# ELECTRICAL DISCHARGES IN THE MARTIAN DUST DEVILS AND DUST STORMS.

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**Introduction:** The Mars Global Surveyor Mars Orbiter Camera (MOC) shows that aeolian processes have been actively modifying the surface of Mars [1]. The evidence of these processes in the form of wind erosion features, dust devils, and dust storms is abundant and visible even in images of the MOC wide-angle camera. Dust devils are ubiquitous features of terrestrial deserts and the martian landscape during the warm season. On Mars, dust devils are much larger and stronger than on Earth. Terrestrial dust devils have typical diameters of less than 10 m and are seldom higher than a few 100 m [2]. In contrast, dust devils with diameters between 100 m and 1 km, and heights of up to 7 km are frequently observed on Mars [1, 3]. Martian dust devils also have greater dust content than the terrestrial vortices. The dust devils observed in the images of the Mars Pathfinder panoramic camera have about 700 times the dust content of the local background atmosphere [4].

Regional dust storms occur rather frequently on Mars (Figure 1). In general, they are highly convective and many are similar to terrestrial hurricanes [5]. Sometimes regional dust storms grow and become global in extent. Enhanced dust devil activity might be a precursor of regional and global dust storms. There is evidence that regional and global dust storms frequently form in regions where theory predicts high occurrence of dust devils [6]. The theoretical framework applicable to convective vortices such as dust devils, waterspouts and hurricanes predicts that dust devils and dust storms have a higher probability of occurrence and are potentially more intense in regions of sloping terrain and large horizontal temperature gradients [6, 7, 8, 9], such as the region near the edge of the south polar cap during the warm season [8, 10, 11]. This is the region where regional and global dust storms are frequently observed [10, 12].

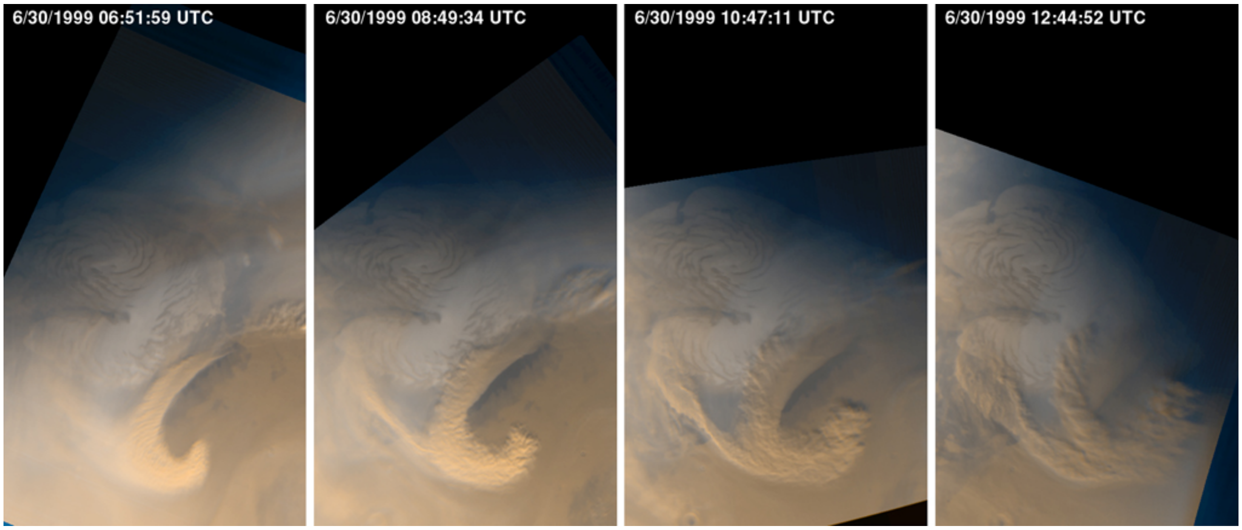

**Figure 1.** Mars Orbital Camera images of a regional martian dust storm developing at the edge of the north polar cap during the spring. This figure is a courtesy of NASA/JPL/Malin Space Science Systems.

**Electrification of Dust Devils and Dust Storms:** Triboelectric charging of saltating and colliding dust particles produces strong electric fields in terrestrial dust devils [13]. Electric fields in excess of 50 kV/m have been measured [14, 15]. All observations of terrestrial dust devils show negative charges aloft, and this distribution of charges agrees with the idea that negative charges are transferred to the smaller particles during collisions [16]. Acceleration of charged particles and electrical discharges between them generate wideband electromagnetic radiation that can be detected by nearby radio receivers. The wavelength of the radio emission depends on the nature of the changes in the electric field. Impulsive discharges between individual dust particles produce short wave radio emission [17], whereas large-scale fluctuations of the electric field produce long wave radio emission [18].

Triboelectric charging of dust is also expected to be an important phenomenon on Mars. Evidence for this was the charging of the Pathfinder Sojourner Rover wheel while it operated in a martian environmental chamber [19]. Because of Mars' low atmospheric density, electrical discharges occur at lower electric potential than on Earth, and therefore should be more frequent. The breakdown electric field on Mars is expected to be between ~5 and 20 kV/m, compared to ~3000 kV/m on Earth. Electrical discharges in martian dust events would also produce wideband radio emission.

A possible explanation for the short wave radio emission by dust events is discussed next. Charges are exchanged during collisions between individual sand and/or dust particles. As the charged particles move away from each other, the electric field between them increases until it exceeds the breakdown potential, producing an impulsive discharge. This hypothesis is based on the physics of light emission by colliding ice particles proposed by Keith and Saunders [20]. The current flow associated with the impulsive discharges produce wideband electromagnetic radiation.

Several ground-based radio observations of Mars, are summarized in the next section. The observations show a strong correlation between martian dust activity and anomalously high radio emission, in wavelengths ranging from 1.35 to 6 cm. We suggest that the observed anomalous radio emissions are caused by electric activity in dust devils and dust storms, rather than thermal emission by the dusty and warmer atmosphere. Dust suspended in the atmosphere directly absorbs and scatters solar radiation, while absorbing infrared radiation, and therefore affects atmospheric heating rate and modifies the surface radiative balance [5, 21, 22]. Airborne dust produces increases in the atmospheric temperature near the top of the dust layer and decreases in the temperature at lower levels and the surface. As a result, the thermal emission by the surface and the lower atmosphere decreases, while the emission by the upper regions of the dust layer increases. Since the thermal emission at wavelengths of a few cm peaks at the surface, it is unlikely that the observed enhancement of microwave emission in regions of dust activity is of thermal origin. At radio wavelengths, scattering by atmospheric dust is insignificant, and therefore produces negligible changes in the microwave brightness temperature [23]. Hence, the thermal effect of dust is to decrease the planet's brightness temperature (see Figure 2), and any observed increase in microwave brightness must be due to non-thermal effects.

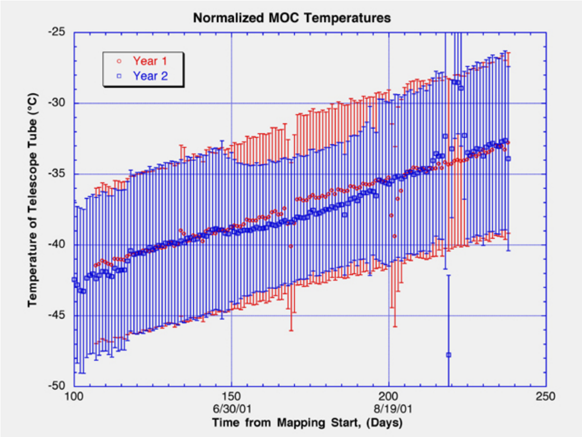

**Figure 2.** Temperature of the Mars Orbital Camera telescope tube during a year of weak dust storm activity (Year 1, 2000; red, lighter curve) and during a year of intense dust storm activity (Year 2, 2001; blue, darker curve). This figure is a courtesy of NASA/JPL/Malin Space Science Systems.

**Radio Observations of Martian Dust Activity:** Observations of Mars at 2.8 cm with the 46 m telescope of Algonquin Radio Observatory were made in December 1975 [24, 25] and January 1978 [26]. These observations indicated that the martian disk brightness temperature was a function of the longitude of its central meridian during both set of observations. However, the brightness temperature of the longitudes ranging from 240° to 360° displayed strong variation between these two observation campaigns, and large temporal variation during the 1978 campaign. In addition, both the value of the emission and its variability are strongest in the regions of known enhanced dust activity as summarized in Figure 3. Indeed, from January to May 1978, various regional dust storms were observed in the region of anomalously high radio emission. The disk average brightness temperature observed in 1978 was so much higher than the one observed in 1975 that there were suggestions of the possibility of errors in the calibration of the two measurements [24, 25]. However, even after corrections for all probable calibration errors were done, the 1978 observations still showed significantly larger values (by more than 10 K) as shown in Figure 3. Decreases in brightness temperature might be due to cooling of the surface by dust aloft, while increases in the brightness might be due to discharges between individual dust particles.

Mars was observed with the Very Large Array (VLA) at wavelengths of 2 and 6 cm during the martian northern spring in 1983 [27]. The observations were done at the sub-earth local time of about 2 p.m., the time of largest dust devil activity. The data from these observations exhibited behavior not well predicted by a suite of models of thermal emission. The anomalous behavior was concentrated mainly in a region of the south hemisphere bounded by the Hellas and Argyre Planitia, well known regions of large dust activity [12]. In addition, anomalous behavior was observed around the region of largest temperature gradient of the north hemisphere. This is where theoretical model predicts intense dust devils and dust storms. Indeed, Rudy et al. [27] suggested that some of the anomaly could have been caused by dust storms.

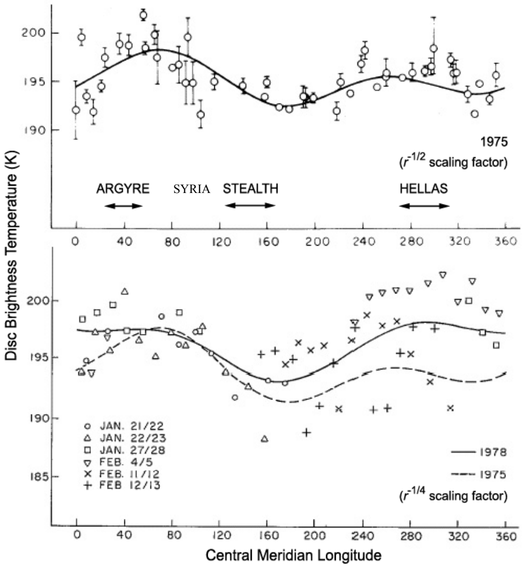

**Figure 3.** Measured martian disk radio brightness temperatures as a function of the central meridian longitude for 1975 (top) and 1978 (bottom) campaigns. The re-normalized brightness temperature for 1975 is also shown in the bottom plot (after [26]). Some of the most active dust devil/storm incubator regions are marked in plot at the top.

The Tharsis and Amazonis regions of Mars (referred to as the Stealth region because of its weak radar signature) were observed with the VLA at 1.35 cm during the martian northern spring in 1995 [28]. The observations of variations in surface brightness temperature of this region during a period of 12 hours were compared with theoretical predictions made with a model of the martian surface/atmosphere system. The observed anomaly (discrepancy between model and observations) in the microwave emission was found to be highest between the local noon and 4 p.m., the period in which dust devils are most frequent and strongest [2, 6]. This is also the time period in which the reduction in surface temperature by atmospheric aerosols is the highest (Figure 2). The low radar signature of the Stealth region has been attributed to the existence of loose and unconsolidated sediments such as a thick mantle of fine sand or volcanic ash [29]. The time variation of the anomalously high radio emission and the existence of large amounts of fine grains in the region are consistent with the idea that the anomalously high radio emission is caused by a large number of electrically active dust devils in the region.

**Summary:** The observations summarized in this article show a strong correlation between anomalously high martian microwave brightness temperature and the occurrence of dust devils and/or dust storms. We suggest that the observed anomalies are caused by impulsive discharges between dust particles, triboelectrically charged during dust events. The understanding of electrical activity associated with dust events might have important implications for the chemistry of the martian atmosphere and the safe operation of Mars landers and rovers.

**References:** [1] Malin et al. (1998) *Science 279,* 1681. [2] Sinclair P. C. (1973) *J. Atmos. Sci., 30,* 1599–1619. [3] Thomas P. and Gierasch P. J. (1985) *Science, 230,* 175–177. [4] Metzger S.M. et al. (1999) *GRL, 26,* 2781–2784. [5] Gierasch P. J. and Goody R. M. (1972) *J. Atmos. Sci., 29,* 400–402. [6] Renno N. O. et al. (1998) *J. Atmos. Sci., 55,* 3244–3252. [7] Emanuel K. A. (1986) *J. Atmos. Sci., 43,* 585–604. [8] Renno N. O. et al. (2000) *JGR, 105,* 1859–1865. [9] Renno N. O. and Bluestein H. B. (2001) *J. Atmos. Sci., 58,* 927–932. [10] Cantor B. A. et al. (2001) *JGR, 106E10,* 23,653-23,687. [11] Cantor B. A. et al. (2002) *JGR, 107E3,* 101,029–101,036. [12] Kieffer H. H. et al. (1992) *Mars*, Univ. Arizona Press. [13] Krauss C. E. et al. (2002) *AGU 83(47),* Fall Abstract P51A-0338. [14] Delory G. T et al. (2002) *AGU 83(47),* Fall Abstract P51A-0335. [15] Towner M. C. et al. (2002) *AGU 83(47),* Fall Abstract P51A-0342. [16] Ette A. I. I. (1971) *J. Atmos. Terr. Phys., 33,* 295. [17] Wilson J. (2002) personal comm. [18] Farrell W. et al. (2002) *AGU 83(47),* Fall Abstract P51A-0336. [19] Ferguson D. C. et al. (1999) *JGR, 104E4,* 8747–8759. [20] Keith W. D. and Saunders C. P. R. (1988) *Nature, 336–364,* 362. [21] Zurek R. W. (1978) *Icarus, 35,* 196–208. [22] Davies D. W. (1979) *JGR, 84,* 8289–8293. [23] Paltridge G. W. and Platt C. M. R. (1976) *Radiative Processes in Meteorology and Climatology,* Chap. 9, Elsevier. [24] Andrew B. H. et al. (1977) *ApJ, 213,* L131–134. [25] Andrew B. H. et al. (1978) *ApJ, 220,* L61. [26] Doherty L. H. (1979) *ApJ, 233,* L165–L168. [27] Rudy D. J. et al. (1987) *Icarus, 71,* 159–177. [28] Ivanov A. B. et al. (1998) *Icarus, 133,* 163–173. [29] Muhleman D. O. et al. (1991) *Science, 253,* 1508–1513.