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Analysis of continuous multi-seasonal in-situ subsurface temperature measurements on Mars

M. D. Paton (1), A. –M. Harri (1), T. Mäkinen (1), H. Savijärvi (2) O. Kemppinen (1) and A. Hagermann (3)

(1) Finnish Meteorological Institute, PO Box 503, FIN-00101 Helsinki, Finland (2) Department of Physics, University of Helsinki, PO Box 503, Finland (3) Department of Physical Sciences, the Open University, Milton Keynes, UK

Abstract

Our investigations reveal the local thermal properties on the Martian surface at the Viking Lander 1 (VL-1) site. We achieved this by using the VL-1 footpad temperature sensor which was buried, and due to its location, was under shadow for extensive periods of time during each sol. Reconstruction of the surface and subsurface temperature history of the regolith in the vicinity of the temperature sensor was made using a 1-D atmospheric column model (UH-FMI) together with a thermal model of the lander. The results have implications for the interpretation of subsurface thermal measurements made close to a spacecraft or rock, interpretation of remote sensing measurements of thermal inertia and understanding the micro-scale behavior of the Martian atmosphere.

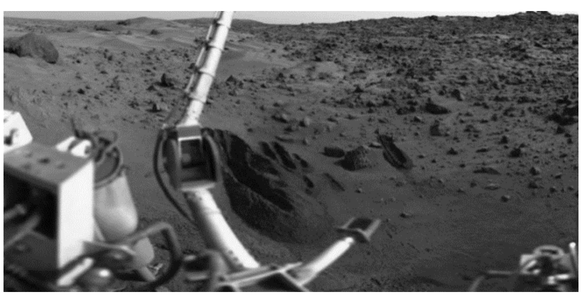

Figure 1: A view of the terrain at the Viking lander site.

1. Introduction

In situ thermal measurements of the regolith are required on Mars as they can complement thermal inertia measurements made remotely from orbit, provide a ground truth, characterise the thermal properties with depth to investigate the regolith structure, study the evolution of the thermal properties with time to investigate the exchange of volatiles with the atmosphere. Thermal probes have been included on spacecraft landers to investigate the surface energy balance, evolution of volatiles and key thermal properties, e.g. most recently Phoenix on Mars and the Philae lander on P67/Churyumov–Gerasimenko, and in the future the InSight mission will deploy a mole into the Martian regolith to measure the thermal and environmental properties.

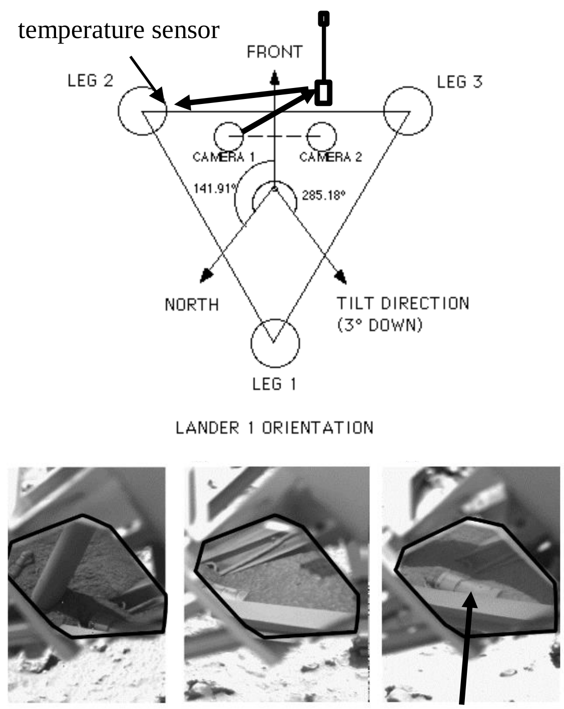

Figure 2: Images of the footpad temperature sensor (bottom) reflected in the sampler boom mirror at different times. Bold arrows in the above schematic show viewing orientation. Modified top image from reference [3].

2. Viking lander 1

The landing of Viking Lander 1 (VL-1) took place in June 1976 during the Martian northern hemisphere summer at a solar longitude of Ls 97 at 22.697 N 48.222 W. The spacecraft landed on mixed terrain with areas of fine grained material and areas of coarser grained material. As VL-1 touched down on the Martian surface its footpad #2 penetrated loose fine grained material burying the footpad and temperature sensor. The sensor survived and continued to make measurements for the duration of the mission (> 3 Martian years). The footpad temperature sensor was buried between 1.2 and 2.4 cm [2].

3. Results

A 3D spacecraft model was used to determine the timings of the shadows cast by the lander. A thermal model of the spacecraft together with a 1-D column model of the atmosphere and regolith [1] was used to predict the subsurface temperatures of the regolith around the footpad temperature sensor (see fig. 2).

Figure 3 shows the sensitivity of the predicted temperatures on the uncertainties of the input parameters. Measurement from the footpad temperature sensor is also shown for comparison. The uncertainty of the spacecraft model input parameters, e.g. reflected and emitted radiation from the regolith.

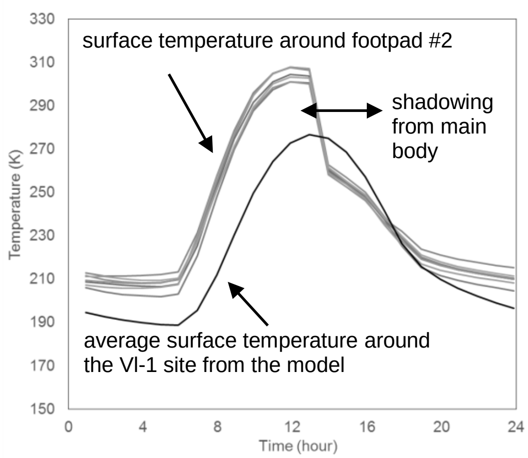

Figure 3: Thermal modelling results showing the sensitivity of the surface temperature on the uncertainty of the spacecraft model inputs. The season is Ls 180º (autumn equinox).

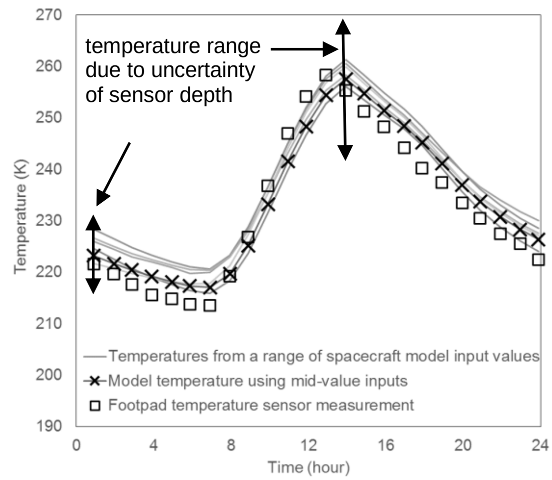

Figure 4: Model results compared to measurements for Ls 180º. Depth is 1.8 cm and thermal inertia is 98 tiu (Thermal Inertia Units). Reasonable fits also obtained for other combinations of depths and thermal inertias. Temperature range due to depth uncertainty - arrow.

4. Concluding remarks

We unravel the thermal influences of the VL-1 on a patch of regolith around its footpad. Even though there is extensive shadowing from the spacecraft it appears thermal radiation emitted from the lander raises the regolith temperature above the surrounding regolith.

A thermal inertia, around the VL-1 footpad #2, of 98 tiu +/- 20 tiu is consistent with our modelling approach given the uncertainty in knowing the depth of the sensor. This is likely much lower than the thermal inertia of the adjacent area of coarser grained material. A consequence is that adjacent areas will have divergent surface temperatures that then could influence the local climate at the VL-1 site.

References

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[2] H. J. Moore, R. E. Hutton, G. D. Clow, and C. R. Spitzer, Physical Properties of the Surface Materials at the Viking Landing Sites on Mars, U.S. Geological Survey Professional Paper 1389, 1987.

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