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The motion of Martian glaciers and volcanic activity

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Abstract

The role of density of the heat flow on the velocity of motion of Martian glaciers is investigated using numerical model. We find that for enhanced heat flow the motion could increase dramatically. Similar effect could be achieved by thick insulating thermally layer on the top of the glacier.

1. Introduction

The rheology of ice forming glaciers is complicated. Generally it is solid but for very slow processes it behaves like a viscous fluid with the viscosity given by:

$$\eta(\sigma, T) = \eta_0 \sigma^{(1-i)} \exp\left(\frac{E}{RT}\right)$$

where η_0 is a constant, σ is the second invariant of deviatoric of stress tensor (σ is high for fast deformation), i is the power law index (i=1 corresponds to a Newtonian fluid, but rather i>3). $E=Eo+pVo$ is the activation energy of the dominant mechanism of deformation, where p is the pressure. R =8.314 [J K^{-1} $mole^{-1}$] is the universal gas constant [1, 2].

Parameters η_0, Eo, Vo and i depend on many factors; e.g. size of ice crystal, content of gases, etc. Note that E is proportional to the melting temperature.

2. Equations of our model

We model considered processes of glacier's flow using the following equations [3]:

$$\rho \frac{D\boldsymbol{v}}{Dt} = -\nabla p + \nabla \cdot (2\eta \boldsymbol{D}) + \rho \boldsymbol{g}$$

$$\frac{\partial T}{\partial t} + \boldsymbol{v} \cdot \nabla T = \kappa \nabla^2 T$$

where t is time [s], $\boldsymbol{v}$ the velocity vector [m s^{-1}], $\boldsymbol{D}$ tensor of rate of deformation [s^{-1}], ρ density [kg m^{-3}], $\boldsymbol{g}$ gravity [m s^{-2}], T temperature [K], c specific heat [J kg^{-1} K^{-1}], κ coefficient of temperature diffusion [m^2 s] (note: $\kappa = k/(\rho\, c)$ where k is thermal conductivity [W $K^{-1}m^{-1}$]).

We consider 1 dimensional (1 D) model. It could be used for regions in the middle part of glaciers – Fig. 1.

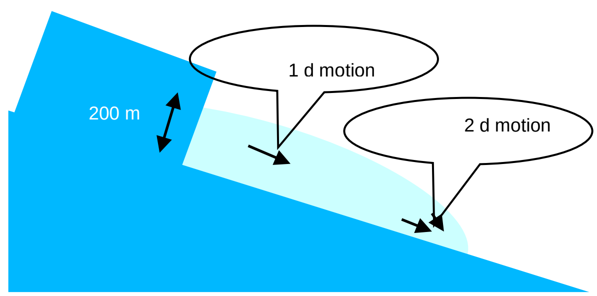

Figure 1: Sketch of flow regimes in a glacier. Note that 1D flow is a good approximation of the flow in the middle part of the glacier.

3. The role of geothermal heat flow

We observe dramatic increase of the velocity for some critical value of the heat flow density for limited heat flow (~0.2 W m^{-2}) – Fig. 2. Note that this value of heat flow is substantially less than for volcanic region (~20 W m^{-2}).

We found also that heat flow required for the fast motion depends on thermal conductivity of the glacier. For thick regolith layer of low conductivity on the top, the glacier could move significantly faster.

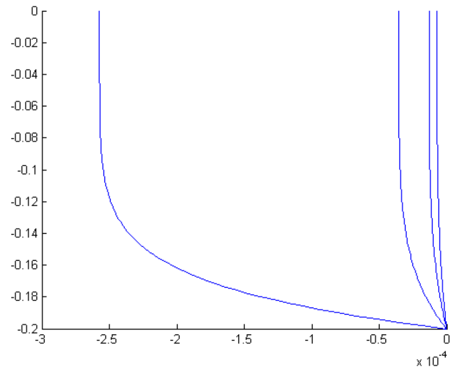

Figure 2. Effects of the heat flow variation for the velocity profiles. The vertical scale gives depth in m, the horizontal scale gives velocity in m s^{-1}. The profiles correspond the values of heat flow density of: 0.02, 0.05, 0.1, 0.2 W m^{-2}, respectively (the leftmost line corresponds to the highest heat flow).

4. Summary and plans

The velocity of glaciers depends strongly on the geothermal heat flow. For the average heat flow, typical for Mars, the flow velocity is rather limited. For enhanced heat flow (but still significantly below values typical for a volcanic area) the velocity could increase dramatically. The role of insulating layer of regolith will be the main subject of future research.

Acknowledgements

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