Wind Measurements of Martian Dust Devils from HiRISE.

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The High Resolution Imaging Science Experiment (HiRISE) camera [1] enables a new approach to the study of Martian dust devils [2]. HiRISE includes a central color swath; this swath is imaged by separate CCDs through blue-green, red, and near-IR filters. When crossing an actively moving feature such as a dust devil, this provides three separate views closely spaced in time, and changes can be observed. This feature of HiRISE has previously been used to estimate the speed of avalanches on the Martian north polar cap [3]. The serendipitous capture of an evolving dust devil by the three-frame cadence of each HiRISE observation allows for the direct measurement of Martian dust devil velocities, as features in the dust cloud move between color frames. We utilize an automatic feature tracking technique previously applied to cloud features on Jovian planets [4] to extract velocity measurements at points throughout the dust devil.

Feature Tracking

Figure 1 shows the evolution of a portion of an active dust devil. By treating features in an image pair as passive tracers of motion, our feature tracking software extracts a square window from one image in the pair and compares it with numerous windows in the later image of the pair. The software then determines the specific comparison with the highest statistical cross-correlation score, and the spatial separation between these two windows is the basis for the wind measurement. Our software systematically examines the entire image, resulting in numerous vectors arranged in a regular grid. One limitation to our software is that we must set the correlation window size manually. Visual estimation of the characteristic size of the dust cloud features in these images allows us to set this parameter between 20 and 40 pixels.

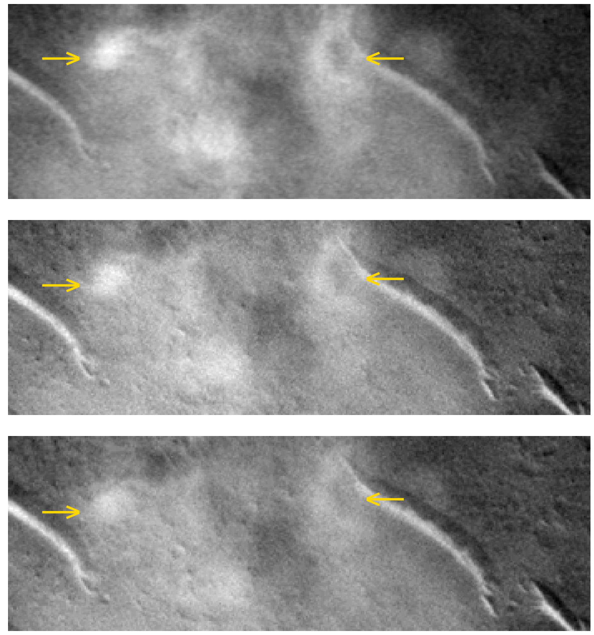

Figure 1: Active dust devil imaged by HiRISE (ESP_013199_1900) using the blue-green (*top*), red (*middle*), and near-IR (*bottom*) filters. The interval between images is ~0.1 s. Note that the feature highlighted by the arrows on the left advects towards the bottom of the image by a greater amount compared with the feature highlighted by the arrows on the right.

Figure 2 shows preliminary measurements from our software using a correlation window size of 40 pixels. In PSP_009819_2130, the dust devil exhibits clockwise rotation, with typical velocities along the outer edge of the dust devil between 20–30 m s^{-1}. Measurements in the interior of the dust devil suggest slower winds toward a circulation center, but vectors in this region are limited. In ESP_013199_1900, dust clouds move towards the bottom and right, with peak velocities of 30–40 m s^{-1} along the left edges of the dust devil. This is higher by a factor of two than previous measurements from *Viking* orbiter images [5] obtained through non-automated techniques.

Dust devils possess a rotational (tangential) velocity component and a translational velocity component as it moves across the Martian surface. We cannot reliably decompose these components in our measurements, but our preliminary results, particularly for PSP_009819_2130, indicate that our measurements are more representative of the inherent rotation of each dust devil. Wind velocities in Figure 2 modestly increase along a radial profile from center to edge, though establishing a true circulation center is somewhat ambiguous for ESP_013199_1900. Furthermore, translational velocities of Martian dust devils tend to be lower than 15 m s^{-1} [6, 7], though higher translational velocities of up to ~60 m s^{-1} have been noted in a few cases.

At present, our technique is unsuccessful in areas with diminished dust opacity, resulting in surface features (stationary except for some minor spacecraft jitter) dominating the correlation comparison and producing a near-zero wind vector measurement. At the opposite extreme, dust devils may exhibit isolated bright

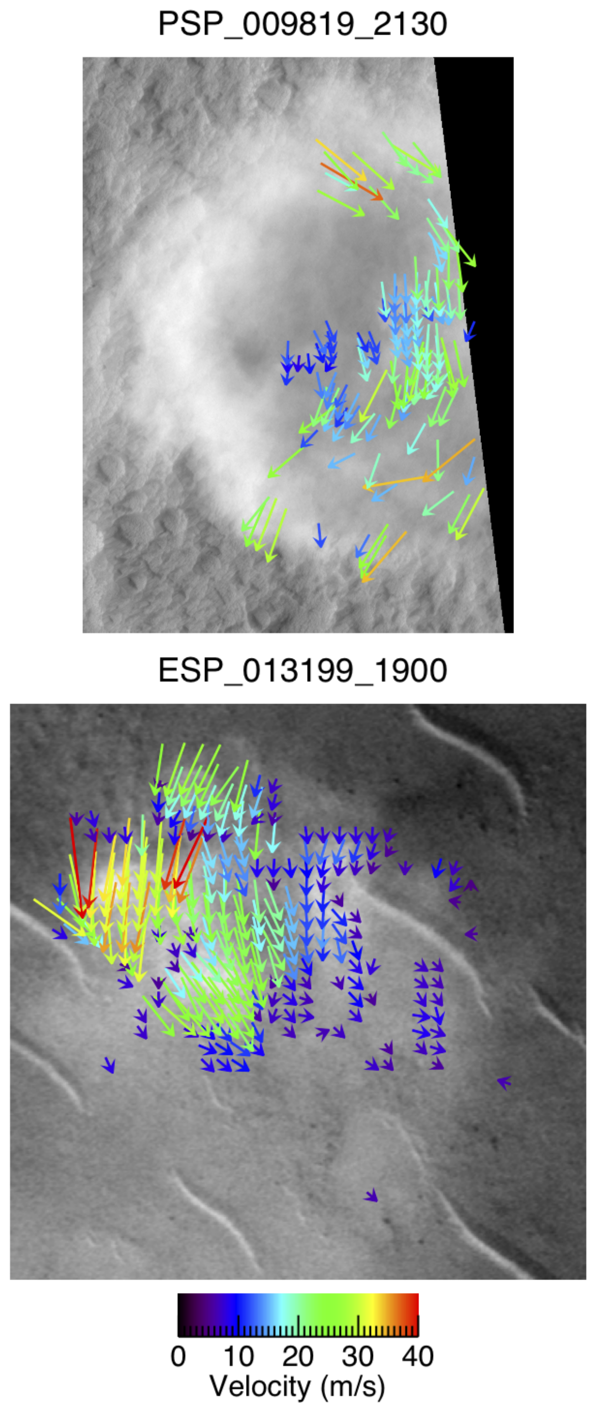

Figure 2: Wind vector maps of dust devils overlain on the blue-green filter image of the indicated observations. The center of each wind vector corresponds to the location of each particular measurement. For clarity, only a small percentage of successfully measured wind vectors are shown.

areas where dust concentration is high. However, these areas do not necessarily coincide with areas in which feature tracking was successful, as they may lack sufficient contrast (for example, the left side of the dust devil in PSP_009819_2130). Currently, optimal tracking occurs in areas where dust clouds adequately block the underlying surface, and possess enough texture and morphology for the software to track.

Discussion

We note several cautionary points regarding the use of this technique. First, the time for HiRISE to scan over a given dust devil can be comparable in magnitude to the time interval between the color images, so the north and south edges of the dust devil are imaged at slightly different times. However, both the cloud features and the movements that we observe are much smaller than the dust devil diameters. In practice this means that velocities in the northern and southern sections of the dust devil are measured at slightly different times.

Second, HiRISE applies a time-delay integration (TDI) technique to improve signal-to-noise, which makes the light collection time for a pixel as much as 11% of the interval between frames; the TDI time for CCDs with different filters is not necessarily the same within an image. This effectively introduces some smearing of features due to dust devil movement during TDI, but the time is always an order of magnitude less than the image interval.

Finally, the optical properties of dust at different wavelengths may cause some cloud features to look different. This is unavoidable for this data set, but somewhat mitigated by the identical illumination angles for each filter image.

Future analysis plans include software modifications and/or supplementation of automated measurements with manual tracking as a way of overcoming the difficulties introduced by the tenuous dust clouds. Image enhancement techniques (such as removal of the background surface) may improve results, but remains unexplored. Active dust devils are undoubtedly present in the color swath of other HiRISE images, but a systematic search has not yet been conducted.

References

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