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The influence of obliquity change on flow rates of ice-rich deposits on Mars

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Geomorphological features on Mars obtained from Viking orbiter images suggest viscous relaxation of topography such as lobate debris aprons, lineated valley fill and concentric crater fill, and terrain softening. The relaxation is considered to be caused by creep deformation of a water ice component. High-resolution images obtained from the Mars Global Surveyor (MGS) Mars Orbiter Camera (MOC) and Mars Odyssey Thermal Emission Imaging System (THEMIS) provide opportunity to research these features in more detail and make a discovery of more small-scale features such as arcuate ridges, mantle terrains and lobate features on local slopes, which are also believed to contain high proportions of ice. The origin of these small-scale features is uncertain, but the morphology can be suitably explained by atmospheric deposition of ice-dust mixtures rather than infiltration of ice into the near-surface Martian crust.

When discussing creep deformation of ice-dust mixtures on Mars, the Glen's law which shows a relation between strain rate and shear stress is generally used. Flow rate of water ice strongly depends on temperature and crystal size. When temperature becomes high or crystal size becomes small, flow rate drastically increases. Milliken et al. [2003] estimate strain rates of viscous flow features on Mars to be 10ˆ-11-10ˆ-16 /s under shear stress between 10ˆ-1.5-10ˆ-2.5 Mpa. The estimate of the flow rates should have ranges of some order of magnitude, because there is little information about crystal size of water ice component in ice-dust mixtures on Mars. In order to explain the deformation features under the present Martian conditions, Milliken et al. [2003] estimate that crystal size of water ice should be less than 0.1 mm in nominal case. However, crystal size of ice in polar glaciers on Earth is generally grater than 1 mm. There are three possibilities to understand this: (1) ice-rich deposits on Mars really have small ice crystals, (2) warmer climates allowed higher flow rates in the past, (3) the mechanism other than the Glen's law controls deformation of ice-rich deposits on Mars.

Here, we focus on the second possibility. Surface and subsurface temperature on Mars would have widely varied with insolation variations caused by obliquity change. Considerably high ground temperature is predicted on poleward-facing slopes in middle latitudes in summer during periods of high obliquity [Mellon and Phillips, 2001; Costard et al., 2002], which might enable ice-rich deposits to flow much faster. If it were the case, the required flow rates can be explained in larger crystal size than that estimated by Milliken et al. [2003]. In this study, we investigate the influence of the insolation variations caused by obliquity change on the flow rate of ice-dust mixtures. We calculate temperature of an ice slab on a slope by using an Energy Balance Model (EBM) which includes effects of insolation variations due to obliquity change and slope inclination. Strain rates are estimated by using a flow law for polycrystalline ice proposed by Goldsby and Kohlstedt [2001]. Assuming a one-dimensional laminar flow, we estimate surface flow rates of the ice slab.

References
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