SURFACE CHANGES ON MARS: GRADUAL OR EPISODIC? Paul E. Geissler[1] and Marie-therese Enga[2], [1]U.S. Geological Survey, Flagstaff, AZ 86001; pgeissler@usgs.gov, [2]Northern Arizona University, Flagstaff, AZ 86011; mb348@nau.edu.

Summary: Repeated observations by the Mars Global Surveyor spacecraft over 4 Martian years suggest that surface albedo changes take place both episodically, during major dust storms, and also gradually by the cumulative action of winds and dust devils over several seasonal cycles.

Background: The changing appearance of Mars has fascinated observers for centuries, yet much is still unknown about the winds and sediments that alter the albedo of vast areas of the planet's surface. A variety of aeolian processes probably contribute to the deposition and erosion of dust on Mars, with distinct causes and timescales that vary with season and location. Much of the dust deposition takes place during regional and global dust storms that sprinkle thin coatings of dust over broad regions and brighten formerly dark surfaces. Subsequent darkening takes place by erosion and concentration of the bright dust deposits.

Over decadal timescales, these processes act to alter the planetary albedo distribution enough to significantly impact the climate and global circulation of winds on Mars. Nearly a quarter of the surface area of the planet darkened during the 20 year interval between the Viking and Mars Global Surveyor (MGS) missions, much of it in the southern highlands where solar insolation is at a maximum [1]. Recent calculations [2] predict enhanced wind stress in the newly darkened areas and decreased wind stress in brightened areas, leading to a positive feedback system in which the albedo changes strengthen the winds that produce the changes. The simulations also indicate net global warming of ~0.6 K and decreased seasonal CO_2 condensation, perhaps explaining the "swiss cheese" appearance of the residual southern polar cap [3].

These results raise the possibility of a Martian climatic cycle that begins with a major global dust storm depositing dust which is gradually eroded by increasingly strengthening winds, culminating in conditions ripe for generating another major global dust storm. Several processes that could contribute to gradual dust erosion were identified in a study of high resolution Mars Orbiter Camera (MOC) images of Martian variable features [1]. Persistent seasonal winds appear to dominate erosion at low latitudes, producing linear wind streaks that typically trend in the direction of strong southern spring and summer winds. Dust devils apparently dominate erosion in the higher latitudes, where recently darkened terrain is crisscrossed by the dark tracks of dust-devils, forming irregular albedo boundaries with sharp margins. Local dust storms darken areas that exhibit neither dust-devil tracks nor consistent wind streaks. Ephemeral wind streaks in these areas are possibly produced by gusts of wind from seasonal dust storms. Dark sand dunes are widely distributed throughout the southern highlands, a region that darkened without forming conspicuous albedo boundaries. Dark streaks downwind of giant intercrater dunes represent either stains of dark silt or surfaces scoured of dust by actively saltating sands.

The imaging observations show us the most recent aeolian processes affecting the surface, and we assume that the effects of these processes accumulate over many seasons to produce profound changes in the planetary albedo. On the other hand, it is argued [4] that such gradual processes are ineffective at lifting dust and producing surface albedo changes in comparison to global dust storms, since the winds generated by severe storms are much stronger than those expected from regularly repeating seasonal phenomena. We can address this question – gradual or episodic – by monitoring Martian variable features over extended periods.

Approach: We chose to analyze the MGS MOC daily global color image swaths because of their frequency and long time base, spanning 4 Martian years from 1998 to 2006. We assembled global color mosaics of these data at 30 degree solar longitude intervals, showing the seasonal variations of clouds, surface frosts, and the polar hood in addition to global dust storms and longer term surface albedo changes. Movies made from these images were used to select regions for more detailed studies using higher resolution images. Our attention was attracted to two specific regions representing opposite extremes of temporal behavior.

Solis/Sinai Planum: Frequent surface changes were spotted on the vast plateau south of the Valles Marineris. This plateau, centered at 26 S, 268 E, is rimmed by mountains to the south and east and is the location of the classical albedo feature Solis Lacus. Albedo changes in this area were documented during the global dust storms of 1956 [5] and 1977 [6]. MGS era observations show dramatic brightening after the global dust storm of 2001 [1,4], followed by episodic darkening of broad patches in the north, south and east of the plateau.

High resolution MOC images of this region show a preponderance of wind streaks, most often indicating northwesterly winds but sometimes produced by winds from the northeast or southeast. Dark surfaces appear scoured of dust, with only a few isolated drifts in place of the dust ripples common elsewhere. Dust devil tracks are seen in some but not all of the southern summertime images. Albedo boundaries tend to be generally diffuse and gradational throughout the region (Figure 1). Distinct wind streaks that are aligned with the predicted southern summer winds are seen to the east of Solis/Sinai Planum leading southwards from Eos Chasma, in an area where intercrater sand dunes have also been spotted (MOC image S0602599).

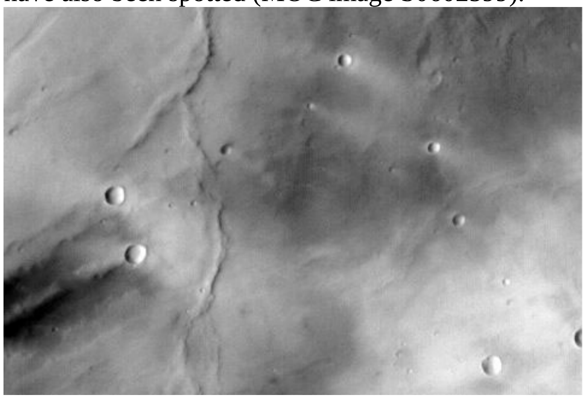

Figure 1. Diffuse albedo boundaries and wind streaks in Solis Planum. Moc image R0601381, processed by MSSS.

Utopia Planitia: More subtle changes were noted along the northern margin of Utopia Planitia (44 N, 106 E), east of the classical albedo feature Nilosyrtis. Viking images showed rapid changes in this region after the 1977 global dust storms. The distinct margin between the darker northern terrain and the bright lowland plains to the south shifted southwards between the Viking era and the start of the MGS observations, darkening an area of over 1 million km^2 [1]. More recent MGS observations show that the albedo margin has continued to advance southwards, progressively darkening the surface during each of the last 3 Martian years while maintaining a sharp but irregular boundary between the northern dark band and the bright southern plains.

High resolution MOC images of this region show a plethora of dust devil tracks during northern spring and summer, and a dearth of wind streaks that would indicate directed winds. Dust devil tracks are detected in nearly every image of the region acquired at a suitable season (local Spring – Fall). Albedo boundaries tend to be distinct (Figure 2), in contrast to the diffuse and gradational boundaries seen in Solis/Sinai. Repeated MOC observations (e.g., images M0102546 vs. R0101080) suggest that the regional darkening takes place nonuniformly, as some small dark spots are cleared of dust while others remain unchanged.

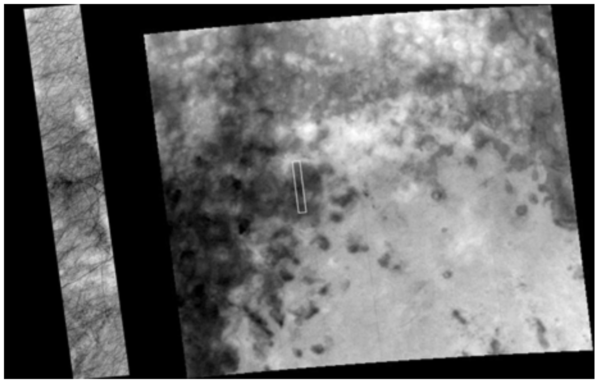

Figure 2. Sharp, irregular albedo boundaries and dust devil tracks in Utopia Planitia. MOC image R0300302/3, processed by MSSS.

Discussion: The continuous advance of the Utopia Planitia albedo boundary during the last few Martian years leads us to believe that the region may be gradually shedding the dust deposits laid down during the global dust storms of 1977. The rate of this advance is sufficient to account for the net changes that took place between 1977 and the present. These changes likely represent gradual erosion by cumulative action of the wind over several seasonal cycles.

The mechanism by which the northern Utopia Planitia surface is cleaned of dust is not yet known. Global circulation models for this region predict moderate westerly winds during northern fall and winter and only light winds during local summer. Dust storms have been seen in the area (e.g., image R0600704) but have not left behind noticeable wind streaks. In any case, dust storms would be unlikely to produce a slow southward shift in an albedo boundary that spans a broad swath of longitude. Directed winds can be ruled out because they would leave streaks on the surface and erase the ubiquitous dust devil tracks. We are left with the least unlikely hypothesis that the gradual erosion is produced by dust devils, perhaps concentrating rather than removing the dust.

The contrasting behavior of Solis/Sinai Planum and Utopia Planitia highlight the competition between the various processes that alter the appearance of Mars. Both regions exhibit evidence of both dust devils and dust storms, but the relative importance of these two mechanisms for local surface alteration is interchanged. Such insights yield a clearer understanding of the complex interaction between the surface and the atmosphere of Mars.

References: [1] Geissler, P.E. (2005) *JGR, 110, E02001*, doi:10.1029/2004JE002345. [2] Fenton, L. et al. (2007) submitted. [3] Fenton, L. et al. (2007) *LPS*, this meeting. [4] Szwast, M. (2006) *JGR, 111, E11008*, 10.1029/2005JE002485. [5] Dollfus, A. (1965) *Ann. Astrophys., 28,* 722-754. [6] Lee, S. (1986) *LPI Contrib. 599*, 57.