GAS TRANSPORT IN MARTIAN REGOLITH BY THERMAL CREEP.

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Introduction

Mars is the only planet in the Solar System that provides perfect conditions for the natural occurrence of thermal creep within its soil. This is due to the low martian surface pressure of 6 mbar. To start the pumping of gas through the pores (Knudsen pump) a temperature gradient ΔT is necessary. This is generated by the insolation and the resulting heating of the upper layers of the soil. Gas flow is from cooler to warmer regions. A potentially resulting gas flow is depicted in figure 1 taken from de Beule et al. (2013). The mass flow rate $\dot{M}$ can be modeled as

$$\dot{M} = p_{avg}\sqrt{\frac{m}{2k_B T_{avg}}}\pi\frac{r^3}{l}\frac{\Delta T}{T_{avg}}Q \qquad (1)$$

where p_{avg} and T_{avg} are the ambient average pressure and temperature, m is the mean molecular mass of the surrounding gas, k_B is the Boltzman constant, r and l are the radius and the length of the pores, ΔT is the temperature difference between the ends of the pore and Q is a dimensionless factor depending on the Knudsen number (Koester et al. submitted, Sone et al. 1990).

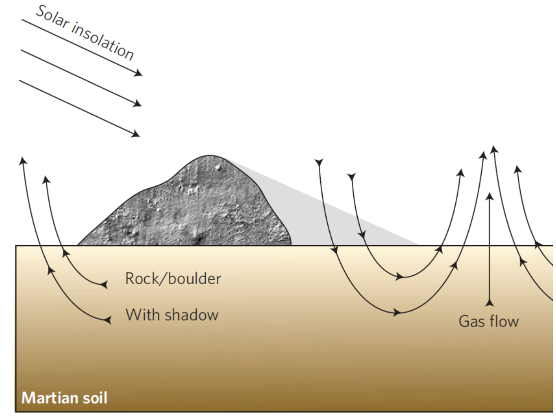

Figure 1: Gas flow within the martian soil driven by thermal creep. The insolation creates temperature gradients. The gas flows, in general, from the cool deeper layers to the warm surface layers. Due to the resulting pressure differences the atmospheric gas in the cool shadowed regions of the surface is soaked up into the soil and pumped towards the warmer parts of the surface.

Microgravity experiments

De Beule et al. (2013) first observed this flow under microgravity at the drop tower in Bremen based on tracer particle motion. Steinpilz et al. (in prep.) quantified the velocity of the gas flow at different pressures (1Pa - 1000 Pa). In this case a granular media with glass beads with diameters between 290 µm and 420 µm was placed between a peltier element. The gas flow was visualized by aerogel particles in that case. From the tracks of the tracer particles (see figure 2) the gas velocity was calculated by eq. (2)

$$x(t) = (v_{gas} - v_0)\tau e^{-t/\tau} + v_{gas}t + x_0 \qquad (2)$$

where x is the x-coordinate of the tracer particle, v_{gas} the gas velocity, v_0 and x_0 the start velocity and start coordinate, and τ the gas grain coupling time. The determined gas velocity varied systematically with the pressure between 0.2 cm/s and 6 cm/s. In order to dispose of gravity which has larger impact on the motion of the tracer particles than the gas flow, the experiments were conducted on parabolic flights.

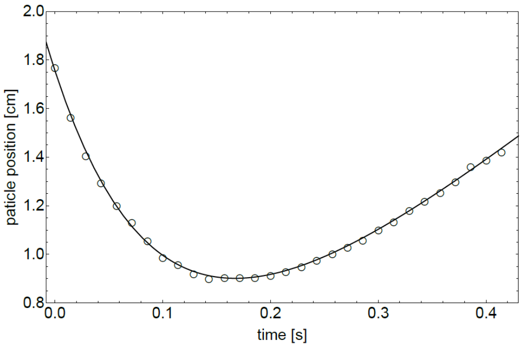

Figure 2: Position of the tracer particle in x direction plotted against the time. The line is the fit based on equation (2).

Conclusion

So far, the gas flow measured is in agreement with model calculations based on flow in capillaries. This analytic model allows a simple implementation in more complex soil models (granular make-up, porosities, temperature profiles, ...). It allows a calculation of gas transport through the martian soil and to describe the interaction at the boundary between soil and atmosphere in the future. We recently carried out further experiments on parabolic flights to test the model with different gas types (He, CO_2, N_2). The analysis of the obtained data is still in process and will be presented at the conference.

References

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