LIGHT PATTERN AND INTENSITY ANALYSIS OF GRAY SPOTS SURROUNDING POLAR DUNES ON MARS.

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Introduction: The NASA Mars Global Surveyor (MGS) Mars Orbital Camera (MOC) has captured many images of polar dunes with spots visible around the base. This study uses properties of light and shadow to analyze spot pattern and intensity in order to show that the spots are shadows cast by "mound-like" features on the planet's surface. Fourteen MGS MOC images were used in this study. [1] They comprise a surface area of 698 km^2 and contain an estimated 11,100 spots. Although the "mounds" are not directly observable in most images, various aspects of the mounds can be determined indirectly through the use of five methods of analysis: 1) Orientation of spots to sun azimuth, 2) Shadow Length versus sun inclination, 3) Shadow shape versus surface geometry, 4) Spot intensity comparison with known dune shadows, and 5) Shadow phase versus MOC view angle.

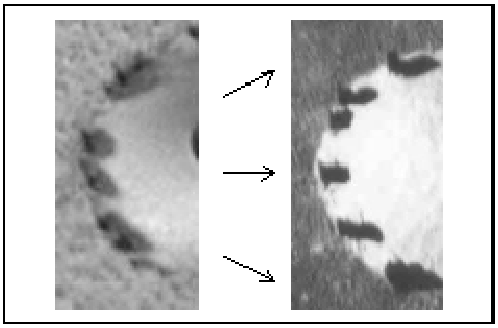

Fig. 1: Using the data from image MOC2-323, a model (right) was created and photographed with the same camera and light source angles. The resulting shadows in the model are a close match to the gray spots in the MOC2-323 image (left).

Though difficult to imagine a process, whether chemical, geological, or biological, that can create "mound-like" features large enough to cause shadows visible from space, the measured data from seven MOC images indicate heights reaching 24.5 meters.

Orientation: Of the 13 images in the northern polar region containing spots, eight images contain spots with directional orientation that match sun direction, as given by NASA ancillary data or derived by use of dune shadows. This is what would be expected of shadows cast by the sun. The gray spot direction could not be determined in the remaining five images, due to image resolution and other factors.

Shadow Length Versus Sun Inclination: Image E16-00714 was taken on 5/11/2002 and has a sun inclination of 71.79° from vertical. On 7/9/2002 image E18-00494 captured the same dune field. This image has an inclination of 61.41°. The 10-degrees difference allows for a measurable difference in shadow length.

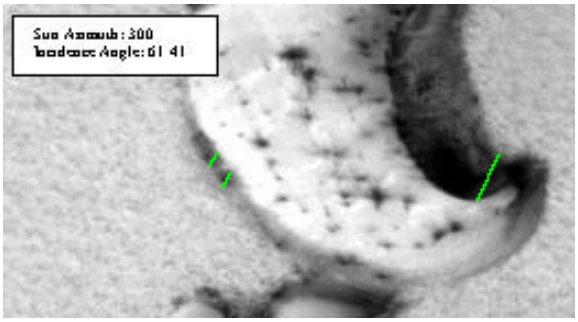

Fig. 2a: MOC Image E18-00494, 7/9/2002

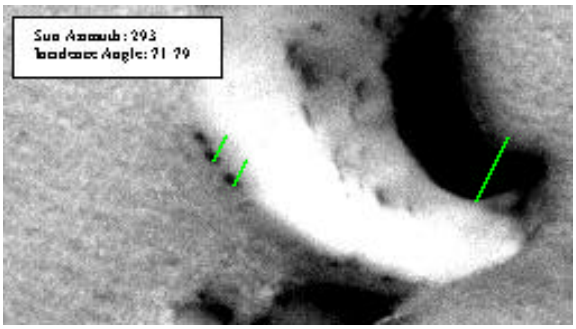

Fig 2b: MOC Image E16-00714, 5/11/2002

Shadow Shape Versus Surface Geometry: Given the Sun Angle and a known Slope Angle the expected slope shadow length can be calculated and expressed as a ratio of slope shadow / flat shadow. It is fortunate that the gray spots in several of the images are falling on Birchen dunes as they form in areas where the wind blows consistently from one direction, resulting in well-defined shapes and predictable dune height and brink location in relation to dune size. [2] Twelve dunes in image MOC2-323 were measured and, utilizing the 25.47-degree sun angle provided in the ancillary data, yield an average slope of 15.2 degrees. This results in a Predicted Slope shadow / flat shadow ratio of 63.68%. In order to compare actual Slope Shadow / Flat Shadow Ratio with the predicted value, measurements were taken of seventy gray spots in the MOC2-323 image. The average values were then used to arrive at a Measured slope shadow vs. flat shadow ratio of 66.35%.

Spot Intensity Compared to Dune Shadows: Intensity levels provide a method of comparative analysis of shadows cast by the dunes and the gray

spots. A section of dune from MOC image E16-00714 was imported into Adobe Photoshop 6.0 as a grayscale image. The highest "k" value for each area was recorded. For the black portion of the spots (blue in Fig. 3), 81% was the highest "k" value.

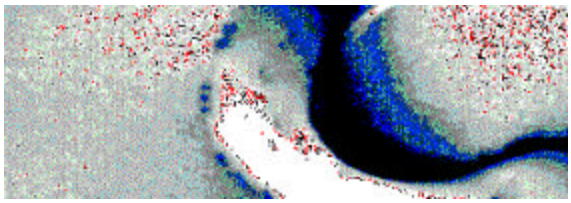

Fig. 3: MOC Image E16-00714 imported into Adobe Photo Shop as grayscale image.

This "Mound in Shadow" value compares fairly closely to the "Dune in Shadow" high value of 84%. The "Dune Shadow on the Plain" and the "Mound Shadow on the Dune" values were also comparable, with each having two zones of intensity measuring 40% and 53%. The close match is a good indicator that the spots are also shadows.

Spot Orientation Versus Dune Phase: In MOC image M20-00416 spot direction varies from 301° at the top to 230° at the bottom. Comparing ancillary data revealed that not only was the MOC recording this image from the opposite direction of the other 14 spot images, there was also a side-view angle involved. This causes a shadow phase change (like the phases of a moon) when the (MOC) changes viewpoint during the image recording. The images in Fig. 4 compare a portion of the top of the dune field (left) and a portion 22km lower in the dune field (right). It is readily apparent that the dune phase direction (dark side of dune indicated by blue arrows) has changed from nearly horizontal to a 45-degree angle. Measurements show that dune shadow phase and spot orientation undergo identical shifts.

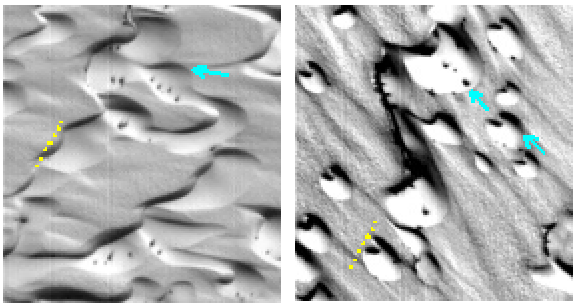

Fig. 4: Top of MOC Image M20-00416 (left) and 22km lower in image (right).

Conclusion: Using the solar inclination values in the ancillary data and the average length of ten shadows in each of seven images, the height of the largest Martian mound-like features casting the gray-spot shadows is estimated to range from 11.7 to 24.5 meters.

Fig. 5: Model of Martian dune, created 1 Feb 2003

The generally accepted explanation that dark spots indicate areas where cold, carbon dioxide frost has begun to sublime away [3] is not evident from this study. Plotting spot size versus season (provided in ancillary data, where 0° = start of spring, and 90° = end) shows that, if anything, the spots grow smaller with advancing season (Chart 1, left side).

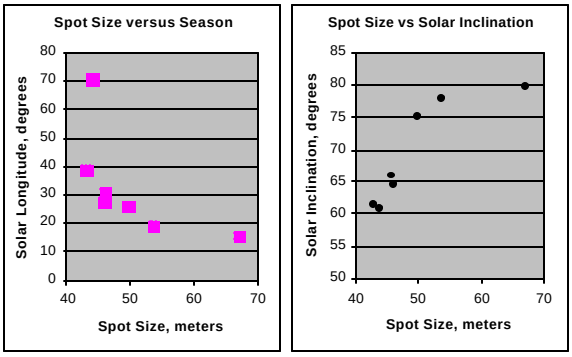

Chart 1: Spot size, as measured in seven MOC images, versus solar inclination

Using the same measured data, a second plot of size versus solar inclination (Chart 1, right side) shows average spot length increasing as the solar inclination increases (sun lower on the horizon). This is inline with expectations if the spots are caused by shadows.

References: [1] NASA/JPL/Malin Space Science Systems [2] Sauermann, Kroy, & Herrmann (2001) "Saturation Transients in Saltation and their Implications in Dune Slopes" [3] NASA/JPL/Malin Space Science Systems, MGS MOC Release No. MOC2-517, 18 OCT 2003.