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Investigating the coupling between the Martian atmosphere and its subsurface

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Abstract

In-situ measurements are necessary to provide ground truths for remote observations, to conduct focused investigations on local scales and working as a network to investigate large scale phenomenon and their relation to local scale processes [1]. In this work we are interested in the coupling between the Martian atmosphere and the subsurface in terms of the thermal and mass exchange processes as this is not fully understood yet.

A thermal model combined with temperature measurements is a useful way to characterise the subsurface properties [2]. A model is developed that simulates heat transfer through convection and conduction. The model is applied to the temperatures measured by the Viking 1 footpad sensor that was in direct contact with the Martian surface. The sensor is shown to be in shadow and the thermal properties used in the model suggest the influence of the footpad thermal properties.

1. Introduction

Detailed thermophysical modelling together with observations by Odyssey's Gamma Ray Spectrometer, thermal inertia and albedo maps, morphology of craters and most recently the imaging of ice excavated from recent impacts suggest that clean water ice is present close to the surface (~1 m) at mid-latitudes where sampled .

Water ice is unstable between latitudes +30° and -30° when considering the thermal conditions yet there is evidence of ice present in the regolith at these locations. This maybe metastable subsurface ice left over from a previous epoch, hydrated salts and liquid aquifers. Pockets of subsurface water ice at low latitude could exist near the surface due to local geography such as on northward facing slopes.

By establishing a range of regolith subsurface thermal properties it may be possible to constrain, using computer modeling, the material composition of the Martian subsurface and to further understand the exchange processes between the regolith and the atmosphere.

2. Computer modelling

Conduction and convection are modelled using a 2D numerical finite element method that allows the inclusion of composite material such as dust-ice layers. The temperature dependant thermal properties of the materials are also included in the model. A 1D atmospheric column model, developed at the University of Helsinki, has been updated with a 1D subsurface thermal scheme that models conduction only. The 2D conduction-convection model may be coupled to the atmospheric model for future investigations.

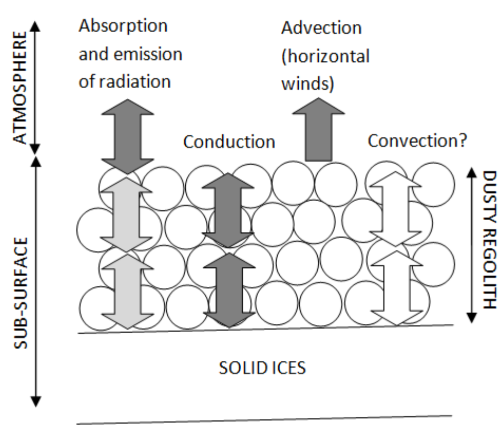

Figure 1: Regolith heat transfer mechanisms

Temperature measurements have been made in the laboratory using a heater attached to a penetrometer to investigate convection in porous medium and to validate the computer model. The experiment is shown in figure 2.

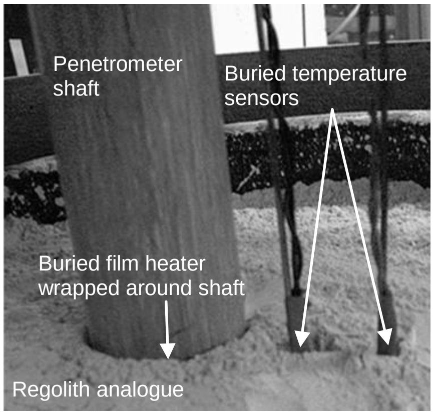

Figure 2: Laboratory measurements

3. Martian in-situ measurements

The Viking 1 lander landed on Mars in 1976 at latitude 22.5°N during the Martian spring [3] and continued to operate for over three Martian years on the surface taking measurements using meteorological instruments. A temperature sensor located, on the footpad of the lander (Fig. 3) survived the landing and continued to take measurements for several years [4]. These measurements may provide some insights into the properties of the local Martian regolith. The sensor is shown in the diagram below.

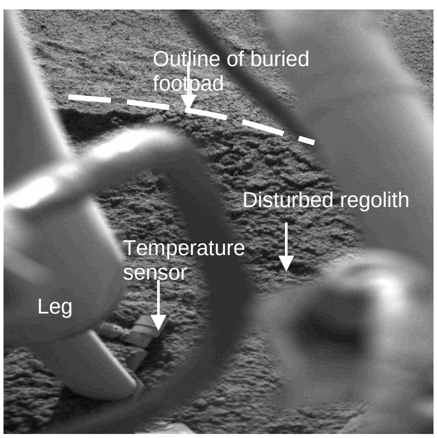

Figure 3: Viking 1 temperature sensor on footpad #3.

4. Preliminary modelling results

Figure 4 shows measurements made by the temperature sensor footpad #3 of Viking 1. The dotted lines are from a model of the temperatures from the 1D sub surface conduction model. The measurements are consistent with the sensor being in the shadow of the lander from about sol 1500 to 1800.

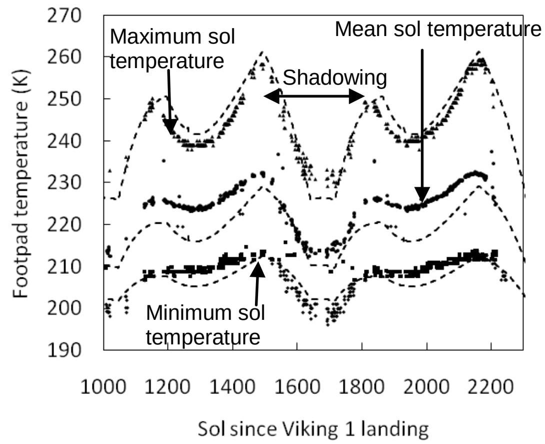

Figure 4: Viking 1 footpad temperatures with model.

Concluding remarks

A computer thermal model has been developed building on previous work [2] to numerically simulate heat transfer by conduction and convection through porous media. A 1D version of this model has been used to investigate the Viking 1 footpad temperature observations. The interpretation of these observations is challenging due to apparent blockage of direct solar insolation on the footpad. We simulated the effect of the shadow of the Viking Lander body on the measurements of the footpad temperatures. The shadow effect was found to be consistent with the footpad sensor observations coupled with our heat transfer model.

References

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