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Subsurface Volatile Deposition on Mars

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Abstract

We have modelled the transport of heat in the martian regolith, taking into account the change in thermal properties caused by an increase in water ice content. Under these conditions we have found that the addition of water ice allows for increased ice formation at depth, rather than under the assumption that thermal properties are unchanged. This is important because it will affect estimates of global subsurface volatile deposition.

1. Introduction

Present day observations on Mars have shown water ice is present at the poles and within the subsurface [1]. At both poles, there is a water ice cap overlain by a carbon dioxide ice cap, due to the lower temperatures required for carbon dioxide to freeze [1]. Both polar caps have a permanent and seasonal component, with the CO_2 ice layer reducing in size during the summer in each hemisphere [1]. Within the subsurface at lower latitudes, water ice has been observed by the Phoenix lander [2] and exposed at cliff faces [3]. The depth to the water ice table has been shown to increase with decreasing latitude [1]. However, the global distribution has also been shown to vary over time with the obliquity cycle and to a smaller extent with the eccentricity and precession cycles [4, 5]. In order to study the effect of the obliquity cycle, the UK version of the Mars Global Circulation Model (GCM) [6, 7] is coupled with an updated regolith model which is presented here.

2. Theory

Subsurface volatile deposition is heavily dependent on the thermal properties of the subsurface [8], primarily variations in thermal conductivity (k), density (ρ) and specific heat (c).

Studies of thermal inertia [8] have shown that variations in thermal conductivity have a more significant effect on heat conduction than the volumetric specific heat (ρc), because the value of thermal conductivity can vary by around two orders of magnitude. Previous studies of thermal conductivity in martian regolith have shown that it is a complex function of many factors, including composition, bulk porosity, the shape and size of the grains, gas pressure within pores and temperature [9, 10].

Alongside these factors, the addition of water ice has also been shown to significantly increase the thermal conductivity of the bulk regolith [10, 11], affecting heat conduction and thus impacting the stability of ice within the subsurface. Experiments [11] and models [10, 12] show that thermal conductivity increases rapidly and non-linearly with ice content. Consequently, the effect of increasing ice content on thermal conductivity is not well understood. Here, we present a regolith model that uses the Hertz factor to determine the effect of water ice content, as suggested previously for porous water ices [13], which will be coupled with the Mars GCM [6, 7].

3. Regolith Model

The regolith model is an updated version of the 1D thermal model of [5] with an improved method for determining thermal conductivity throughout the porous regolith. The model determines the distribution of water between the vapour, adsorbate and ice phases, and the distribution with depth of each of these phases at a single location, given surface temperatures and geothermal heat flux as the upper and lower boundary conditions, respectively.

The thermal conductivity in the model varies with depth and ice content, as shown in Figure 1, as well as temperature. The variation in thermal conductivity of the regolith with depth is based on the model described in [9], and the variation in thermal conductivity of water ice with temperature is based on the model described in [14]. The increase in thermal conductivity with ice content is calculated using the Hertz factor for contact area, assuming that ice grows at sinter necks between two spherical grains.

The geothermal heat flux value is currently assumed

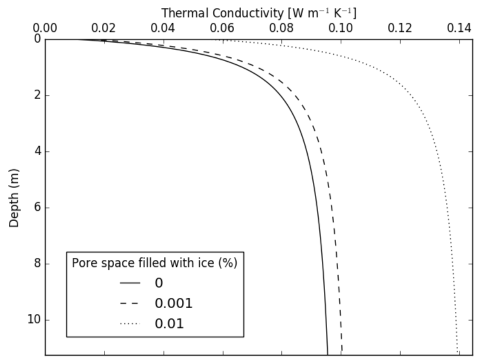

Figure 1: Thermal conductivity with depth for a regolith with a porosity of 47%. The solid line represents the thermal conductivity for a regolith containing no ice, and the dashed lines represent the effect of the addition of ice into the pore space.

to be constant and is based on previous studies [15]. However, the HP^3 instrument on the InSight lander, which is due to arrive in November 2018, will make the first surface heat flux measurements on Mars. These measurements will be used as the geothermal flux boundary at the base of the thermal model.

4. Summary and Future Work

We found that the addition of water ice increases ice stability at depth and this is so far like [10]. We plan to extend this model by performing global simulations at different obliquities to investigate the resulting change in ice distribution.

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