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Coupling of the Martian atmosphere and regolith

M. D. Paton (1), A. –M. Harri (1), T. Mäkinen (1), H. Savijärvi (2), O. Kemppinen (1), A. Hagermann (3)
(1) Finnish Meteorological Institute, PO Box 503, FIN-0010 Helsinki, Finland, (2) Department of Physics, University of Helsinki, PO Box 503, Finland, (3) Department of Physical Sciences, the Open University, Milton Keynes, UK (mark.paton@fmi.fi)

Abstract

The Martian atmosphere is coupled with surface over long and short time periods through heat and mass exchange processes. For example there is exchange of dust and volatiles. Thermal inertia can be used to determine the properties of the surface and has been observed to vary over seasonal time periods possibly due to atmospheric effects such as clouds or seasonal evolution of the composition regolith itself due to the exchange of volatiles with the atmosphere, e.g. see [1]. Figure 1 shows the possible compositional and structural states of the regolith when mixed with ice.

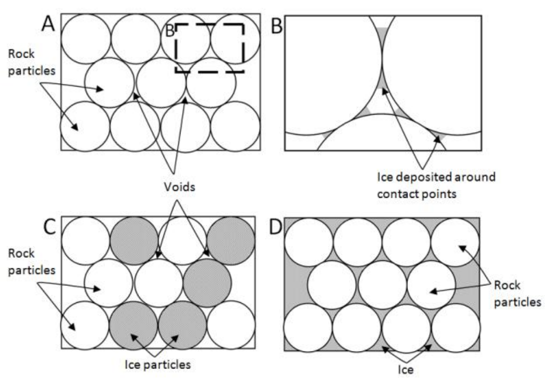


Fig.1. Schematics of the possible distribution and structure of water ice and dust in the Martian regolith. Diagram A shows a representation of Martian dust. Diagram B shows a magnified area from diagram A to reveal water ice deposited around the contact points between the grains. Diagram C shows a mixture of dust and water ice particles. Diagram D shows dust particles embedded in a continuum of water ice..

We measure the thermal inertia of the fine grained material at the Viking 1 lander site (22°N) in situ using its footpad temperature sensor (fig. 1), The sensor was buried when Viking 1 landed and the footpad penetrated the fine grained material possibly arrested by underlying bedrock [2]. The thermal inertia of this material has never been measured in situ. It can provide important information regarding grain size and hence dust transport on Mars. The variation of the thermal inertia over the season could provide important information regarding volatile exchange processes with the regolith. The thermal analysis of the temperature sensor is complicated by shadowing from the lander structure and heat exchange with the lander body [2].

We determine when the footpad temperature sensor is in the shadow caused by the lander structure using a 3-D model of the lander, see fig. 2. The significance of perturbations due to heat transfer through conduction with the lander are investigated using a 2-D numerical thermal model [3]. A 1-D atmospheric column model developed, at the University of Helsinki and FMI [4], is used to calculate the surface and subsurface temperatures.

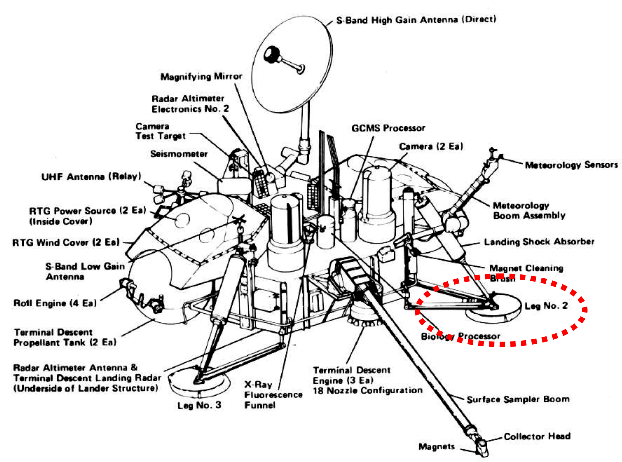


Fig.2. Schematic of the Viking lander (NASA). The sensor of interest for this study is shown located on leg number 2.

The thermal inertia of the fine grained material around the sensor is determined to be 140 ± 20 tiu which is consistent with previous published work and improves on the accuracy of knowing the properties of the fine grained material at the Viking 1 landing site.

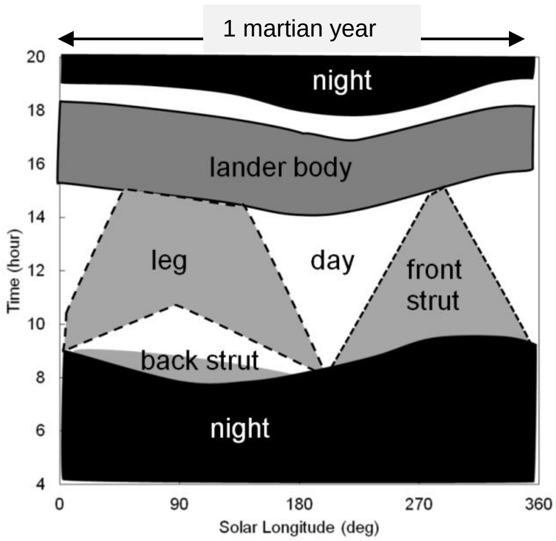
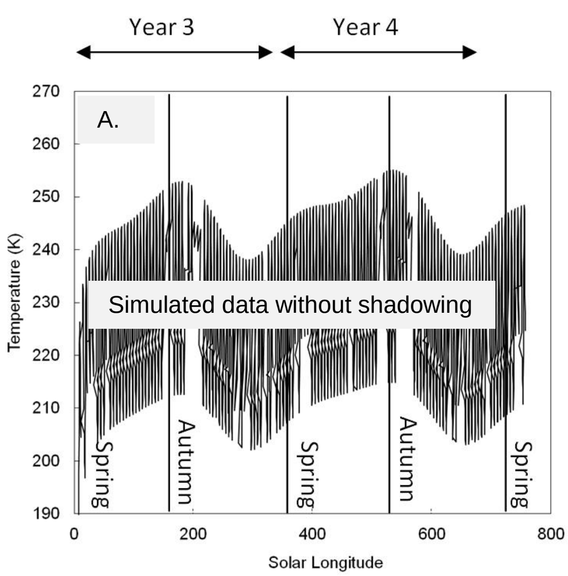


Fig.2. Time when the shadows appear over the sensor during each sol. The landing gear as well as the main body cast shadows.

The seasonal variation in the thermal inertia was studied in more detail. Uncertainties in the energy budget, at the surface, due to shadowing or radiation from the lander could not explain fully the amplitude in the seasonal variation of the thermal inertia. One solution to this could be that the amount of ice, in the pores of the top few mm of the regolith, is varying over the season.



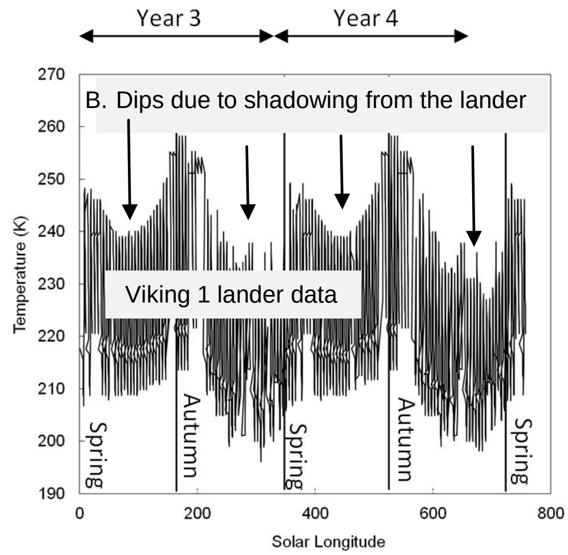


Fig.3. Figure A shows two Martian years of simulated data from a 1-D thermal model of the regolith around the temperature sensor. Figure B shows two Martian years of data from the Viking 1 footpad temperature sensor. The spring and autumn equinoxes are marked on the plots. Around these times the shadowing of the sensor from the lander structure is at a minimum.

Our investigations suggest the top 5 mm of the fine grained material, surrounding the footpad, is completely filled with water ice at the end of the winter and then depleted at the end of summer. The shadows from the lander body may be acting as a cold trap accumulating any water ice, after sunrise, that is deposited around the lander as frost during the night.

References

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