A TIMELAPSE CAMERA ARCHIVE OF DUST DEVIL ACTIVITY AT ELDORADO PLAYA, USA.

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Introduction: Visual observations of dust devils are the oldest form of data on these phenomena, e.g. [1,2]. A classic survey is that by Sinclair [3], and surface imaging of dust devils on Earth and Mars is reviewed in [4]. However, such surveys are labor-intensive, subjective, and often in demanding conditions. As noted in [5], modern digital timelapse technology with large flash memory now permits long-duration, high-cadence visual records to be obtained from the field, in a manner analogous to imaging from Mars landers and rovers. These image records can then be subjected to manual and/or automated image analysis.

We have obtained a timelapse camera record (1 frame/minute) over some 36 days (~32000 images) in May/June 2015 at El Dorado playa (fig.1) near Boulder City, NV. This is a site which is the subject of several previous field studies (e.g. [6,7,8,9]) using visual observation and in-situ measurement.

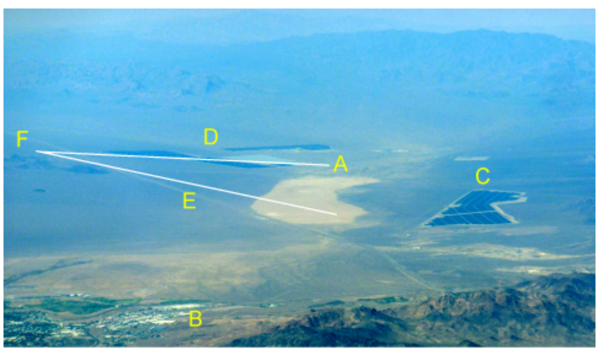

Figure 1: Field site from a commercial airliner looking south from Lake Mead. El Dorado playa (A) is the bright lozenge in center. At the lower left is Boulder City, the CMP04 meteorological station is marked with a 'B'. The polygonal dark feature (C) to the west of the playa, and the rectangles (D) to the south, are photovoltaic solar power facilities. The faint line running past the left-hand edge of the playa is Route 95 (E), and the camera location is marked (F). White lines denote approximate timelapse field of view.

The timelapse image data (~12 GB, e.g. fig.2) are made available for use of the community at the APL data archive (**https://lib.jhuapl.edu**). In addition, a preliminary manual categorization of the images (0,1 - no dust; 2 - dust features [possibly artificial or unstructured dust blow]; 3,4 - definite dust devil) is provided to guide examination or to serve as a benchmark for automated classification. Also, contemporaneous data from a nearby weather station (fig.1) is provided to allow correlation of dust devil characteristics and abundance with meteorological conditions.

Figure 2: Image 28544, in early afternoon (note that the timestamp at the bottom of the image is Eastern time, 3 hours ahead of local) showing route 90 in the foreground and blue skies. The playa, and the solar power installation beyond, are visible as near-horizontal features in the center of the image; a cloud shadow is at center left. A large dust devil is visible a third of the way across the image – note that its visibility is due to the high contrast between the bright dust and the darker hills beyond; the dust is less obvious against the cloudy sky or against the playa itself.

Image Data: Individual color images (2592x2000 pixels, e.g. fig.2) are jpeg-compressed by the camera to a filesize of about 450 kB. This compression algorithm yields a filesize that relates to the information content (entropy) in the image data, and in fact a regular diurnal cycle of filesize is evident during clear conditions but is disrupted by major image features such as heavy cloud. This provides a quick means to reconnoiter the large dataset. The elevated vantage point allows the horizontal range to a dust devil to be estimated, and thus diameter can be measured from the image (with some uncertainty) without requiring stereo (e.g. [6]).

Although the image cadence of 1/min is enough to reliably measure populations and observe the formation and decay of some dust devils – e.g. fig.3 – it is not enough to track small, short-lived devils. Note that many devils are advected into/out of the field of view, rather than being observable throughout their full life cycle. It is notable that dust devils are most clearly seen against the dark hill background. On many occasions multiple dust devils are visible, although our categorization does not identify these cases – this would be an interesting future project.

Analysis Results: The manual image classification indicated that 85% of images with identified dust devils occur between 12:00 and 17:00, with peak activity in the 13:00-15:00 time period, consistent with previous surveys. Overall, 7% of the images in this time window during the survey had dust devils. A fuller discussion is available in [10].

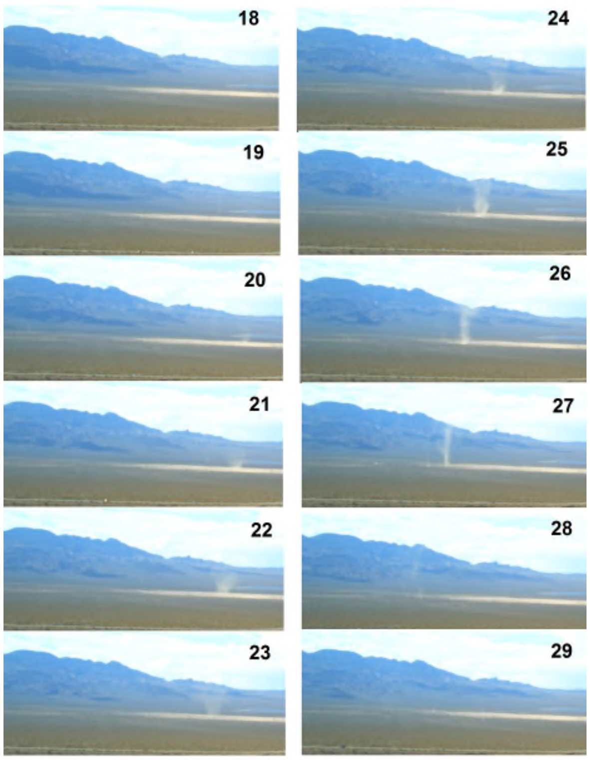

Figure 3. 12-minute sequence showing the development and migration of a dust devil. Devil forms in frame 20 and broadens into a conical form, becoming fainter in frame 23. Devil picks up more dust and maintains a more cylindrical form through frame 26, becoming taller and narrower while migrating to the left (south). Devil disappears (fades, rather than being advected out of view) by frame 29. Images are subframed to 1400x600 pixels.

Persistence of Dust Devil Conditions: The image classification yields a time series of dust devil occurence. Analysis of the data (figure 4) indicates that the likelihood that dust devils persist in a sequence declines exponentially with sequence length. This suggests that the character of dust devil activity may be captured with a simple Markov model [10].

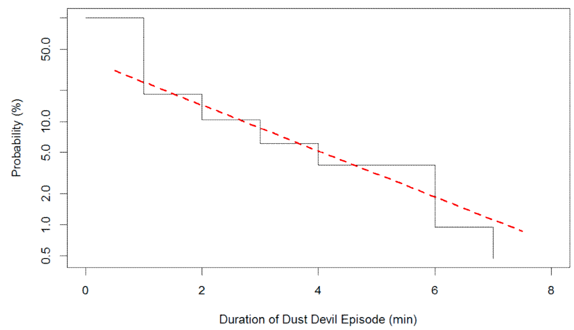

Figure 4: The distribution of run lengths of image sequences of category 3 or higher (i.e. definite dust devils). The red line is an analytic function with each additional minute causing the probability of encountering such a sequence to decrease by a multiple of 55%.

Conclusions: We have obtained and made available a timelapse image dataset for dust devil studies (although there may be other applications). The dataset spans 36 days at 1 image/min and shows about 300 episodes of dust devil activity (as well as other dust-raising events). We invite the community to conduct analyses of these data, to characterize the dust devil population and its dependence on meteorological conditions (e.g. does tilt or morphology depend on ambient wind conditions?), with a view to applying the results of such correlations to image data from Mars.

References: [1] Flower, W.D.(1936) Sand devils. *Lond. Meteorol. Off. Prof. Notes* 5, 1–16. [2] Lorenz, R.. et al. (2017) pp.1-38 in Reiss, D. et al. (eds) *Dust Devils*, Springer. [3] Sinclair, P.C., (1969). *J. Appl. Meteorol.* 8, 32–45. [4] Murphy, J. et al. (2017) pp.39-87 in Reiss, D. et al. (eds) *Dust Devils*, Springer. [5] Lorenz, R. et al. (2010), *J. Atmospheric and Oceanic Technology*, 27, 246-256 [6] Balme, M. et al. (2012) *Icarus* 221, 632–645 [7] Metzger, S. et al., (2011) *Icarus* 214, 766–772. [8] Lorenz, R. and P. Lanagan. (2014) *Boundary Layer Meteorology*, 53, 555–568 [9] Lorenz, R. and B. Jackson (2015) *GeoResJ*, 5, 1-11 [10] Lorenz, R. et al., *Aeolian Research* (submitted).

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