TRANSIENT AEOLIAN FEATURES DETECTED AUTONOMOUSLY IN HiRISE IMAGES OF EL DORADO, COLUMBIA HILLS, GUSEV CRATER, MARS. Mary Pendleton Hoffer[1], Ronald Greeley[1], Kiri L. Wagstaff[2], and Adnan Ansar[2]. [1]School of Earth and Space Exploration, Arizona State University,Tempe, Box 871404, AZ 85287. [2]Jet Propulsion Laboratory, California Institute of Technology.

Introduction: Since the 1970s, images taken of Mars have shown the presence of transient aeolian features such as dust devil tracks, bedforms and windstreaks. High-resolution images of a small portion of Gusev crater were chosen to test the development of autonomous recognition algorithms for these transient features. A pair of images representing a difference of three years in time was analyzed using the automated techniques. The analysis successfully highlighted areas of potential change between the images, and led to discovery of actual change in two feature types: small bedforms and dust devil tracks.

Background: Mariner 9 first showed abundant aeolian features on Mars, in images returned in the 1970s [1]. Global coverage by orbiting spacecraft (Viking, MGS, Mars Odyssey, MRO, Mars Express) demonstrated the ubiquity of these features, and provided evidence of the dominance of this geologic surface process. Landers and surface rovers (Viking 1 and 2, Pathfinder, MER rovers) showed that wind and its processes are currently active on Mars [2]. There are now thousands of images of these aeolian features, representing four decades of observation. The sheer volume of images is daunting, and the features, often characterized by albedo differences, are not always easy to identify. An autonomous algorithm for identifying these features and for noting changes to them in different images could significantly enhance the analysis and understanding of these features and their processes. It would facilitate evaluation of the image resources already available, as well as those that will be produced by future spacecraft.

Method: HiRISE images of MER Spirit's surface traverse were selected for their consistent repeat coverage; recent study of a small ripple field, El Dorado, documented current aeolian activity [3]. Images PSP_001513_1655 (PSP_1513), and ESP_016677_1650 (ESP_16677) are the oldest and the most recent images of El Dorado, and represent a difference of 3.25 years. We used a dynamic landmarking approach to analyze the selected pair of images which automatically highlights areas of change [4]. This process registered the images on a pixel-to-pixel level using nonlinear warping, and computed their difference, showing regions of significant change. We followed up with a review, using a visualization program that morphs between the two images, causing any changes to stand out sharply. ***Figure 1*** shows the portion of the two El Dorado images that was accurately registered in order to apply the landmarking and differencing algorithms. In this figure, blue indicates areas that have become darker over time, while yellow shows areas that have brightened. Darkening was inferred to indicate decreased dust on the surface, and brightening to indicate increased dust. Brightening could also indicate morphologic change, where a new topographic profile exposed that portion of the surface to greater illumination.

Results: Darkening appeared primarily as broad streaks across the landmarked and differenced image. These streaks corresponded to dark tracks on ESP_16677. They were inferred to represent tracks left by the passage of dust devils, which suction dust from the surface [5]. Brightening occurred in several areas of the image, to the west, center and southeast, where dust devil tracks disappeared or where there appeared to be no morphologic change. This brightening was assumed to be due to deposition of dust following the third (documented) dust devil season [6]. Brightening to the northeast was associated with bedform crest morphology.

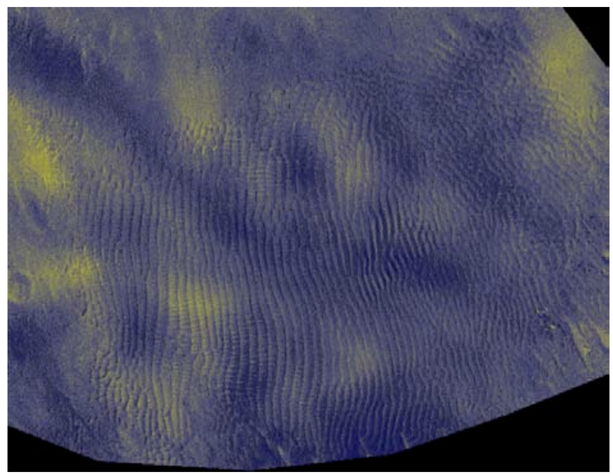

Fig. 1. Difference image from automated comparison of PSP_001513_1655 and ESP_016677_1650. Yellow indicates areas which brightened over time; blue, areas which darkened. North is up and the surface width is ~200m.

Two forms of change were indicated: 1) orientation of the NE bedform crests; 2) orientation and number of dust devil tracks. ***Figure 2a*** shows El Dorado in PSP_1513, and ***2b***, annotations of the initial condition of these features. ***Figure 3a*** shows ESP_16677 and ***3b*** annotates the observed changes. The documented changes to the surface occurred in slightly more than 3 years, and may indicate that the near-surface winds have altered as much as 90 degrees in orientation.

Discussion and further work: The landmarking and differencing algorithms developed in this project successfully highlighted changes to albedo in images of the surface of Mars. The processing technique was limited in that it showed non-specific change, and required extended human evaluation. The technique also was constrained by the difficulty in accurately registering pairs of images. Despite these constraints, changes to the orientation of bedform crests and dust devil tracks were found to be directly associated with the bright and dark areas produced by the processed image pairs. The surface changes, which occurred over an extremely short time period, may lead to a better understanding of regional wind patterns and aspects of the climate on Mars.

Future work will include the development of the algorithm to portray changes in shape as well albedo. Improved registration techniques should allow the use of images from separate data sets with different image resolutions. The importance of phase angle, atmospheric opacity and seasonal illumination to this type of image comparison will be defined. Further image evaluation will include the examination of similar surface features in the Columbia Hills, to expand the use of the autonomous technique as well as to develop and confirm the types of change occurring on the surface.

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References: [1] Sagan, C., et al. (1972) ***Icarus 17***, 2, 346-372. [2] Edgett, K. and Malin, M. (2000) ***JGR 105***, E1, 1623-1650. [3] Sullivan, R., et al. (2008) ***JGR 113***, E06S07, doi:10.1029/2008JE003101. [4] Wagstaff, K.L., et al. in preparation. [5] Greeley, R., et al. (2005) ***JGR 110***, E06002, doi:10.1029/2005JE002403. [6] Greeley, R. et al. (2010) ***JGR 115***, E00F02, doi: 10.1029/2010JE003698.

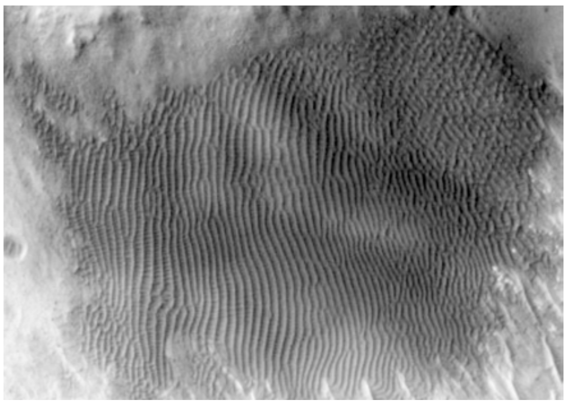

Fig. 2a PSP_001513_1655. Dust devil tracks and N/S trending bedform crests are readily visible. Cross-hatching occurs in the NE. North is up; width is ~200m (all images).

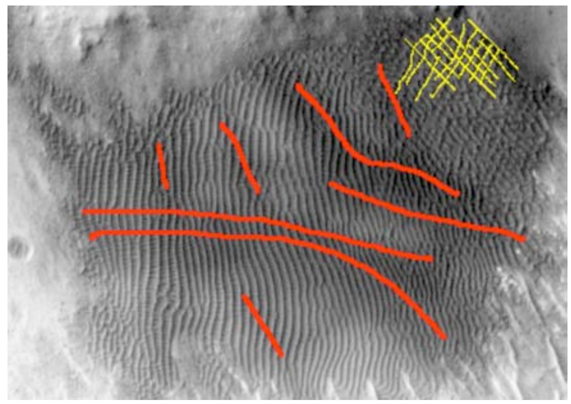

Fig. 2b Annotation. Red: dust devil tracks; W/E and NW/SE orientations are visible. Yellow: bedform trough orientations; NW/SE and NE/SW predominate.

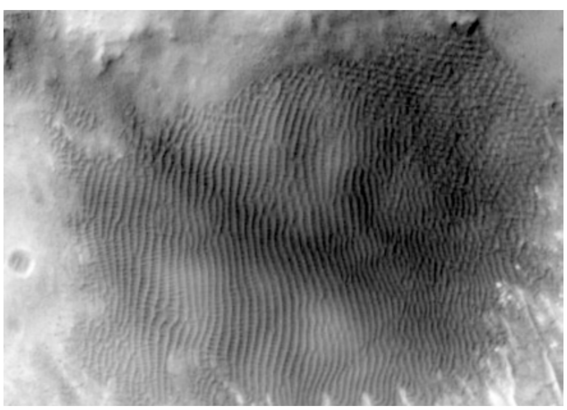

Fig. 3a ESP_016677_1650. Dust devil tracks are more prevalent; N/S crest orientation is still present; NE cross-hatching appears changed.

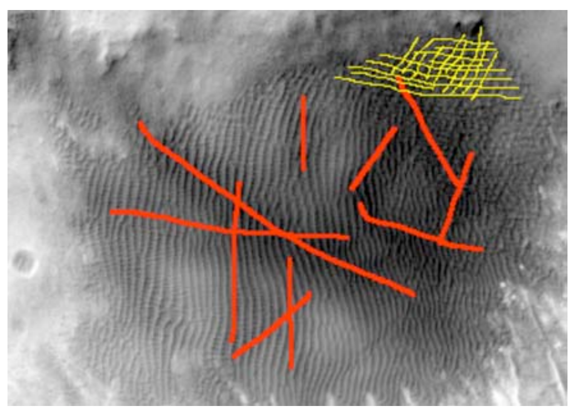

Fig. 3b Annotation. Red: dust devil tracks; NW/SE, N/S and NE/SW oriented tracks are present. Yellow: bedform trough orientations; E/W orientation is more apparent.