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Forecasting atmospheric dust loading on Mars using statistics of past observations

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1. Introduction

The onset of local dust storms on Mars can happen very suddenly, and the development into large regional or even planetary-encircling storms can be rapid and rather unpredictable, taken into account the current knowledge of dust lifting mechanisms and meteorological feedback.

Forecasting at least the dust optical depth of the atmospheric column (if not the dust opacity profile and the size of the dust particles) expected at a particular location and season is a key issue for safe spacecraft landing on Mars. Next spacecraft to land on the martian surface will be ESA's Exomars 2016 'Schiaparelli' module in Meridiani Planum (-6.1° lon, -1.9° lat) during the so-called 'dust storm season' (northern hemisphere winter, around L_s~245°). It will be followed by ESA's Exomars 2018 Rover and NASA's 2020 Rover, whose landing sites have yet to be confirmed, as of May 2015.

Although operative dust storm forecast currently presents significant challenges, a forecast based on the statistics of past information is more readily achievable, thanks to the plethora of dust optical depth observations available since the Mariner era. In particular, Montabone et al. [3] have reconstructed the atmospheric dust climatology at all locations on the planet from MY 24 through MY 31 using observations from the Mars Global Surveyor/TES, the Mars Odyssey/THEMIS, and the Mars Reconnaissance Orbiter/MCS. The multiannual dataset of daily gridded maps of retrieved IR column dust optical depth (CDOD) they have produced can serve the purpose of statistically forecasting the dust loading at selected seasons and locations on the planet. Specifically to Meridiani Planum and Gusev Crater, moreover, the Mars Exploration Rovers (MER) 'Opportunity' and 'Spirit' have continuously collected near-IR CDOD observations (as retrieved by Lemmon et al. [1]), from L_s~330°, MY 26, to date for Opportunity, and until L_s~67°, MY 29, for Spirit.

2. Statistical dust loading forecast

In this study, as a test-case of statistical dust loading forecast, we use the MER 'Opportunity' dataset [1] and the multiannual dust climatology dataset [3] to estimate the CDOD expected in Meridiani at the season of Schiaparelli's landing, and to examine how much the atmospheric dust loading can change (in statistical terms) over a given time period. In other words, we want to estimate the probability Y % that the CDOD changes by X % after n sols, for each sol within Schiaparelli's extended landing window (L_s=[220°, 270°]) in the Meridiani Planum area.

The lower panel of Fig. 1 shows that, in this particular case, the dust loading decreases with time after sol-of-year 475 (see the sol-based Mars calendar in [3]), L_s~245°. The histogram of the CDOD relative difference for "10-sol ahead of time" conditions in Meridiani clearly shows the signature of this decrease – a significant negative bias in the mean value (Fig. 2, including all years). This happens despite regional dust storms occurring in MY 27 and 29, and a planet-encircling dust storm occurring in MY 28, within the considered time range (Fig. 1). The cumulative histogram in Fig. 3 allows us to estimate the probability of dust loading change (independently of increase or decrease) in Meridiani for "10-sol ahead of time" conditions.

When looking at the specificity of Meridiani Planum during the considered season, Fig. 4 illustrates that it is rather representative of the global situation. The histograms are obviously smoother (more grid points are taken into account), but the negative bias in the mean value due to the general decrease of the dust loading after sol-of-year 475 is still present.

The global decrease in dust loading after L_s~245° can be linked to the solsticial pause in baroclinic wave activity [2], which considerably reduces dust lifting in the northern plains. This phenomenon has the consequence of reducing the probability of large regional cross-equatorial storms, which are one of the main sources of dust loading increase in the northern hemisphere autumn and winter seasons.

3. Figures

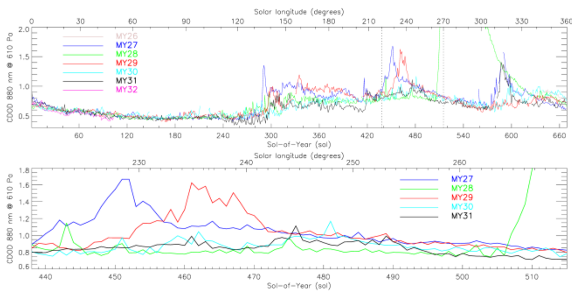

Figure 1: Time series of near-IR (880 nm) CDOD as retrieved by [1] from MER 'Opportunity' at Meridiani Planum over 7 Mars years (data are plotted until L_s~50° in MY 32, although Opportunity is still collecting observations as of May 2015). The dashed vertical lines in the upper panel indicate the time range considered in the lower panel and in the subsequent analysis. The CDOD values are normalised to the 610 Pa reference pressure.

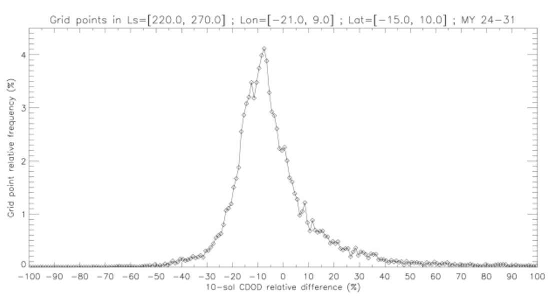

Figure 2: Using the Montabone et al. [3] multiannual dust climatology dataset, we have calculated the CDOD relative difference between each sol in the solar longitude range L_s=[220°, 270°] and 10 sols ahead in time, within a grid box centred on Meridiani Planum ([-21°, 9°] lon, [-15°, 10°] lat), for Martian years 24 through 31. This figure shows the histogram of this relative difference.

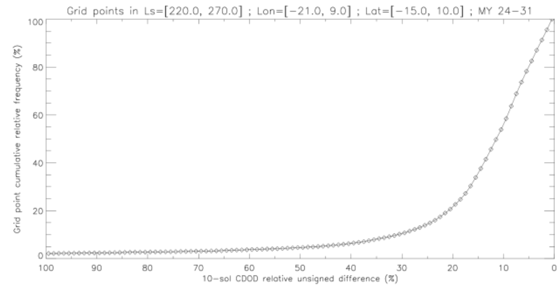

Figure 3: Cumulative histogram for the absolute value of the same variable as in Fig. 2.

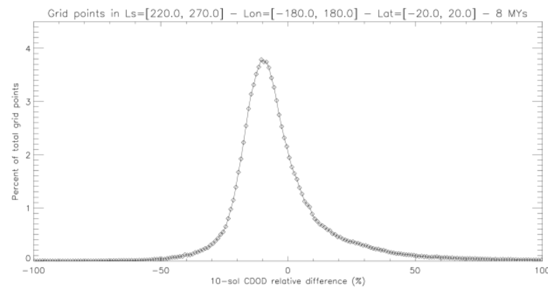

Figure 4: Same as in Fig. 2 for a latitude band [-20°, 20°] and all longitudes.

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References

[1] Lemmon, M.T., M.J. Wolff, J.F. Bell III, M.D. Smith, B.A. Cantor, P.H. Smith: Dust aerosol, clouds, and the atmospheric optical depth record over 5 Mars years of the Mars Exploration Rover mission. Icarus 251, 96-111, 2015.

[2] Lewis, S.R. D. P. Mulholland, P. L. Read, L. Montabone, R. J. Wilson, and M. D. Smith: The solsticial pause on Mars: 1 A planetary wave reanalysis; preprint submitted to Icarus, 2015.

[3] Montabone, L., F. Forget, E. Millour, R.J. Wilson, S.R. Lewis, B. Cantor, D. Kass, A. Kleinboehl, M.T. Lemmon, M.D. Smith, M.J. Wolff: Eight-year climatology of dust optical depth on Mars. Icarus 251, 65-95, 2015.