DETECTION OF MARTIAN VARIABLE FEATURES AS A FUNCTION OF IMAGE FILTER: HRSC COMPARISONS.

R. Greeley[1], P. Pinet[2], D. A. Williams[1], C. Butler-Freeman, L. D. V. Neakrase[1], and G. Neukum[3], [1]Arizona State University, School of Earth and Space Exploration, Box 871404, Tempe AZ 85287-1404, greeley@asu.edu, [2]DTP/UMR 5562/CNRS/OMP, Toulouse III University, 31400, France, [3]Institute of Geosciences, Freie Universitaet Berlin.

Introduction: *Variable features* were defined by [1,2] for albedo patterns on Mars that appeared, disappeared, or changed shape as a function of time, as seen on Mariner 9 images. They are attributed to the interaction of the atmosphere with the surface and are considered to represent erosion, deposition, and/or repositioning of sand and dust by the wind [3-5]. Variable features associated with topographic landforms, such as craters, are called *wind streaks* and are thought to represent the prevailing wind direction at the time of their formation. As such, they have used to map local, regional, and global wind patterns [6] and as a means to assess the validity of models of atmospheric circulation.

The detection of albedo features is sensitive to many variables, including the imaging system on the spacecraft, the illumination and viewing geometry (defined by the incidence angle and phase angle), and the filter through which the image was acquired [7]. Initial systematic studies of Martian variable features were based on Mariner 9 and Viking orbiter images, both of which carried vidicon cameras. Mixing these variables can lead to erroneous conclusions. For example, Figure 1 shows the highlands south of Isidis Planitia imaged in 1980 by Viking orbiter through the blue filter (473 nm), in 2002 through a red filter (575-625 nm) by the Mars Orbiter Camera (MOC; [8]) on MGS, and in 2004 by the High Resolution Stereo Camera (HRSC; [9]) on Mars Express through the red filter (730-770 nm). The bright wind streaks associated with the small craters in the smooth plains are well-seen in the HRSC image, can be detected in the MOC image, but do not appear to be present in the Viking orbiter "blue" image. Although the bright streaks could have formed between 1980 and 2002, the apparent change could be a function of the filter used in the Viking image, or the viewing geometry (note that the illumination is different in the three images. Figure 2 shows an area in Memnonia, also imaged

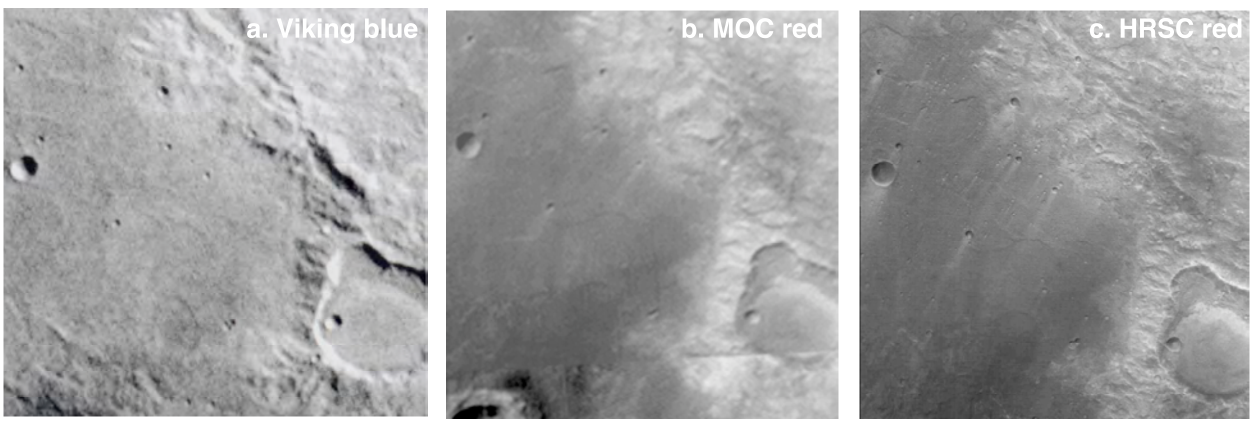

Fig. 1. Area south of Isidis Planitia showing wind streaks: a) Viking orbiter 377S85 image taken in 1980 through a blue filter; b) MOC image taken through the red filter in 2002; c) HRSC image taken through the red filter in 2004.

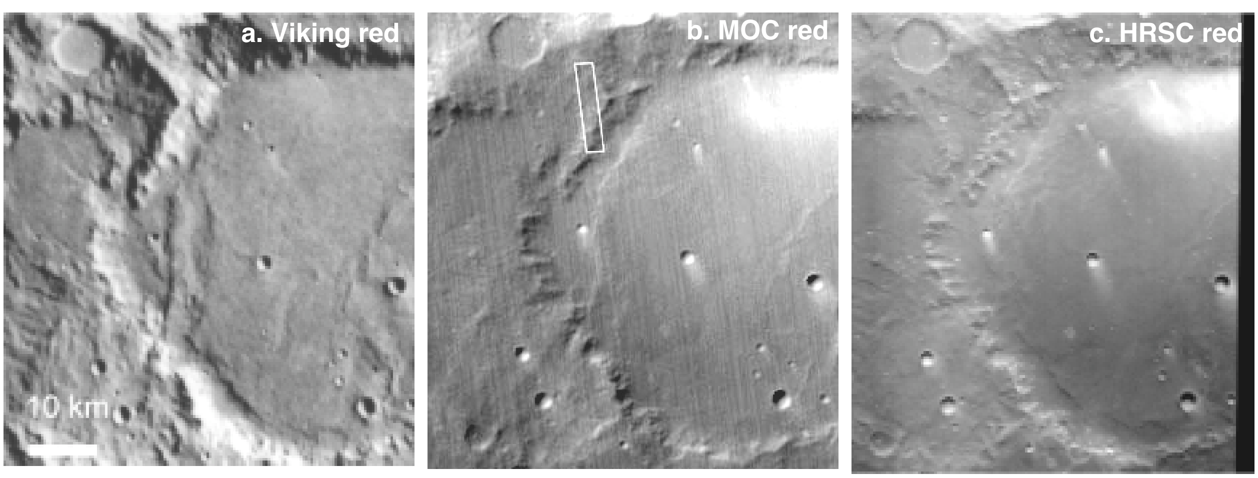

Fig. 2. Memnonia area showing wind streaks: a) Viking image taken through red filter in 1976; b) MOC image taken through red filter in 2000; c) HRSC image taken through red image in 2004.

by Viking, MOC, and HRSC, but all through red filters. Bright wind streaks are visible in all three images, but it would appear that the bright streak in the middle of the image formed between the Viking orbiter and MOC image times. However, again, the illumination is different for the three frames, leaving some uncertainties in the analysis.

HRSC provides the means to asses the influence of filter wavelength, illumination, and viewing geometry in the detection and analysis of variable features. HRSC is a "push-broom" imaging system based on charge-couple device (CCD) detectors using 9 line-arrays, four of which are for color reconstruction in wavelengths of red (725-775 nm), blue (405-485 nm), green (495-585 nm), and near infrared (915-995 nm), plus the "nadir" channel which is panchromatic (585-765 nm), all of which are acquired in near real-time under nearly the same illumination and viewing geometries. Figure 3 shows an area in Terra Cimmeria showing concurrent HRSC images taken through the red, near infrared, blue, green, and nadir channels, demonstrating that red and infrared images are best for the analysis of variable features. Although this result has been inferred for some time and is well known in photometry, HRSC provides the opportunity to demonstrate this effect clearly.

Indeed, a more advanced strategy than what has been done so far for detecting and monitoring systematically martian variable features might be implemented, taking advantage of HRSC high resolution observations. It would be based on the analysis of multi-angular observations repeated through time under close geometry and illumination conditions. This should be the "reference" case for disentangling surface changes through time (i.e., true variable features) from optical changes induced by the surface properties (e.g., subpixel roughness [10-12]) and/or complex photometric effects related to the presence of an irregular mixed granular-rocky interface (e.g., [13-16]) which must not be underestimated. As recently demonstrated [17], HRSC observations have revealed the complexity associated with the color observations produced under different geometry and illumination conditions, arising from the interplay between shade, shadow and the presence of a scattering atmosphere, in contrast with the Mars Odyssey THEMIS-VIS nadir-pointing observations, also imaging Mars from orbit in color at sub-100 meter scales, which suggest that spectral variability in the visible at such scales linked with compositional or mineralogic variability is rather rare and subtle [18]. It hints at the fact that a cautious approach should be taken in addressing the detection of martian variable features based on qualitative inspections of albedo contrasts and brightness variations.

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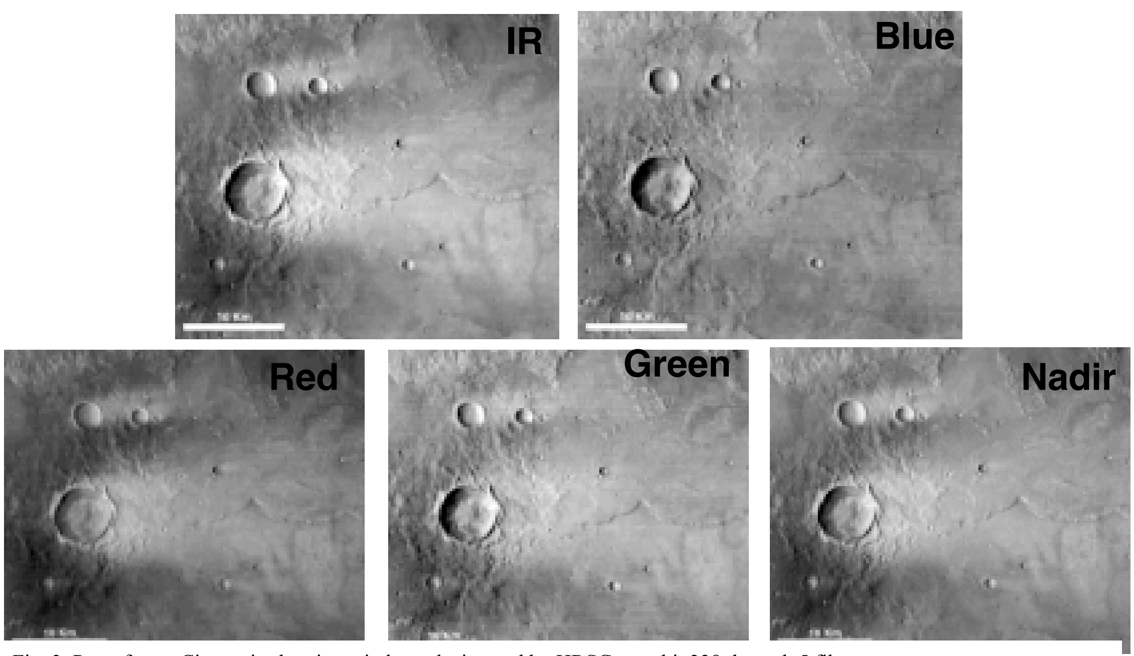

Fig. 3. Part of terra Cimmeria showing wind streaks imaged by HRSC on orbit 228 through 5 filters.