MARS ORBITER CAMERA METEOROLOGICAL OBSERVATIONS

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Introduction:

Since March 9, 1999, Mars Global Surveyor (MGS) has been observing Mars from an almost circular orbit at an altitude of about 400 km, which is fixed relative to the sun in such a way that the local time on the illuminated side of the planet is 14:00 at the spacecraft's nadir. Because there is no scan platform on MGS, the Mars Observer Camera (MOC) onboard MGS is always pointed at the nadir. MOC is a three-component imaging system consisting of one narrow-angle (NA) and two wide-angle (WA) cameras, each composed of a single linear CCD array (NA: 2048 pixels; WA: 3456 pixels). MOC uses the spacecraft's orbital motion, in what is called line array image or pushbroom imaging, to move the scene across the detectors. In the mapping orbit, the NA camera covers an area of just over 3 km across at a resolution of better than 1.5 m/pixel. The wide-angle cameras cover two broad wavelength bands spanning from the blue (400-450 nm) to the red (575-625 nm) and with a 140° field of view can acquire limb-to-limb views of the planet at a resolution of 230 m/pixel at the nadir to about 1.5 km/pixel at the limbs.

As of December 12, 2002, MOC will have completed its primary and first extended mapping missions, which spans a period of 2 Martian years. During this time the WA cameras have been continuously mapping the dayside of Mars at a constant resolution of 7.5 km/pixel, using a cross-track variable-summing algorithm. At the equator the local time across these low-resolution images, called daily global map (DGM) images, ranges from 12:17 to 15:43. Some overlap exists between DGM swaths taken on consecutive orbits, allowing for complete global coverage of the planet to be obtained in two colors in 12 to 13 orbital passes or about once per a sol.

The MGS-MOC experiment has provided a unique opportunity to study Martian weather phenomena (dust devils, dust storms/clouds, condensate clouds, as well as, the seasonal behavior of the Martian polar caps) on time scales ranging from semi-diurnally to interannually. Because of the limited space provided, we present here a very brief overview of Martian dust phenomena in terms of the interannual invariability of these events, as observed by MOC over the past 3 Martian years.

MOC has observed dust events across much of the planet from the depths of Hellas basin to the summit of Arsia Mons. These events range in size from dust devils to global dust veils.

Dust Devils:

Martian dust devils range in size from a few to 10s of meters across to 100s of meters across and over 6 km high. Though dust devils occur throughout most of the Martian year, each hemisphere has a "dust devil season" that generally follows the subsolar latitude and appears to be repeatable from year-to-year. An exception is NW Amazonis, which has frequent, large dust devils throughout northern spring and summer; see Figure 1. The Amazonis and other

Figure 1. Dust Devils in Northern Amazonis, during northern summer.

MOC observations show no evidence that dust devils cause, lead to, or have a systematic relationship with dust storms. However, dust devils sometimes do occur near small, localized storms; and one specific relation occurred during the onset of the global dust events of 2001: slightly elevated levels of atmospheric dust (an optically thin cloud) triggered a very short period of dust devil activity in NW Amazonis in early northern autumn. The redistribution of dust by the initial onset of the 2001 global dust activity may have also affected subsequent spring and summer dust devil activity in Hellas, where considerably fewer dust devils occurred in 2001-2002 than 1999-2000. In SW Syria, frequent, large dust devils occurred after the 2001 global activity and persisted through southern summer. While dust devils have no specific relation to dust storms, they might play a role in maintaining the low background dust opacity of the Martian atmosphere, as well as, the seasonal "wave of darkening" at middle and high latitudes by removing or disrupting thin veneers of dust.

Dust Storms:

Global maps are important for monitoring all but the smallest scale dust activity on Mars. MGS global observations have shown that storms occur almost daily with few exceptions, with thousands occurring each year in the present Martian environment, dispelling the notion of a "Classical Dust Storm Season". However, there does appear to be an annual dust storm cycle, with storms developing in specific locations during certain seasons. MOC observations taken during the past 3 Martian years, suggest that this dust cycle was in general, repeatable from year-to-year. The majority of storms develop near the receding seasonal polar cap edge or along the corresponding polar hood boundaries in there respective hemispheres, suggesting that large thermal gradients and the surface winds they generate are the triggering mechanism for some of the dust activity. Because of MGS's polar orbit, some of these high-latitude local dust storms have been monitored with sufficient temporal sampling density (every 2 hours) to observe their semi-diurnal evolution; see Figure 2. These observations showed that most high-latitude storms formed in the early to late morning hours when boundary layer instabilities would be greatest and would expand rapidly, covering a large area in a matter of just 4-6 hours.

Figure 2. Semi-diurnal evolution of summertime, local dust events in the southern hemisphere.

In the northern plains, spiral dust events tend to be seen in the spring and summer seasons and resemble terrestrial polar lows "cold fronts". Those seen during late northern summer tend to resemble terrestrial baroclinic fronts and are accompanied by condensate clouds, traveling eastward at about 12-15 m/s for several days before dissipating. Still other storms develop in the low laying regions where atmospheric conditions are optimized for dust lifting (e.g., plains on the windward side of Olympus and Elysium Mons and Alba Patera, in Hellas and Argyre Basins, in Chryse Planitia, ect…).

Dust storms such as the cross-equatorial events that form in Acidalia/Chryse and travel southward following the low-lying topography into Valles Marineris, also tend to follow a seasonal trend occurring in two periods from about L_s = 208°-224° and L_s = 315°-333°; see Figure 3. They appear to be associated with the strengthening of the Hadley circulation during the southern spring and summer seasons. These storms are part of a class of large dust events referred to in the scientific literature as "Regional" dust storms because of their great extent and duration (> 3 sols). Though limited in number with a few 10s of regional storms occurring per Martian year, their size, duration, and unrestricted seasonality make them ideal tracers of atmospheric circulation for global mapping investigations. MOC has used this capability to observe for the first time the north-to-south cross-equatorial circulation associated with the lower-branch Hadley circulation in the Chryse/Valles Marineris region (as noted above), as well as, the general circulation at high latitudes in both hemispheres. At present our understanding of regional storms is fairly limited. Analysis of the historical records suggested that regional dust storms occur in all seasons, but are absent during two periods of the year L_s = 130°-160° and L_s = 330°-20°. Recent MOC observations suggest that this later time period may be even shorter (L_s = 0°-20°). As for why some local storms become regional is unclear, but DGM images suggest that about half of the larger regional storms may form from the merge of two or more active local storms.

The largest and rarest of dust phenomena on Mars are referred to as the "Great Storms" or "Global Storms". These dust events can encircle the planet in specific latitude bands, such as the southern subtropics ("planet encircling" storm) or on occasion have been observed to enshroud the planet ("global" storm). These dust events are quite rare, with only 6 confirmed events on record, 4 planet-encircling and 2 global. The MGS MOC global imaging investigation has provided the first comprehensive planet-wide views of almost the entire development of the 2001 global "planet enshrouding" storm. Such global mapping has led to new insights into the initiation and evolution of these global atmospheric phenomena, as well as place constraints on model predictions. With MOC we have observed that global dust events are not individual storms but are composed of a number of local and regional storms (sources). The storms that created the global dust veil lasted from a few days to a few months, as in the case of the Syria/Claritas/Solis Planum regional storm, which lasted for over 3 months in the same location. It was the dust raised into the upper atmosphere by the larger, longer-lasting storms that appears to have stimulated further storm activity across the planet, possibly due of diabatic heating of atmospheric dust, and are also responsible for the global dust veil. MOC also observed that the storms responsible for the initiation of the start of the "global dust activity" did not form in the southern subtropics, but developed in the mid-latitudes adjacent to the receding south polar cap. These storms then traveled northward into the subtropics, which is consistent with the class of global storm generating mechanism models that emphasize enhancement of the planetary scale circulation. The effects of the global dust activity on the Martian climate are at best minimal, in fact, dust storm and condensate cloud activity returned to their normal predictable seasonal behavior within a few months of the ending of the global event.

Though dust storms occur throughout the Martian year and across most of the planet, there are regions and times where dust activity was at a minimum or non-existent. One region where MOC has observed no dust activity over the past 3 Martian years is Arabia Terra. In the Northern Hemisphere, the period of minimum dust activity occurs during northern fall between about L_s = 235°-270°. In the southern hemisphere, there appears to be three periods of minimum dust activity, the most significant occurs while the seasonal south polar cap is forming between about L_s = 65°-130°. The other two occur during southern summer between about L_s = 275°-290° and L_s = 313°-340°. Because of the lingering effects of the global dust veil of 2001, MOC was not able to confirm whether the period of minimum dust activity in the Northern Hemisphere was repeatable from year-to-year. The periods of minimum dust activity in the Southern Hemisphere have been fairly repeatable, with the exception that the southern fall/winter minimum was of shorter duration (by about two months) in 2002. Possibly the result of the redistribution of surface dust caused by the long-lived (90-sol duration) dust storm in the Syria/Claritas/Solis Planum region, part of the global dust activity of 2001.

In summary, MOC has observed that dust events follow general seasonal cycles that are reproducible from one year to the next and that global dust events do not signify climatic changes, but are only short-term perturbations to the interannual repeatable dust and condensate cloud cycles of Mars.

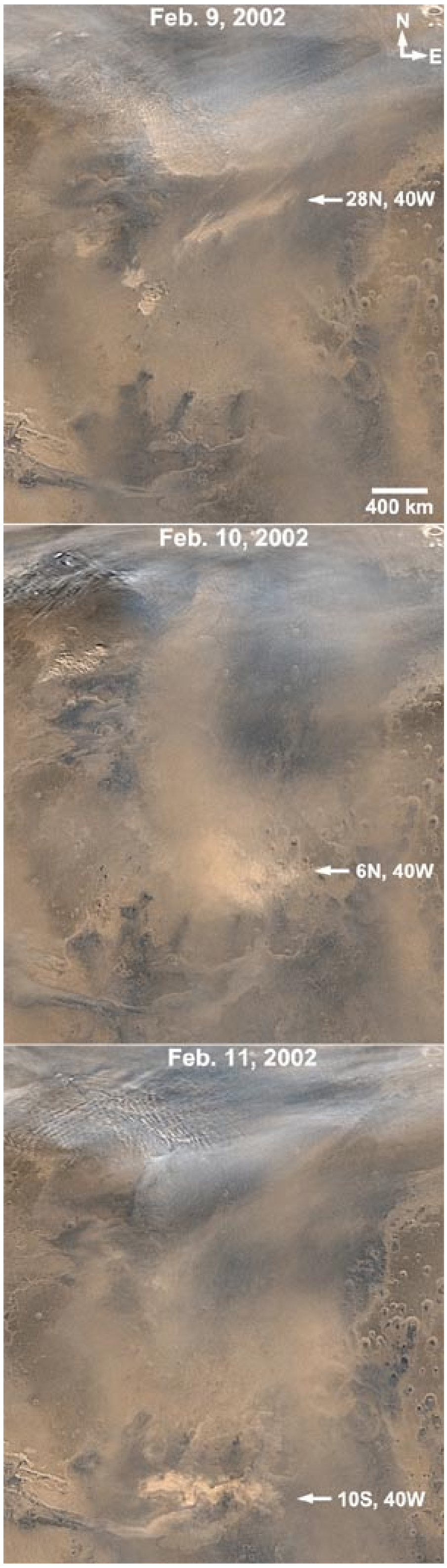

Figure 3. Cross-equatorial dust storm observed during northern winter.