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A timelapse camera dataset and Markov model of dust devil activity at Eldorado playa, Nevada, USA

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ABSTRACT

We report a May-June 2015 survey of dust devil activity on a Nevada desert playa using an inexpensive digital timelapse camera. We discuss techniques for exploiting the large volume of data (~32,700 images, made publicly-available) generated in these observations, similar to imaging from Mars landers and rovers, noting the diurnal image filesize variations as a useful quick-look metric of weather conditions. We present results from a semi-automated image classification: this classification is available to other workers, for example for benchmarking automated procedures. The acquisition of images at 1/min for some 36 days permits study of the diurnal variation of dust devil activity (e.g. 85% of the dust devil images [i.e. those images manually classified as showing dust devils] occur between 12:00 and 17:00; during the period of peak activity 13:00–15:00 about 7% of images contain well-defined dust devils of several meters diameter or larger). The data also permit the dependence of dust devil characteristics on ambient conditions. We construct a simple two-state Markov model for the occurrence and persistence of dust devils (a few per cent chance that new dust devil activity appears in the next image; and a ~45% chance that activity stops) which may help inform strategies for acquiring and interpreting field observations.

1. Introduction

Dust devils are of interest as a phenomenon in their own right (e.g. Lorenz et al., 2016; Balme and Greeley, 2006) but also as a factor in dust-lifting and air quality more generally (e.g. Gilette and Sinclair, 1990). Dust devil activity has been assessed visually in the past (e.g. Sinclair, 1969; Snow and McLelland, 1990; Pathare et al., 2010), with observations recorded by hand in real time. This enterprise is demanding (not merely in time, but in terms of heat and boredom) and yields only crude classifications of dust devil sizes. Photographic surveys, with human operators on-site, can yield quantitative size and trajectory information (e.g. Balme et al., 2012) but are similarly inefficient in terms of their high labor cost.

Modern technology, and specifically digital cameras with large flash memories (Lorenz et al., 2010), allows long-duration visual surveillance of field sites in a manner not dissimilar from that in which visual observations are made from landers and rovers on Mars (e.g. Greeley et al., 2006). Such cameras are a powerful 'force multiplier' in that weeks or months of observations can be made and examined (under office conditions) with only hours or days of effort. Automated image analysis procedures can also be applied to this problem (e.g. Castano et al., 2008), although these are not the focus of the present paper.

2. Methods

2.1. Field site

The study site was Eldorado playa (Fig. 1), a lake bed conveniently accessible from Las Vegas, Nevada in the Southwestern USA. This location has been the site of numerous prior dust devil investigations (e.g. Pathare et al., 2010; Metzger et al., 2011; Mason et al., 2014; Balme et al., 2012). Previously, we have documented (Lorenz and Lanagan, 2014; Jackson and Lorenz, 2015) statistically robust in-situ barometric surveys of dust devil vortices on Earth at this location, and an evaluation of the populations of dustless and dust-laden vortices using loggers that recorded both sunlight and pressure (Lorenz and Jackson, 2015).

A tradeoff exists in siting a camera to view dust devils. Downlooking views (as from orbit) give precise locations and diameters, but (except via shadows) give little vertical structure information. Horizontal-looking cameras expose vertical structure well, but yield no

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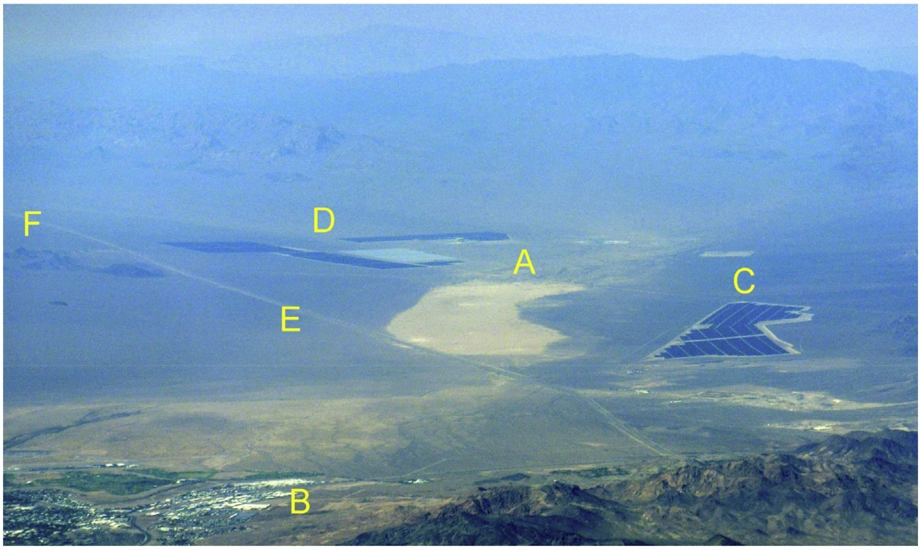

Fig. 1. Field site from a commercial airliner looking south-southwest from Lake Mead. Eldorado dry lake (A) is the bright lozenge in center. At the lower left is Boulder City, the CMP04 meteorological station is marked with a 'B'. The polygonal dark feature (C) to the west of the playa, and the rectangles (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). It is evident from this image that winds from the south will have encountered smoother terrain before encountering the playa that winds from the north.

information on the range to the devil and thus image scale: this ambiguity can be removed by stereo imaging (e.g. Balme et al., 2012). A typical elevated vantage point may, as in this instance, have a generally horizontal view, but there is some distance (range) information to a dust devil from the (foreshortened) vertical coordinate of the base of the dust devil in the image plane. An elevated viewpoint also means that dust devils are seen against a surface background rather than against the sky: in the present location at least, this appears to give typically better contrast. For horizontal viewing in the northern hemisphere, a northward camera boresight avoids looking into the sun, which generally gives poor results. In practice, the practical consideration of choosing a site where a camera can be easily accessed but safely left unattended for long periods may dictate the choice of location.

The camera was deployed in a recessed position among some rocks to protect from direct sunlight and possible human disturbance. The site chosen (and verified with relevant authorities – see acknowledgments), on a small hill to the south of the playa on the other side of Route 95 (Fig. 2), has a good view of the playa and is quickly reached from 95, but requires care to access by climbing on steep slopes with nearby mine workings. Abundant spent cartridges, ceramic skeet fragments, and occasional gunfire noise attest to the informal use of the site for recreational shooting. However, in several years of experimental deployments, hardware attrition has been minimal, and no adverse effects on personnel (beyond occasional scrapes on the rocky slopes) have been encountered.

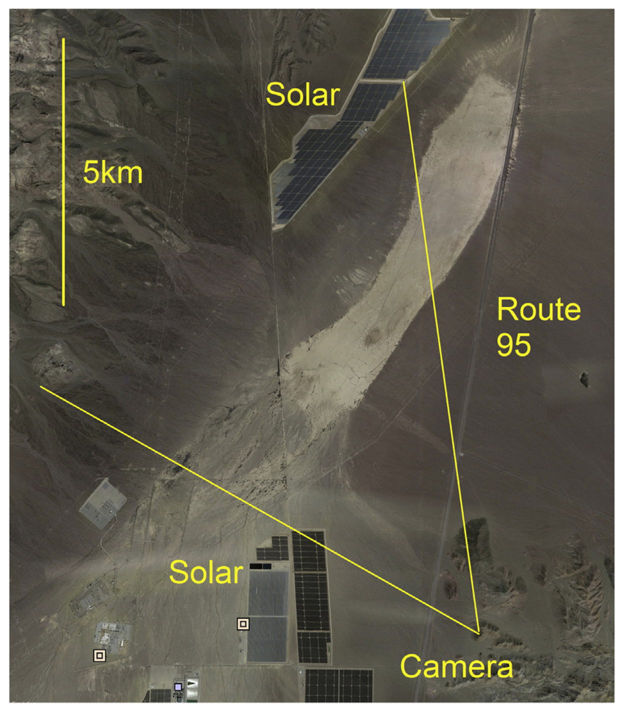

Fig. 2. Satellite view, Landsat data courtesy of Google Earth, with the camera location and 45° field of view shown. The solar power facilities and route 95 serve as useful fiducial marks in the image.

2.2. Camera instrumentation

We have previously noted (Lorenz et al., 2010) the application of then-emerging digital timelapse camera technology exploiting flash memory to perform surveys of transient meteorological phenomena such as dust devils or playa flooding. Since that work, with somewhat primitive custom-built equipment, new consumer camera products have provided progressively higher-quality images and larger memory capacity, with more image acquisition flexibility (e.g. video bursts) and better packaging.

For the present study, we used a Cuddeback 'Attack' camera, a unit with which we have had satisfactory experience in meteorological monitoring (e.g. playa flooding and rock movement at Death Valley's Racetrack Playa – Lorenz et al., 2014). Although principally sold as a trail camera for monitoring wildlife (its motion detection and night-time near-IR illumination capabilities were not relevant in our application), its robust waterproof housing, accommodation of D-cells for long battery life and ease of set-up in the field have generally given good results: example images are shown in Figs. 3 and 4.

As discussed in Lorenz et al. (2010) there are inevitable tradeoffs in any timelapse program. In particular, the image cadence and survey duration are usually limited by memory size and/or battery capacity, with image resolution sometimes an adjustable parameter. For playa flooding, an hourly or half-hourly cadence is adequate, but for faster transient events such as aeolian ripple migration (e.g. Lorenz and Valdez, 2011), a timescale of a few tens of seconds to a couple of minutes is more appropriate.

We have previously trialled 5-minute surveys at this site. While this approach is reasonable for an overall activity census (and allows multi-month unattended operation, since the memory card fills and the batteries run down slowly), this interval is too long to reliably track individual devils: Following Lorenz (2013), the typical longevity of a dust