BUILDING THE LONG-TERM, MULTI-INSTRUMENT RECORD OF LARGE-SCALE DUST EVENTS ON MARS

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Introduction:

We have had almost uninterrupted observations of dust from orbit for more than 20 years to date. Missions like Mars Global Surveyor (MGS), Mars Odyssey (MO), Mars Express (MEx), and Mars Reconnaissance Orbiter (MRO) have been contributing to accumulate a long-term, multi-instrument record of dust observations yet to be fully analysed. More recently, instruments aboard the Trace Gas Orbiter (TGO), and the Emirates Mars Mission (EMM, or "Hope") have joined the effort to observe dust on Mars and extend the long-term record further. Sporadic dust observations have also been provided by the Mars Atmosphere and Volatile Evolution (MAVEN) mission, the Mars Orbiter Mission (MOM, or "Mangalyaan"), and the Tianwen-1 orbiter (although observations from this last mission are not readily available).

Such a long-term and multi-instrument record can be used to identify dust events occurring on Mars in the last two decades (13 Martian Years –MY- and counting). Several types of events can be distinguished, in terms of spatial and temporal scales: dust devils, local dust storms, regional dust storms, up to extreme, planet-encircling dust events (also plainly called "global dust storms"). In our work, we focus on large-scale events lasting several sols, i.e. "regional" and "global" dust storms.

Production of MY24-MY36 daily dust maps:

The plethora of dust observations carried out more or less discontinuously and asynchronously by different instruments aboard different missions, operating at different wavelengths, require the application of techniques of data reduction and integration. We have developed an iterative, weighted, running mean methodology to grid the available retrievals of infrared column dust optical depth (CDOD) from MGS/TES and MO/THEMIS nadir observations, as well as the estimates of this quantity from MRO/MCS limb observations [1, 2]. The application of this methodology produces daily gridded maps of CDOD from MY 24 to the current MY 36 (see Figs. 1 and 2). Given the lack of dust observations at certain times and locations, the daily gridded maps have missing values at some grid points. Kriging spatial interpolation can be used to produce regular maps that are useful as multiannual dust scenarios for model simulations, and for the Mars Climate Database (MCD) statistics [3]. This is a long-term, ongoing project, which makes continuous use of new observations and routinely updates its methodology in order to build a reliable dust climatology. For instance, MGS/TES infrared CDOD retrievals for MY 24 to MY 27 have been recently updated and included in the production of the corresponding gridded daily dust maps. Updated infrared retrievals (as well as new visible retrievals of CDOD from MGS/TES emission phase function sequences) and dust maps are going to be available on NASA PDS Atmospheric node in ASCII format. Dust maps will subsequently become available on the MCD webpage in NetCDF format, as is the case for currently available maps.

Analysis of the large-scale dust events:

Once the asynchronous information on infrared CDOD from different instruments is reduced to synoptic, daily maps (taking into account limitations and uncertainties), we can carry out an analysis of the large-scale dust events with multiple goals: 1) building a long-term record of key dust event characteristics (e.g. time series of storm location, area, and optical depth. See Fig. 3 for an example of time series of storm area), 2) validating this record using independent data (e.g. derived from observations at visible wavelengths), and 3) producing reliable statistics for Mars science and exploration (e.g. leading to statistical dust storm prediction -i.e. not including the temporal dimension- or forecasting).

References:

[1] Montabone, L., et al. (2015) Icarus 251, pp. 65-95, doi: 10.1016/j.icarus.2014.12.034

[2] Montabone, L., et al. (2020) J. Geophys. Res. - Planets, doi: 10.1029/2019JE006111

[3] http://www-mars.lmd.jussieu.fr

Publicly available gridded and kriged CDOD maps can be found by clicking on the "climatologies of Martian atmospheric dust" link under "Martian dust Climatology" at the above MCD webpage.

Figures:

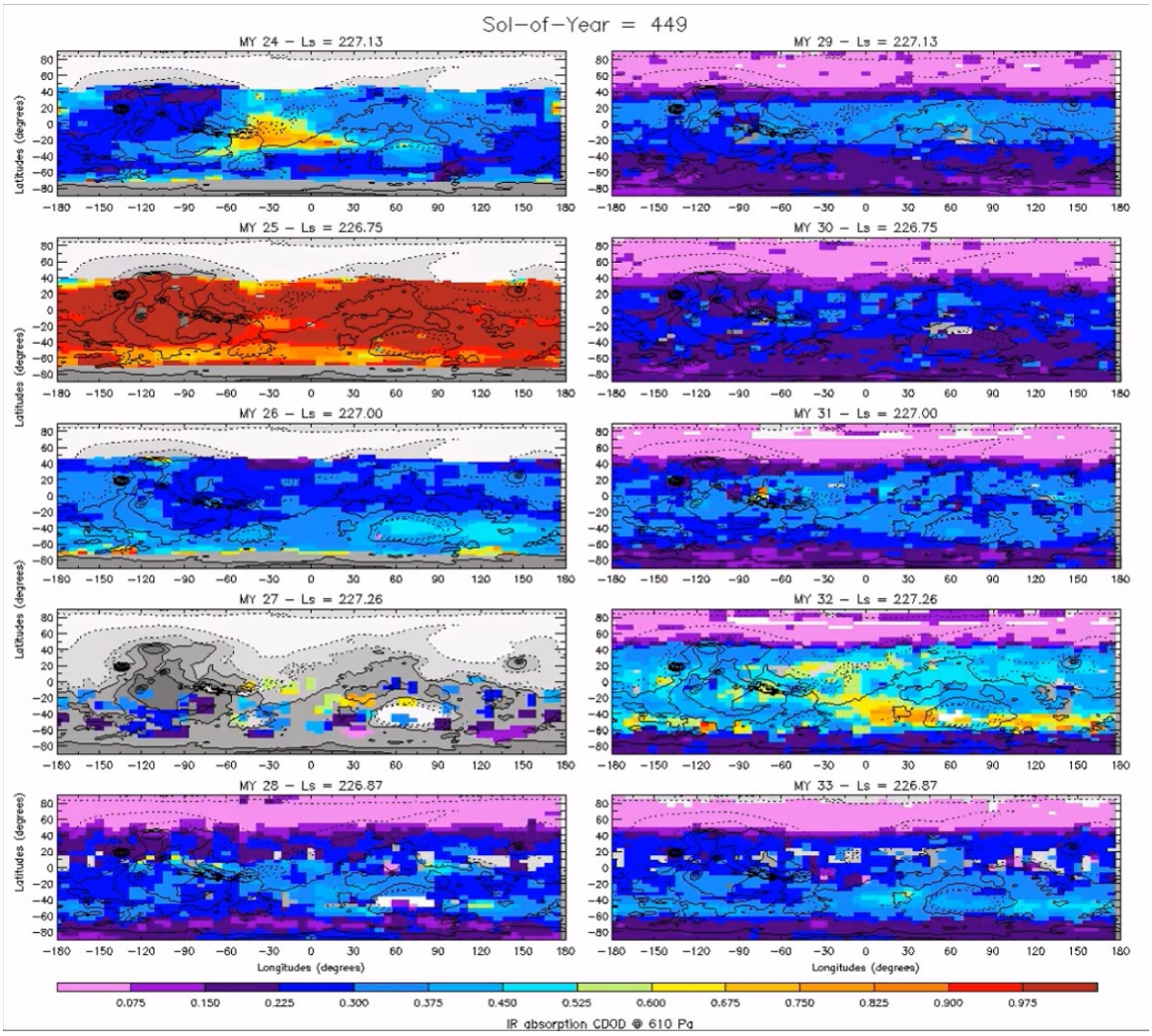

Figure 1: Examples of daily CDOD gridded maps normalised to the reference pressure of 610 Pa at Sol-of-Year 449 ($L_S \approx 227°$) in MY 24 to 33. No kriging interpolation is applied to produce these maps, only the iterative weighted gridding detailed in [1, 2]). See Appendix 1 in [1] for the definition of the sol-based Martian calendar used in these maps. It can be observed that MY 24 has a regional dust storm developing at the time when other regional dust storms develop in MY 27 and MY 32, and an extreme, planet-encircling dust event ("global dust storm") develops in MY 25. It is difficult to assess the development of the storm in MY 27, because of the lack of observations, but the development of the other storms in MY 24, MY 25, and MY 32 can be tracked throughout the daily maps. A full animation of the gridded maps of daily CDOD in MY 24 to 33 is available on the MCD webpage dedicated to the Martian Dust Climatology, or clicking this link. The same animation but for kriged maps of daily CDOD is available by clicking this link.

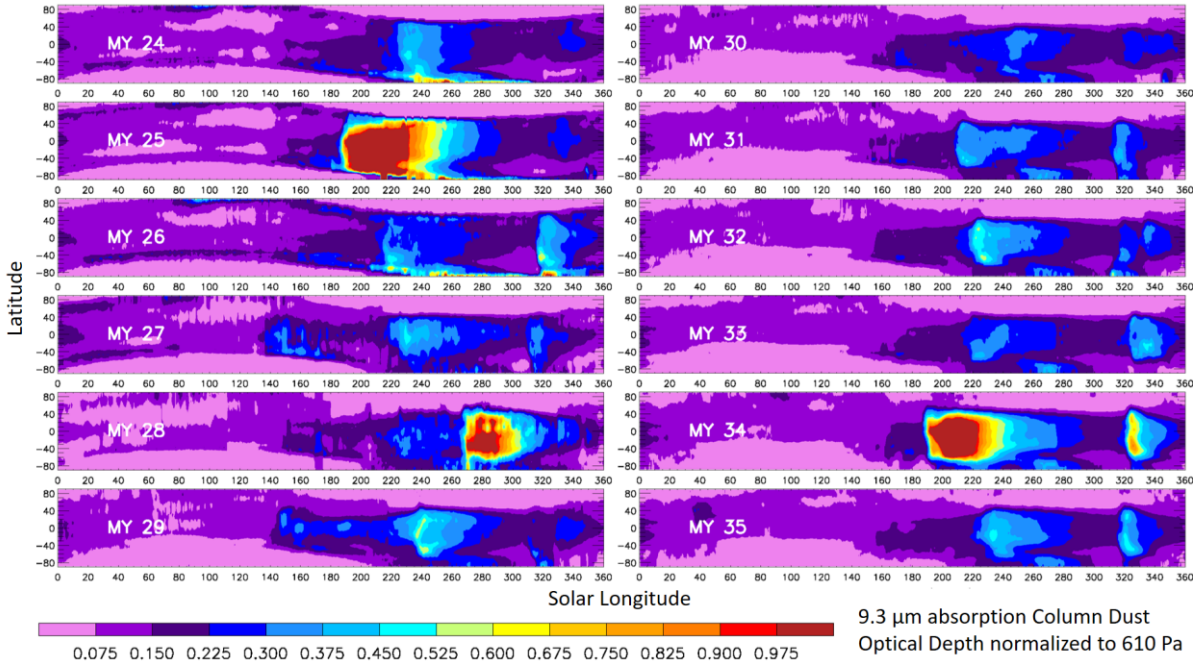

Figure 2: Multi-annual zonal means of kriged CDOD maps normalised to the reference pressure of 610 Pa, plotted as a function of latitude and solar longitude. The corresponding zonal mean plot for gridded CDOD maps is available on the MCD webpage dedicated to the Martian Dust Climatology, or clicking this link.

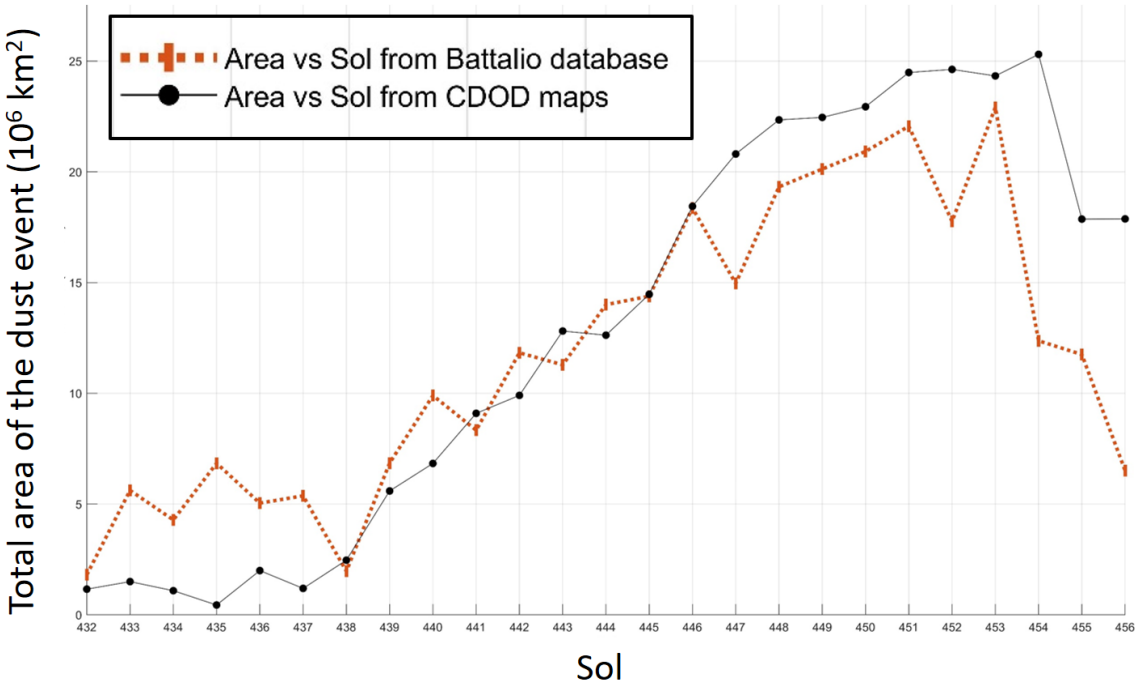

Figure 3: Example of time series (as a function of Sol-of-Year) of total area of a regional dust storm calculated from the daily gridded maps of (non-normalised) infrared CDOD (9.3 µm in absorption) compared to the same quantity provided by Battalio & Wang, Icarus 354, https://doi.org/10.1016/j.icarus.2020.114059 (2021) using MGS/MOC RGB images. The regional dust storm analysed here is the MY 24 storm occurring around $L_S \approx 227°$ and shown in the upper left panel of Fig.1. The area of the storm in the CDOD maps is calculated by selecting the grid points with CDOD > 0.35 (assumed as threshold value between the storm zone and the non-storm zone).