IMPROVED DUST CLIMATOLOGY ON MARS WITH NEW AND REVISED MGS/TES AEROSOL RETRIEVALS

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Acronyms: MY → Martian Year, CDOD → Column Dust Optical Depth, EPF → Emission Phase Function, MGS → Mars Global Surveyor, TES → Thermal Emission Spectrometer, MOC → Mars Orbiter Camera, MO → Mars Odyssey, THEMIS → Thermal Emission Imaging Spectrometer, MRO → Mars Reconnaissance Orbiter, MCS → Mars Climate Sounder, CRISM → Compact Reconnaissance Imager Spectrometer for Mars, MARCI → Mars Color Imager, MER → Mars Exploration Rover, MSL → Mars Science Laboratory, MeX → Mars Express, PFS → Planetary Fourier Spectrometer, OMEGA → Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité, TGO → Trace Gas Orbiter, PDS → Planetary Data System

Introduction: The spatial and temporal distributions of dust aerosol are essential observables for any fundamental or applied study related to the Martian atmosphere, including weather monitoring and forecast for robotic and possible future human exploration missions.

In the past Martian decade (MY 24 to 33), three datasets providing quantitative information on the dust distribution became publicly available – those retrieved from MGS/TES, MO/THEMIS and MRO/MCS observations. The information in the horizontal, longitude-latitude plane is specifically presented as CDOD values at infrared wavelengths. Another instrument –MeX/PFS- could have the potential to provide an additional key dataset of CDODs, covering multiple local times. Several other datasets are available, but their coverage is less ideal for providing continuous global quantitative information on the dust distribution (e.g. the datasets retrieved from observations by MRO/CRISM, MeX/OMEGA, the PanCam cameras aboard the MERs, the MastCam camera aboard MSL, etc.). Finally, qualitative information on the dust distribution can be directly obtained by visible images taken by orbiting cameras such as MGS/MOC, and MRO/MARCI. TGO will have the capability to add new information on the dust distribution, extending the climatology in the next Martian decade.

Montabone et al. [1] used retrieved TES, THEMIS, and estimated MCS infrared CDODs to produce gridded daily maps of the 2D dust distribution from L_S~104° in MY 24 through the end of MY 31. Recently, this publicly available gridded dataset has been extended to MY 32 and 33 [2]. While producing their multi-annual dataset of dust climatology, [1] noticed that there were some systematic differences between the years observed by TES and those observed by MCS. In particular, the main differences could be seen at the polar cap edges, and in the polar regions in general (see [1], Fig. 18, and Section 5).

Because of the results of this climatological inter-comparison between two different instruments aboard two different spacecraft, we decided to carry out a detailed revision of TES retrievals of infrared CDOD, as well as to retrieve new CDODs in the visible using TES solar band EPF sequences (see e.g. [3, 4]).

We present the latest results of this ongoing work, also to stress the importance of instrument inter-comparison at the dawn of TGO era.

TES IR and VIS aerosol retrievals: We have made significant progress in developing an improved retrieval for aerosol optical depth using TES infrared spectra. The retrieval algorithm is based on the existing TES retrievals delivered to the PDS ([5]), but has several key improvements that increase the latitude coverage and the accuracy of valid retrieved values for dust as well as water ice optical depth. Specifically, the criterion for performing a retrieval has been changed from a strict minimum surface temperature (e.g. T_{surf}>210 K) to a numerical determination of the sensitivity of each observation to a change in the aerosol optical depth. This new approach is more physically based, allows a greater latitude range of observations to be retrieved, and enables a meaningful uncertainty to be estimated for each individual retrieval. In addition, an error in the original TES retrieval algorithm has been isolated and fixed that had caused biases in retrieved optical depth when surface temperatures were cool. An improved calibration of TES observed radiances has also been used ([6, 7]). These improvements have yielded new insights into winter hemisphere aerosol optical depth and have moved the TES retrievals into better agreement with those from MCS.

We have also made progress in developing the retrieval for aerosol optical depth using TES solar band EPF sequences. The solar band retrieval uses the Hapke function for modelling surface reflectance on bare land, and Lambert albedo for icy surfaces in the polar regions.

Results: We have mainly focused on three "seasons" where the disagreement between TES and MCS was the strongest: around northern summer solstice (L_S = 80°-100°), around northern autumn equinox (L_S = 165°-185°), and around northern winter solstice (L_S = 250°-310°). In Figure 1 we show the comparison between old infrared retrievals (left panels) and revised retrievals (right panels) for dust in the three seasons. At low latitudes the revised retrievals are essentially the same as the old. The revised retrievals give a bit more latitude coverage and they have trends at the latitude extremes that agree better with other instruments. For the L_S = 165°-185° sets, there is generally lower dust opacity at the southern edge. For the L_S = 250°-310° sets, the revised retrievals show low dust opacity in the far north (winter). The revised retrievals quickly become very noisy at the highest latitudes. The new uncertainty estimate is based on (1 / thermal contrast) and scaled by an estimate of the instrument noise. The uncertainty provides an objective constrain about quality and reliability when using these data.

As for TES visible CDOD retrievals, we have tested the code on the northern summer solstice (L_S = 80°-100°) season, and latitudinal trends in the distribution of visible CDODs seem to match those obtained using infrared ones.

An important aspect of this work is the validation of the new results using MGS/MOC visible images. This inter-comparison of quantitative and qualitative information has the potential to reveal biases and, therefore, to call for possible revisions of the retrieval assumptions. In order to properly validate our new TES retrievals, we use high-quality, map-projected MOC daily global images. Together with the standard false-color simple cylindrical daily global maps, we have produced false-color north polar stereographic maps, and false-color south polar stereographic maps using MOC wide-angle daily global mapping images taken between MY 24 and MY26.

Application to improved dust climatology: Once the new TES (infrared and visible) CDOD dataset will be completed and validated, we plan to update the gridded daily maps of dust available at [2], also including other technical improvements in the gridding methodology.

Use of these new retrievals in all other applications (e.g. data assimilation) is also planned. We expect that the legacy of the over 20-year-old TES instrument will contribute to establish reliable long-term climatology records of both dust and water ice on Mars, before TGO enters the climax of its science mission phase.

The new TES dust optical depths will be released to the NASA PDS Atmospheric Node at the end of the project.

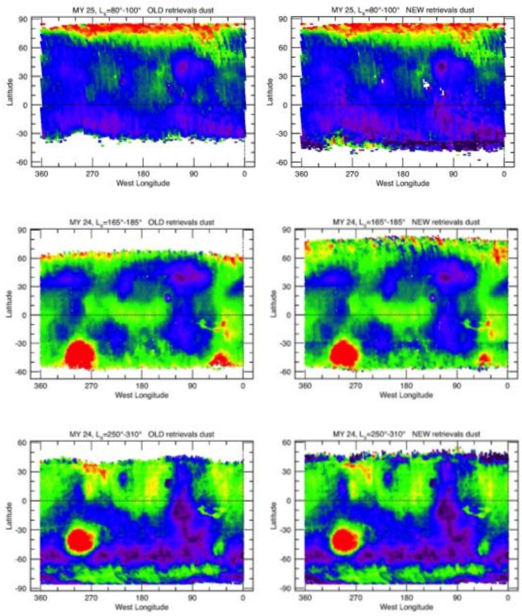

Figure 1: Comparison between TES "old" infrared retrievals (upper panels) and revised retrievals (lower panels) for dust in the 3 seasons mentioned in the text. We have applied smoothing with a 5° longitude x 2° latitude box that averages the median 40% of retrievals within the box.

References:

[1] Montabone, L., et al., **Icarus** *251*, 65-95, 2015. [2] The complete dataset is publicly available on the "Mars Climate Database" webpage: http://www-mars.lmd.jussieu.fr/mars/dust_climatology. [3] Clancy, R. T., et al., **J. Geophys. Res**. *108*, 5098, 2003. [4] Wolff, M. J., et al., **J. Geophys. Res.** *114*, E00D04, 2009. [5] Smith, M.D, **Icarus** *167*, 148-165, 2014. [6] Pankine, A., **Planet. Space Sci.** *109*, 64-75, 2015. [7] Pankine, A., **Planet. Space Sci.** *134*, 112-121, 2016.

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