EPSC Abstracts
Vol. 13, EPSC-DPS2019-76-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Potential effects of Martian atmospheric collapse on heat flow measurements by InSight

Nicholas Attree (1), Axel Hagermann (1), Narissa Patel (2), Matthias Grott (3), Tilman Spohn (3) and Matthew Siegler (4)
(1) Earth and Planetary Observation Centre, Faculty of Natural Sciences, University of Stirling, UK, (2) School of Physical Sciences, The Open University, Milton Keynes, UK, (3) DLR Institute for Planetary Research, Berlin, Germany, (4) Deadman College of Humanities and Sciences, Southern Methodist University, Dallas, USA

Abstract

It has been suggested that Martian obliquity cycles might cause periodic collapses in atmospheric pressure, leading to corresponding decreases in regolith thermal conductivity (which is controlled by gas in the pore spaces). Geothermal heat would then build up in the subsurface, potentially affecting present–day heat flow — and thus the measurements made by a heat–flow probe such as the InSight HP^3 instrument. To gauge the order of magnitude of this effect, we model the diffusion of a putative heat pulse caused by conductivity changes with a simple numerical scheme and compare it to the heat–flow perturbations caused by other effects. We find that an atmospheric collapse to 300 Pa in the last 40 kyr would lead to a current heat flow that is up to $2 - 8\%$ larger than the average geothermal background. Considering the InSight mission with expected $5 - 15\%$ error bars on the HP^3 measurement, this perturbation would only be detectable in the best-case scenario of full instrument deployment, completed measurement campaign, and a well–modelled surface configuration. The prospects for detecting long-term climate perturbations via spacecraft heat–flow experiments remain challenging.

1. Introduction

During periods of low obliquity, occurring in cycles of roughly 120 kyr and 1.3 Myr periods, polar insolation is reduced, leading atmospheric CO_2 to condense onto the polar ice caps, thereby causing a dramatic reduction in surface pressure [1, 2, 3, 4] . Since the thermal conductivity of Martian dry regolith is dominated by gas filling the pore spaces [5], this leads to a corresponding decrease in its ability to transfer heat, resulting in a steeper temperature gradient in the regolith, and thus raising temperatures below the affected regolith layer. As atmospheric pressure, and regolith thermal conductivity, increases again, the heat stored underneath this insulating layer will diffuse away and the thermal gradient will return to its long–term equilibrium state. During this time, however, an increased heat flow (relative to average conditions) will be found in the near–surface, which may bias the results of any experiments attempting to measure the global average geothermal flux, such as will be done with the HP^3 instrument on the InSight mission.

2. Method

We use a fully implicit, finite control volume approach to solve the one dimensional, time-dependent heat diffusion equation.

We define a simple three-layer structure, to represent regolith with a depth of z_0 with breccia/megaregolith below and bedrock below that. In order for our results to be applicable to InSight, we investigate the effects of varying z_0 between 5 and 10 m, with a fixed 10 m thick breccia layer between this and the bedrock, which itself extends to 2 km depth. Within each layer, the conductivity is fixed at a single value, with conductivities during a severe atmospheric collapse are around five times smaller than current values for coarse sand and ten times smaller for fine sand [2, 5].

3. Results

Figures 1 and 2 show the temperature perturbation at the end of the collapse period, and heat–flow perturbations with time subsequent to that, for various collapse durations and regolith depths. Temperature perturbations do not exceeding 5 K in these models, resulting in heat–flow perturbations of between $\sim 2 - 8\%$ of the current estimated 30 mW m^{-2} global average heat flow at the present time (the most recent collapse is thought to be ~ 40 kyr ago).

Similar results are obtained for 2-layer, rather than 3-layer, models, while even smaller perturbations are

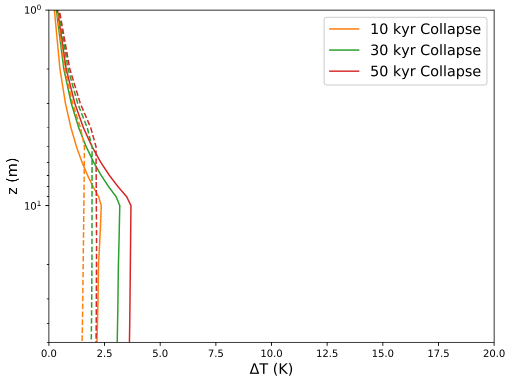

Figure 1: Temperature perturbations expected at the end of a collapse to 300 Pa from various periods of reduced regolith conductivity with varying regolith depth z_0 (solid: $z_0 = 10$ m, dashed: $z_0 = 5$ m) for fine-grained regolith.

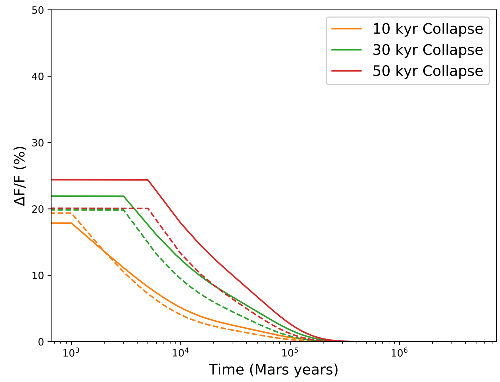

Figure 2: Heat–flow perturbation, with time since the end of an atmospheric collapse to 300 pa, expected at 5 m depth (solid: $z_0 = 10$ m, dashed: $z_0 = 5$ m) for fine-grained regolith.

found for coarser-grained sediment. More severe collapses (for example, down to 30 Pa atmospheric pressure) do induce larger perturbations (up to around 15%), but such collapses appear unlikely in the recent past given our current understanding of Mars climate.

4. Summary and Conclusions

InSight should measure Martian heat flow to an accuracy of between 5 and 15% (with an instrumental limit of around 4%) with its HP^3 instrument. Thus, in the best–case scenario (of full instrument deployment, a complete measurement campaign, and a well-modelled surface configuration) it may be possible to detect the effects of past atmospheric collapse as a slight increase of a few percent in current heat flow. Nonetheless, distinguishing this increase from a higher than expected average flux, as well as other sources of error, will be challenging. The full characterisation of long time-scale perturbations to subsurface temperature requires extremely deep measurements, to depths similar to their skin depths of tens to hundreds of metres, which remains out of the scope of current or future space missions.

Acknowledgements

This work was funded by the UK Space Agency, grant no. ST/R001375/2, with additional support from STFC under grant no. ST/S001271/1.

References

[1] S. E. Wood, S. D. Griffiths, Mars Subsurface Warming at Low Obliquity, Seventh International Conference on Mars 1353 (2007) 3387.

[2] S. E. Wood, S. D. Griffiths, Mars Subsurface Warming Due to Atmospheric Collapse at Low Obliquity, Lunar and Planetary Science Conference 40 (2009a) 2490.

[3] S. E. Wood, S. D. Griffiths, Epochal Seasonal Thermal Modeling of Mars? Polar Surface Energy Balance: Perennial CO2 Ice and Atmospheric Collapse, Third International Workshop on Mars Polar Energy Balance and the CO2 Cycle 1494 (2009b) 65?66.

[4] S. E. Wood, S. D. Griffiths, J. N. Bapst, Mars at Low Obliquity: Perennial CO2 Caps, Atmospheric Collapse, and Subsurface Warming, Eighth International Conference on Mars 1791 (2014) 1495.

[5] M. A. Presley, P. R. Christensen, The effect of bulk density and particle size sorting on the thermal conductivity of particulate materials under Martian atmospheric pressures, Journal of Geophysical Research 102 (1997) 9221-4499230.