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Encounter Rates with Dust Devils and Dustless Vortices : Earth and Mars

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Abstract

Dustless vortices appear to be more abundant on Mars and Earth than dust devils : new field measurements can quantify these populations.

1. Introduction

Dust devils are widely-observed on Mars and in terrestrial arid regions. By definition, they are convective vortices rendered visible by lofted dust, but these features can exist with low or high dust loading, in the limit being barely visible.

Dust devil optical depths reported in orbital imagery by Towner [1] are generally quite low, in the range 0.05-0.2. Lorenz (submitted) has noted that densities (N per km^2 per hr) from orbital measurements at Mars exceed by a factor of several those densities determined from observations on the surface (on Earth or Mars) : this systematic enhancement may be due to the typical aspect ratio (height/diameter) of ~5, which means dust devils have a higher optical contrast when viewed from above.

Abundant vortex passages have been documented by Mars landers in in-situ meteorological data [2,3,4]. To reconcile these counts with optical detections, data on the size, intensity [i.e. velocity and/or pressure drop] and dust loading) is needed.

2. New Field Measurements

As noted in [4,5] new technologies (precision pressure sensors, flash memory) now permit logging of pressure or other data with high precision (<0.1mbar), at the high rates (~1Hz) needed to resolve dust devil passage, for the periods (weeks) needed to obtain statistically-meaningful numbers of encounters. Furthermore, the equipment is now sufficiently small and affordable for instrumentation to be deployed and left unattended.

Measurement campaigns are underway at several locations in the Southwestern USA to detect vortex passage via the transient pressure drop. Additionally, a subset of the pressure loggers are able to record the photocurrent from a solar cell, which typically sees a dip due to the extinction from the dust column [6]. Example data are shown in figures 1 and 2.

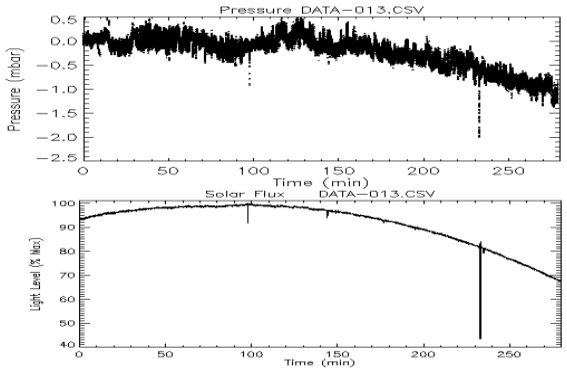

Figure 1. Pressure and light level recorded 1st May 2013 at ElDorado playa (NV) – two prominent dust devils are seen in both records. On a clear day, the optical record is particularly clean.

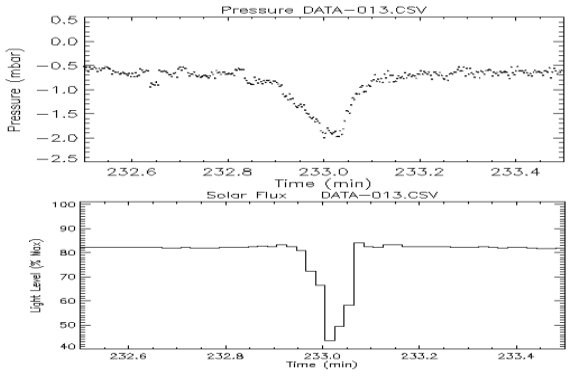

Figure 2. A zoom on the second event. This devil is optically-thick, extinguishing about half the sunlight. Both the pressure and optical records are asymmetric.

These new data will allow the dust devil diameter (measured by an array of loggers, inferred from the duration of the pressure drop, and/or observed in timelapse camera images) to be correlated with the pressure drop and the dust loading. Such correlations may allow the possibility of dust-thermal feedbacks on intensity to be explored [7,8].

3. Encounter Frequencies

The pressure drops associated with dust devils appear to follow a power law [4]. Note that the amplitude of the recorded drop may be much smaller in magnitude than the pressure drop in the center of the vortex. However, assuming no bias in miss distances, this can be ignored in direct comparisons. Good records of pressure drops of some 79 vortex encounters were measured by Pathfinder over 83 sols [2] and by Phoenix (504 encounters over 150 sols [3]). These are plotted in figure 3.

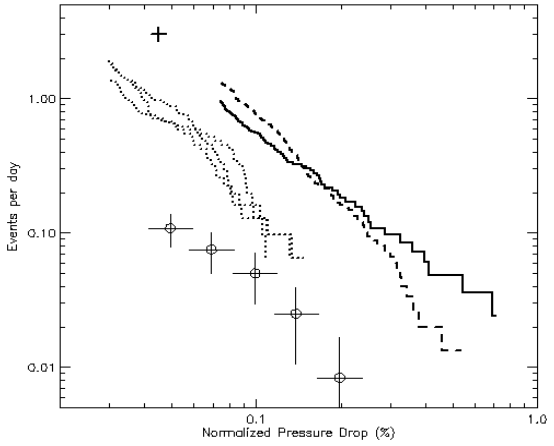

Figure 3. Cumulative pressure drop detection rates for Mars and Earth. Solid line and cross is Phoenix data [3], Dashed line Pathfinder [2], crosses are White Sands from 1966 [9]. New field data (3 different stations at El Dorado playa in June 2012, dotted curves) indicate a much higher detection rate than[9].

It is seen that much of the difference in the reported encounter rate is due to the lower detection threshold in the Phoenix study (30 μbar vs 50 μbar) : the data from the two sites collapse onto essentially the same curve. The only comparable published terrestrial dataset is the (nearly 50 year-old) study, with only 21 events at White Sands [4,9]. These data too are shown : the frequency (normalized by ambient pressure - in a classic vortex $\Delta P/P$ is roughly proportional to V^2) of detections is seen to be very low, perhaps due to only starting the chart recorders when a large - and dusty - dust devil was observed). However, much higher terrestrial detection rates are seen in our new data : month-long surveys using continuous pressure recording, searched post-hoc for vortex events, yield robust statistics, with three stations recording roughly the same number of encounters, at a rate only slightly lower than at Mars.

The surveys are ongoing in summer 2013 and abundant new data will be reported at the meeting.

Acknowledgements

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