HIGH ALTITUDE DUST DEVILS ON ARSIA MONS, MARS: TESTING THE GREENHOUSE AND THERMOPHORESIS HYPOTHESIS OF DUST LIFTING. D. Reiss[1], D. Lüsebrink[1], H. Hiesinger[1], T. Kelling[1], G. Wurm[1], and J. Teiser[1], [1] Institut für Planetologie, Westfälische Wilhelms-Universität, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany (dennis.reiss@uni-muenster.de).

Introduction: High altitude dust devils on Arsia Mons were observed at elevations of ~17 km [1, 2]. It is not yet fully understood how particles of the order of a few µm in size are lifted from the surface into the atmosphere [3, 4]. The most common assumption is that wind stress picks up dust particles from the surface [5]. Wind speeds at mean elevation must be larger than ~30 m/s to lift particles and place them into atmospheric suspension [5, 6]. Such high winds occur locally on Mars, but the average wind speeds as measured at the Viking lander sites and values derived from global circulation models are much lower [7, 8]. At the elevations of the Arsia Mons Caldera the atmospheric pressure is around 1 mbar, which requires wind speeds 2–3 times higher than at the Mars mean elevation for particle entrainment.

Greenhouse and Thermophoresis (GT) effect: We found that the simple illumination of a dust bed at low atmospheric pressure provides a mechanism that efficiently lifts dust particles into the atmosphere [9, 10]. This lifting process is caused by two subtle effects within the dust bed: a greenhouse effect and thermophoresis. Laboratory and microgravity experiments show that the light flux needed for lift to occur is in the same range as that of the solar insolation available on Mars. This mechanism significantly lowers the threshold for dust entrainment by wind stress and may help explain the large amount of suspended dust on Mars overall. Specifically, this lifting process may help provide the initial lift necessary for dust devils.

Data and methods: We searched for active dust devils (dd) within the study region (236.5-243°E and 14-5°S) in Mars Orbiter Camera – Wide Angle (MOC-WA) and Narrow Angle (MOC-NA), Thermal Emission Imaging System – Visible (THEMIS-VIS), High Resolution Stereo Camera (HRSC) and Context Camera (CTX) data. Elevations of dds were derived from Mars Orbiter Laser Altimeter (MOLA) and temperatures and pressures from Thermal Emission Spectrometer (TES) data. The light flux (solar insolation) was calculated for each dd using the solar longitude and local time of the dd occurrence.

All image data were analyzed in a Geographic Information system (Arc-GIS). The identification of dust devils is sometimes difficult, especially in low resolution image data (e.g., MOC-WA). A combination of multitemporal image data sets in Arc-GIS were used to rule out any geological features, which show similiarities to active dds.

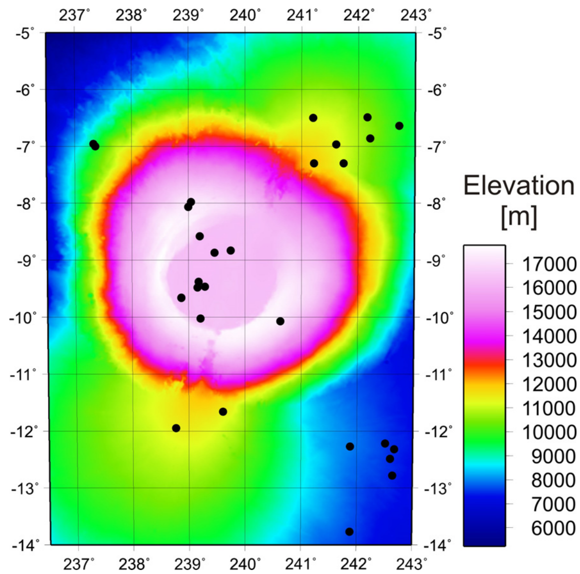

Figure 1. Location of observed active dust devils (black dots) in the study region (Background: MOLA topography).

Observed dust devils: We identified 28 active dds within the study region (Fig. 1); none in MOC-NA, 15 in MOC-WA, 2 in THEMIS-VIS, 2 in HRSC and 9 in CTX imagery. The investigated dds are 70 – 2000 m in diameter and 0.18 - 8 km in height, hence within the range of other Martian dds [11]. 11 dds occur at elevations above 16 km, most of them within the caldera of Arsia Mons (Fig. 1). The elevations of the other identified dds in the study region range between 7-12 km. Based on the areal image coverage we calculated the dd-frequency over the solar longitude (L_S). Relatively high dd-frequencies were found between L_S = 340°-360°, at the end of the southern summer (Fig. 2). However, statistically dds seem to occur over the whole Martian year, although the frequency is very low. The absence of dds in some L_S-bins might be correlated to the low areal image coverage at these times (e.g. note the lack of CTX coverage between LS = 40° - 160°). Figure 3 shows the surface temperatures (black) and calculated I/T-values (red) within the Arsia Mons caldera over one Martian year. Blue triangles show dds at elevations <12 km and green triangles at elevations > 16 km. It is not clear yet if there is a correlation or not between the seasonal occurrence of the dds and surface temperatures as one would expect if dd activity would simply follow the season of maximum insolation [12, 13]. The I/T-threshold for dust lifting over the whole Martian year for the observed dds is > 1.7 W/m^2K (Fig. 3), which is consistent with the minimum threshold value of I/T = 1.5 W/m^2K determined experimentally under Martian conditions [9, 10]. However, the exact I/T-threshold values for Martian dust particles are difficult to constrain and likely vary due to composition, particle size as well as to variations in atmospheric pressures [9].

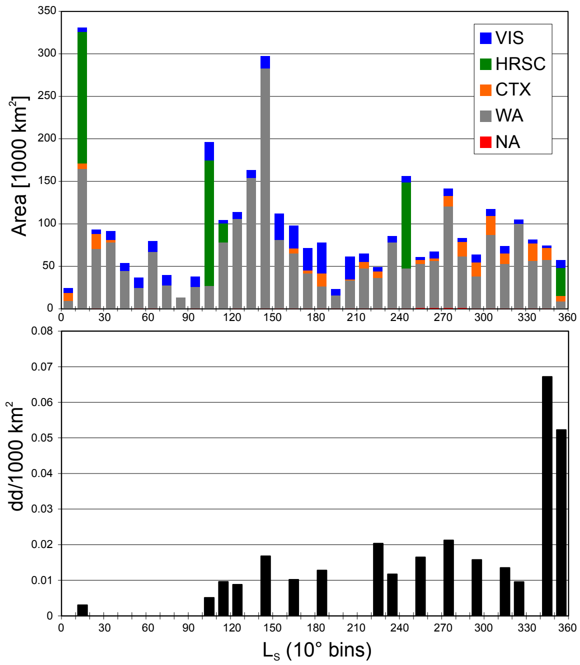

Figure 3. Solar longitude (L_S) versus areal image coverage (top) and dust devil frequency (bottom).

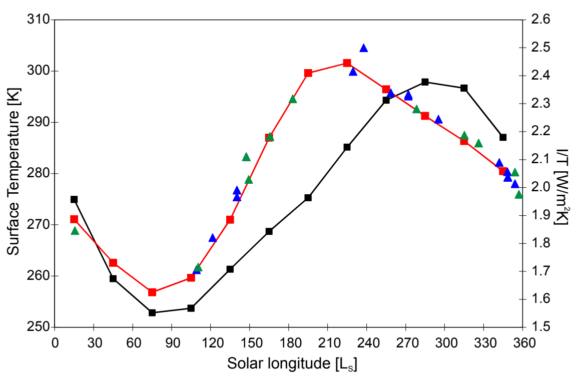

Figure 4. Solar longitude (L_S) versus suface temperature (black) and I/T-threshold (red) for the Arsia Mons caldera. Blue triangles show I/T-values for observed dds at elevations < 12 km and green triangles at elevations > 16 km.

Pressure dependence of the GT-effect: Recently an interplay of a solid-state greenhouse effect (G) and a thermophoretic force (T) that is capable of lifting dust from a surface in low pressure gaseous environments has been discovered [9, 10]. This GT-effect is strongest if the mean free path of the gas molecules is about the dust particles size. Hence, dust particles are affected most in the mbar-regime. Laboratory experiments were designed to determine the I/T (light flux over temperature) threshold of particle ejection for the GT-effect. An unaltered Mars soil simulant (JSC Mars 1A) was used as dust sample. We find that the GT-effect is strongest around pressures of 1 mbar (Fig.4).

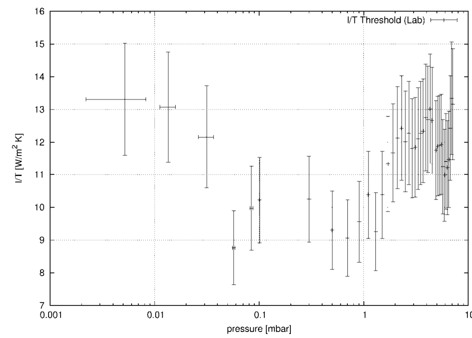

Figure 4. I/T-threshold to overcome gravity and cohesion (Laboratory, 1g). The plot shows the I/T-threshold for a Mars soil simulant (JSC Mars 1A) under Earth gravity conditions. The lowest I/T value (the strongest GT-Effect) is found around 1 mbar.

Conclusions: The analysis of active high altitude dust devils indicate that they do not follow the season of maximum insolation. The initiation of dds only by heating of near surface air by insolation as well as the dust lifting process under such low pressure (~1 mbar) environments are difficult to explain. Laboratory and microgravity experiments showed that the GT-effect significantly lowers the threshold for dust entrainment by wind stress [9, 10]. Recent laboratory experiments showed that the GT-effect is strongest around pressures of 1 mbar, which might explain the existence of high altitude dust devils on Mars. We propose that the GT-effect might be a major factor in overcoming the threshold of dust lifting on Mars.

References: [1] Cushing G. E. et al. (2005) *GRL, 32,* L23202. [2] Cantor B. A. et al. (2006) *JGR, 111,* E12002. [3] Pollack J. B. et al. (1995) *JGR, 100,* 5235–5250. [4] Tomasko M. G. et al. (1999) *JGR, 104,* 8987–9008. [5] Greeley R. et al. (1980) *GRL, 7,* 121–124. [6] White B. R. et al. (1997) *JGR, 102,* 25629–25640. [7] Hess S. L. et al. (1977) *JGR, 82,* 4559–4574. [8] Haberle R. M. et al. (1999) *JGR, 104,* 957–974. [9] Wurm G. et al. (2008) *GRL, 35,* L10201. [10] Wurm G. et al. (2008), *this conference*. [11] Balme M. and R. Greeley (2006) *Rev. of Geophys., 44,* RG3003. [12] Ryan J. A. and Lucich R. D. (1983) *JGR, 88,* 11005–11011. [13] Thomas P. C. and P. J. Gierasch (1985) Science, 230, 175–177.