5] Parsons, R.A. and H. Miyamoto (submitted), JGR.

[6] Plesa, A.-C. et al. (2016), JGR, 121, 2386–2403.

[7] Goldsby, D., and D. Kohlstedt (2001), JGR, 106, 11,017–11,030.

[8] Berman, D.C. et al. (2015), Planet. Space Sci., 111, 83–99.

[9] Mangold, N. (2003), JGR, 108, 8021.

Keywords: Mars, Ice, Flow