Martian and terrestrial dust devils

Conference or Workshop Item

MARTIAN AND TERRESTRIAL DUST DEVILS. T. J. Ringrose and J. C. Zarnecki, Planetary and Space Science Research Institute, The Open University, Walton Hall, Milton Keynes, MK7 6AA, UK., t.j.ringrose@open.ac.uk

Introduction: Dust Devils are relatively common occurrences both here on Earth and on Mars. These warm core vortices form at the bottom of convective plumes, which are reliant on surface heating for their resulting formation. The formation of these vortices is dependent on the correct weather conditions, namely a low ambient wind speed and superadiabatic boundary layer, [1].

When dust devils or convective vortices form they can be identified by specific meteorological parameters, referred to here as a 'signature'. If martian and terrestrial dust devil signatures are compared similarities can be identified.

Detailed studies of dust devil occurrence have been carried out for terrestrial, and to a limited extent martian dust devils. This occurrence data is important in predicting and recognising the formation of dust devils or convective vortices at future martian landing sites.

Dust Devil Parameters: The passage of a dust devil changes certain meteorological parameters. These parameters can be characterized and then used to identify dust devils. Typical dust devil signatures are available for Earth and Mars and show similarities. If martian and terrestrial dust devil signatures are compared they appear to have similar characteristics. Both have a similar change in wind direction, temperature, pressure, and both have a life cycle of minutes. It can also be assumed that the Pathfinder vortex shown in figure 1 had a change in wind speed, although data is not available due to problems with the wind sensor.

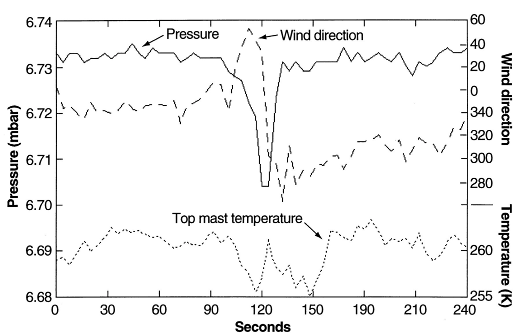

Figure 1 shows the signature of a Martian dust devil observed by Mars Pathfinder, [2].

Simple modelling of the vortex signature can be done using the Rankine vortex method, developed by William Rankine (1820-1872), which describes the nature of the wind flow within an atmospheric vortex. Essentially as a dust devil passes over an observer the wind speed will increase at a rate inversely proportional to the radius, to a maximum at the vortex core boundary. Wind speed then decreases linearly to the core centre. Figure 2 shows four graphs representing a dust devil with a diameter of 50m, and a maximum rotational wind speed of 35ms^{-1}, the graphs show the difference in dust devil signatures. The top graphs represent a 'missed core' event, and the bottom graphs show a 'through core' event. This modelling technique is used to identify convective vortices in meteorological data, and to estimate core miss distance, maximum rotational wind speed, and the radius of martian and terrestrial dust devils.

Temporal Dust Devil Occurrence: It is important to analyse the occurrence data from different studies to help in the detection of convective vortices by future Mars orbiters and landers. Dust devils mainly occur in dry desert landscapes on Earth and Mars. The discovery of dust devils on Mars in the 1970's has helped explain the cause of some of the seasonal dark features on the surface of Mars.

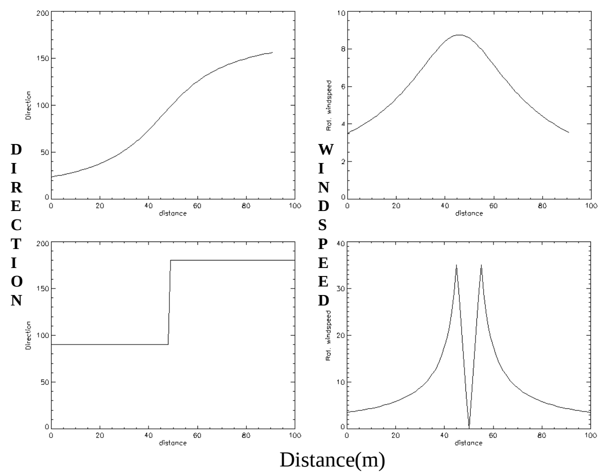

Figure 2

Dust devils do seem to appear everywhere on the planet, but are most common in the equatorial regions. Some limited occurrence data is available for the two Viking lander sites, [3]. These data only show the time of year, illustrated in figure 3. The time of day data is limited to a few dust devil signatures published by Ryan (1983), although the author is analysing Viking lander 2 data for time of day statistics.

Occurrence of convective vortices is connected to the rate of surface heat flux, which is directly related to the Sun's input. The maximum heat flux generally occurs during the hottest part of the day. This is illustrated in table 1, which shows the mean time of maximum vortex formation for Pathfinder and two terrestrial studies, [4].

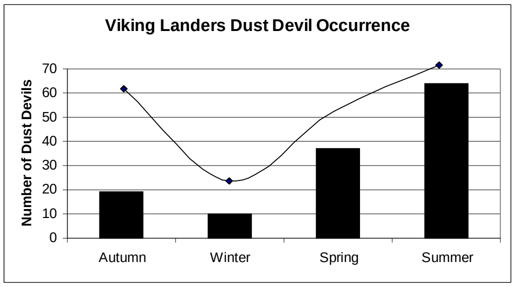

Figure 3 shows the distribution of the dust devils detected by Ryan et al. The curve represents the trend of the seasonal heat flux.

It is shown using the limited data from Mars and the comprehensive terrestrial analysis carried out by Sinclair, [4], that the peak occurrence is between 11 a.m. and 1 p.m. This is to be expected, this time of day will produce the maximum amount of convective heating of the atmosphere in direct contact with the surface. When comparing the data presented it should be noted that the Pathfinder data is in local martian time, and the Sinclair data has been adjusted for American Summer time. These data are important for future Mars missions, giving an indication of when convective vortices will form.

Data Set	**Mean Time**	**Standard Deviation**
Pathfinder	12:03	1.36
Sinclair, area 1,	12:22	1.48
Sinclair, area 2	12:36	1.53

TABLE 1.

The European Space Agency's mission to Mars, Mars Express, is carrying a Mars lander. Beagle 2 is scheduled to land on the martian surface on 26th December 2003 and will be searching for evidence of past or present life. The lander contains a number of instrument packages one being the Environmental Sensor Suite (ESS), [5], which will monitor the atmospheric conditions on the surface of Mars. One of the objectives of the ESS is to look for convective vortices, using temperature, pressure, wind speed, and wind direction sensors. With the occurrence data already collected it is possible to estimate the time of maximum occurrence, how often they should occur, and an indication on the dimensions of the expected dust devil.

Beagle 2 is scheduled to land during the martian winter, and has an expected lifetime on the martian surface of 180 sols taking the spacecraft into the martian spring. The Beagle 2 landing site will be ~10^0N, so dust devil occurrence should be similar to that of the Viking lander 1, which experienced convective vortices on approximately 34% of sols analysed during the winter/spring period, [3]. This indicates that approximately 60 vortices will pass near or over the Beagle 2 lander.

Conclusions: Dust Devils were first observed on Mars in 1976 by the Viking Orbiters and Landers and later by Mars Pathfinder in 1997. Dust devils are formed from convective heating and thus are more likely to form during the hours of 11:00 a.m. to 1:00 p.m., the time of maximum surface heating; which is consistent with existing data. Terrestrial and martian dust devil signatures are similar, although martian wind speeds may be higher. The Rankine vortex model is used to identify certain vortex parameters. These parameters can then be used to identify dust devil 'signatures' as they pass over a surface meteorological package. From analyzing previous dust devil studies it is possible to say that the Beagle 2 landing site will experience approximately 60 convective vortices during its 180 sol lifetime.

References: [1] Carroll J. J. and Ryan J. A., 1970, Atmospheric Vorticity and Dust Devil Rotation, JGR, Vol. 75, No. 27, pp 5179-5184. [2] Schofield J. T. et al., 1997, The Mars Pathfinder Atmospheric Structure Investigation/Meteorology (ASI/MET) Experiment, Science, vol. 278, pp1752-1758. [3] Ryan J., Lucich R., 1983, Possible dust devils, vortices on Mars, JGR, 88,C15, pp 11005-11011. [4] Sinclair P., 1966, A quantitative analysis of the dust devil, University of Arizona, PhD. [5] Towner, M. C. et al., 2000, The Beagle 2 Environment Sensors: Instrument Measurements and Capabilities, 31st Lunar and Planetary Science Conference, March 13-17, Houston, Texas, abstract no. 1028.