LIFTING DUST ON MARS BY GREENHOUSE EFFECTS AND THERMOPHORESIS.

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Introduction: Dust is continuously lifted from the Martian surface and put into atmospheric suspension. This is well visible during dust devil activity [1] and planet encircling dust storms [2].

The mechanism for the atmospheric dust entrainment has been debated for a long time. Wind stress can easily put dust into suspension under Earth conditions, i.e. at ~1000 mbar surface pressure. In principle the same mechanism is able to lift particles from the Martian ground as well and will do so occasionally. However, wind speeds have to be much higher than on Earth due to the low atmospheric pressure of 1 to 10 mbar [3]. Wind speeds necessary to initiate dust lift-off depend on the atmospheric pressure and have to be much larger than 30 m/s on Mars at the highest pressures. These speeds are not available continuously.

While gas drag decreases in strength with decreasing pressure, thermophoretic forces on dust particles increase in strength and are especially strong in the low atmospheric pressure range given on Mars. The lift provided by thermophoresis might facilitate the entrainment of dust from the surface.

GT-effect

Thermophoresis is a force acting on a particle embedded in a gas if a temperature gradient is given within the gas or along the particle. Due to interaction of the gas molecules with the surface of the particle the particle is subject to a thermophoretic force in general directed from the warm to the cold side.

Illumination of a dust bed is one possibility to establish a temperature gradient along the dust particles. On one side, in a porous dust bed light will not only be absorbed at the surface but can penetrate somewhat below the surface and will heat a certain top layer of the dust bed. On the other side, only the surface can cool by radiation. The net result is that the temperature will slightly rise from the surface down to a certain depth (greenhouse effect).

The temperature gradient due to the greenhouse effect results in a thermophoretic force directed upwards. If the thermophoretic force is strong enough to overcome gravity and adhesion between dust particles, dust eruptions occur at the surface of the dust bed. This can easily be seen in laboratory experiments (fig. 1) [4][5]. We name these lifting forces and eruptions **GT**-effect as for **G**reenhouse and **T**hermophoresis.

Fig. 1 Snap shots of a dust eruption from a basalt dust bed (lower line) illuminated by a halogen lamp with several kW/m² (colour inverted, illuminated dust particles appear black). The lowest big dust aggregate disintegrates further while airborne. Scale is about 2cm x 2cm.

On first order, the strength of the GT-effect, i.e. the lifting force on the dust particles depends linearly on the light flux *I* and inversely on the temperature *T* of the dust bed. The threshold for particle ejection varies with the properties of the dust bed (particle size, optical properties, sticking properties, porosity …).

As the effect has only been discovered recently, a thorough study of the influence on these parameters is still missing but ongoing in our laboratory.

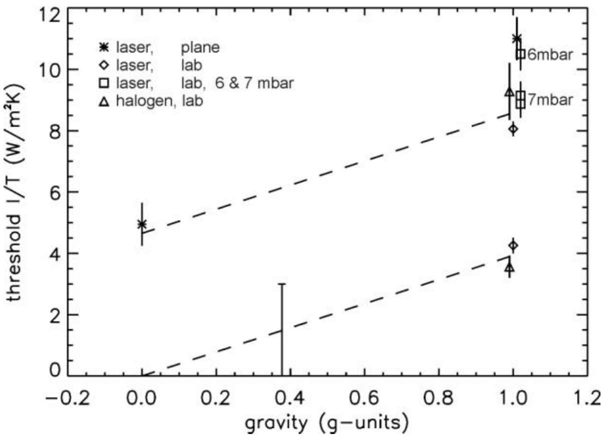

Fig. 2 Threshold for particle ejection due to the GT-effect for a basalt powder (taken from [6]). The lower dashed line is the threshold value with cohesion temporarily removed. Marked at a gravity of 0.38 is the range of Martian *I/T* values.

For a basalt dust sample with a broad particle size distribution we determined *I/T* thresholds for particle ejection (fig. 2). The *I/T* threshold values were determined in laboratory experiments – ground based and microgravity experiments on parabolic flights [6].

A first analysis of airborne ejecta further shows that particles from several ten micrometer down to at least a few micrometer in size can be ejected. Therefore, the GT-effect can generate particles which immediately go into suspension in the Martian atmosphere.

Application to Mars

We find that the values needed to initiate dust eruptions in a dust bed consisting of basalt powder is in the range available on Mars (fig. 3) and argue that this effect will be a significant mechanism to lift dust from the Martian surface.

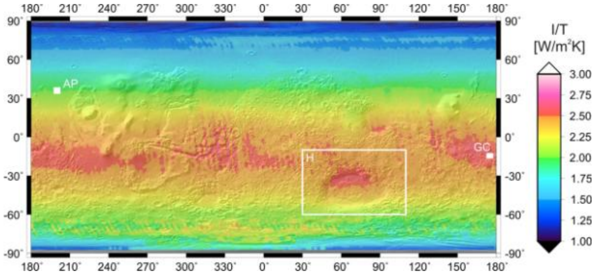

Fig. 3 Maximum values of *I/T* for Mars over the course of a Martian year (taken from [6]). Based on basalt measurements the GT-effect can lift particles at values larger than 1.5 W/m^{2}K (fig. 2). The marked locations refer to fig. 4.

In support of this, it is seen that dust devil activity in selected areas on Mars coincides with large *I/T* values (fig. 4).

We note that the GT-effect does not produce the characteristic atmospheric vortex associated with dust devils but makes it visible by lifting dust into the atmosphere. It still needs the additional gas drag associated with the eddy to remove (part of) the cohesion between dust particles.

Visible dust devil activity at higher elevation further supports the GT-effect and shifts importance to the GT-effect compared to the role of gas drag. At the reduced atmospheric pressure the dynamic pressure at a given wind velocity is strongly reduced while the GT-effect can still increase in strength with decreasing pressure. This is presented separately on this conference [7].

Besides dust devil activity global dust storms seem to be initiated at rising levels of *I/T*, consistent with the threshold values determined in the laboratory (fig. 4b).

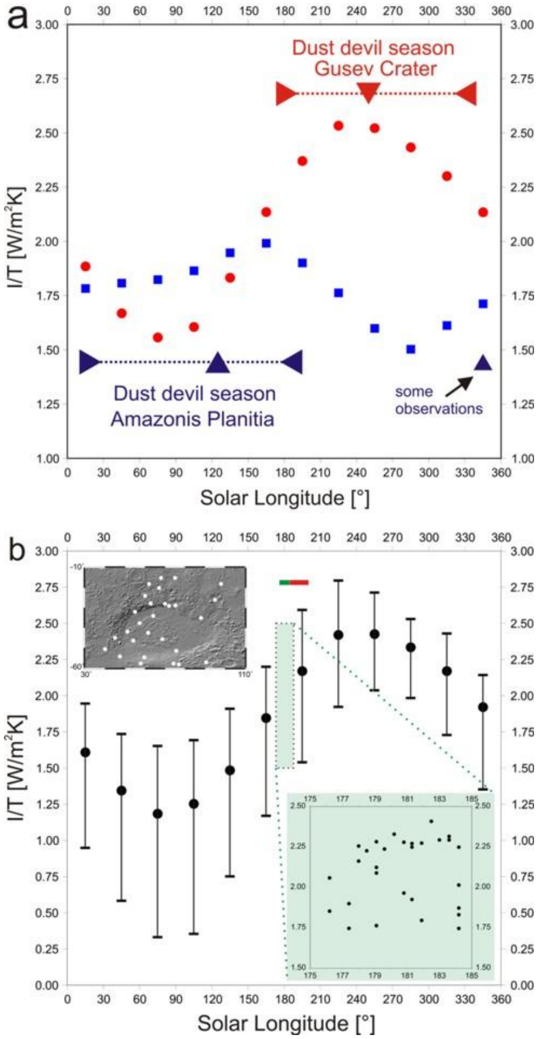

Fig. 4 Values of *I/T* for Mars (taken from [6]). Dust devil activity (a) is correlated with large *I/T* values. A global dust storm (b, see fig. 3) is also initiated at rising levels of *I/T* values.

References

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Acknowledgement

G.W., J.T., and T.K. are supported by the DFG. Access to the parabolic flights was granted by the DLR.