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# Using Reconstructed Dust Climatology to Study the Impacts of Martian Dust Storms on Dynamics

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## Abstract

We have reconstructed the climatology of the dust on Mars using available retrievals and estimates of total dust optical depth covering several Martian years. Two reconstructions are currently available with open access: 1) a reanalysis of the atmospheric state (including the column dust optical depth) for Martian years (MY) 24-27 using the Mars Analysis Correction data assimilation technique (MACDA), and 2) a reconstruction of the dust optical depth climatology based on weighted gridding for Martian years 24-30. These multiannual climatologies of dust optical depth can be used in climate models to produce reliable estimates of the thermal forcing induced by dust storms. This is an essential step towards the study of the impacts of the dust storms on the atmospheric dynamics, for which we will provide two examples.

## 1. Introduction

The dust cycle is currently considered as the key process controlling the Martian climate variability at interseasonal and interannual time scales, as well as the weather variability at much shorter time scales. The atmospheric thermal and dynamical structures, as well as the transport of aerosols and chemical species, are all strongly dependent on the dust spatio-temporal distribution, particle sizes, and optical properties. -In particular, local, regional and planet-encircling dust storms strongly affect the variability on a range of spatial and temporal scales. The enhanced absorption of solar radiation during a dust storm induces a local thermal forcing. This forcing (depending on its magnitude, extension, and location) can alter the dynamical state of the atmosphere, producing effects locally and remotely.
The knowledge of the spatio-temporal distribution of dust opacity associated with dust storms is, therefore, of primarily importance to study the impacts on the atmospheric dynamics, in other words, the "weather" on Mars. This knowledge can be acquired by reconstructing the long term climatology of the dust on Mars using all available observations.
In this paper, we describe two ways by which the dust climatology has been reconstructed on Mars, and we provide two examples where this reconstruction helps to highlight the connection between dust storms and atmospheric dynamics.

## 2. Reconstructed Dust Climatology

In order to reconstruct the dust climatology from observations, we have used:

- **Data assimilation** of Mars Global Surveyor / Thermal Emission Spectrometer (MGS/TES) retrievals of thermal profiles below about 40 km altitude and total dust optical depths. This reconstructed climatology (including but not limited to dust) covers almost 3 years, from MY 24 late summer (North hemisphere) to MY 27 early spring [4].
- **Weighted gridding** of retrievals of total dust optical depth from MGS/TES and Mars Odyssey / THEMIS nadir observations, as well as estimates of total dust optical depth from Mars Reconnaissance Orbiter / Mars Climate Sounder (MRO/MCS) limb and off-nadir observations. This reconstructed dust climatology covers almost 7 complete years (MY 24-30) [6].

Data assimilation techniques (such as the Mars Analysis Correction scheme, [2]) have the advantage of combining state-of the-art global climate models with observations to produce a best estimate of the atmospheric state throughout a historical period ("reanalysis"). They allow access to variables which are not directly observed, such as wind components, vorticity, dust vertical distribution and particle sizes (see also [8]), dynamically consistent with observed variables. The application of the weighted gridding technique, on the other hand, has the advantage of combining all available dust optical depth observations from several different instruments, including sparse observations like THEMIS, and providing an estimate of uncertainties which is not available with the AC data assimilation scheme. To obviate the fact that the maps produced with the gridding technique might have spatial and temporal gaps because of lack of observations, we have spatially interpolated the gridded data using a kriging method. These complete maps, which are based on stated assumptions to obviate for the lack of observations in certain regions and at certain times, can be directly used as realistic dust scenarios in models of the Martian atmosphere. Both the reconstruction of the dust climatology based on weighted gridding/kriging and the climatology based on the MACDA for MGS/TES are publicly available.

# 3. Impact of Dust Storms on Dynamics: Two Examples

## 3.1 MY 25 planet-encircling dust storm

The MY 25 planet-encircling dust storm ($L_s$~180°) was the result of a sequence of regional storms which together created a diffuse and global dust haze lasting for tens of sols [1]. The comprehension of such a global event requires the study of meteorological phenomena operating at different spatial and temporal scales, before, during and after the onset of the storm in Hesperia Planum. Nonetheless, two main dynamical factors are relevant to understand its evolution: 1) the transport by equatorial westerlies of dust lofted to high altitudes in Hesperia towards Tharsis, and 2) the change in the phase difference between the diurnal component of the (migrating) thermal tide and the diurnal Kelvin mode, induced by the local thermal forcing in Hesperia. The dust front that moved towards Tharsis and its associated temperature contrasts might have enhanced the surface winds, and activated secondary lifting centers in Daedalia/Solis Planum/Syria [7]. This effect might also have been achieved by the modification of surface pressure and wind patterns induced “at distance” by the change in thermal tides (“dynamical teleconnection event”, [3]). The study to attribute a relative importance to these two factors is ongoing.

## 3.2 MY 26, $L_s$~320° regional dust storm

We also show that regional dust storms in the southern hemisphere can have profound impacts on the morphology of the northern hemisphere vortex, causing the vortex area and strength to reduce, and the polar air to warm up. This Martian “sudden polar warming” event is another example of dynamical teleconnection event. Similarities and differences with terrestrial stratospheric sudden warmings (SSW) are discussed in [4] (this issue).

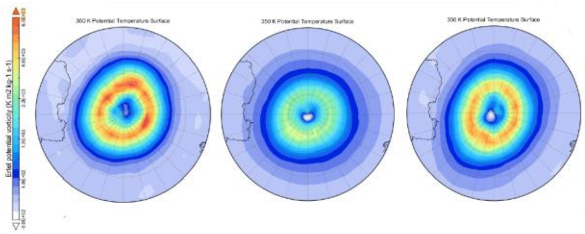

Figure 1: These Ertel PV maps on the 350 K potential temperature surface are separated by 15 sols and centred on $L_s$=324° in MY 26. They show the impact of a regional dust storm occurring in the southern hemisphere on the northern polar vortex.

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