MARTIAN AEOLIAN FEATURES: COMPARISON WITH RESULTS FROM THE GLOBAL CIRCULATION MODEL;

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Aeolian processes link the atmosphere of a planet with its surface. Wind is apparently the dominant agent of surface modification on Mars today, as evidenced by frequent dust storms. Features attributed to aeolian processes include dunes, yardangs, grooves, deflation pits, and albedo patterns that are time-variable. In addition, vast regions appear to be mantled with sediments presumably deposited from the atmosphere.

Some surface features can be used to infer wind directions and strengths. Wind streaks, both bright (depositional) and dark (erosional) probably constitute the best "wind vanes". As described by Thomas (1979) and others, many wind streaks change with time reflecting seasonal shifts in wind patterns. Wind streaks and the interpretation of wind patterns have been relatively well documented by Veverka et al. (1977) and others. Incorporation of Viking IRTM data have enabled assessment of sediment sources, transport paths, and deposition sites of windblown sediments. Important questions remain, however, about the nature of wind streaks, other aeolian features on Mars, and their relationship to past and present winds.

The development of a Global Circulation Model (GCM) for Mars [4,5] makes it possible to address key problems in martian aeolian geology. The GCM is a complex simulation of the martian atmosphere run on a Cray YM-P computer at Ames Research Center. The GCM is three dimensional, presently consisting of a 25 by 40 (7.5° latitude by 9.0° longitude) finite element surface grid with 13 vertical layers (from 0 to 47 km). A large number of input parameters are used in the simulation, including Mars' orbital parameters, large-scale topography, albedo, thermal inertia, and atmospheric opacity. Among the GCM parameter predictions relevant to aeolian geology are surface shear stress patterns. The GCM data used in this study consists of six discrete runs meant to identify changes in surface winds through one martian year. Each run represents 1200 hours of simulated time. For our comparisons, the surface stress field was averaged over the last 240 hours of the run in order to provide a representative sampling of seasonal winds.

Our analysis focused on comparing the azimuths of GCM stress values with global wind streak data sets. Bright and dark streak data have been compiled from the literature [6,9], digitized, and combined with a graphical representation of the surface stress field on a cartographic base. The GCM runs were also compared to a map of rock abundance derived from Viking IRTM measurements [1].

We have devised a "goodness of fit" index to aid in comparing the azimuth of aeolian features with the GCM runs. This parameter is defined between -1 and 1, where a value of 1 indicates perfect alignment of GCM stress vectors with the average azimuth of the streak data for each GCM grid point. A value of -1 indicates perfect anti-correlation. A value of 0 indicates that either the aeolian data are randomly aligned, or the aeolian data are orthogonal to the GCM.

Figure 1 is a summary of the results of the wind streak comparisons. Each set of points represents a comparison of aeolian data with six GCM simulations corresponding to one martian year. Positive values of the fit index for the bright streaks during dust storm season are expected and are consistent with the current theory of bright streak formation. Bright streaks are probably formed by the deposition of suspended atmospheric dust in the lee of topographic obstacles [7]. The fact the fit indices for the bright streaks are less than one is a reflection of the coarse resolution of the GCM; there is considerable variation in the azimuths of the bright streaks within each grid area. The divergence of the bright and dark streak fit indices at $L_S=160$ is expected. As atmospheric opacity increases from dust loading, the increasingly neutral temperature profile should suppress dark streak formation and favor bright streak formation [7].

The global dark streak pattern is difficult to reconcile with the predicted surface stress pattern for any season. All of the fit indices for these features are less than 0 indicating poor correlation (see figure 2). The dark streaks are thought to be formed by the removal of dust in the lee of topographic obstacles, revealing darker underlying material. The vast predominance of dark streaks occurs in the southern sub-tropics, in a continuous band between -10° and -45° south [8]. The streaks in this area are directionally coherent and indicate formation by an easterly wind. This wind is not observed in the GCM in any season. Active formation of dark streaks, however, has been observed in this region following storm activity (L_S=320-350) by Thomas and Veverka, 1979, and others. When the dark streaks between 0° and 45° south are isolated in comparison to the GCM, a strong anti-correlation is observed during this period (see figure 2). Explanation of this discrepancy is critical if the GCM is to be used to model surface aeolian activity.

A preliminary qualitative comparison has also been made for the GCM runs and a global map of rock abundance. As with the bright streak data, there is a close relationship between the surface distribution of rocks and the dust storm circulation (GCM run for L_S=280-287). Stress vector orientations tend to be tangential to contours of rock abundance. High stress values are associated with regions high rock abundance (Chryse, Elysium). Low stresses are associated with low rock abundance (Tharsis, Arabia). Quantitative analysis of surface stress magnitude with rock abundance is in preparation.

Figure 1

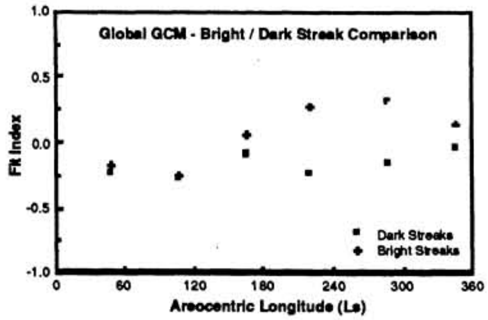
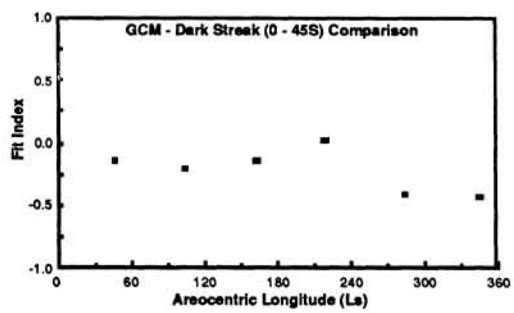


Figure 2



Figures 1 and 2 summarize the comparison between GCM surface stress azimuths for six Ls intervals and bright and dark streak azimuths. Positive fit index values indicate alignment of streaks and GCM surface stress vectors. Negative values indicate anti-correlation. The divergence of the fit indices in figure 1 mark the beginning of dust storm season (southern hemisphere spring) when bright streaks are observed to form. Figure 2 shows the strong anti-correlation between the GCM and the dark streaks between 0° and 45° south for the post dust storm period. Actively forming dark streaks have been observed during this period.

References

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