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A multi-spacecraft reanalysis of the atmosphere of Mars

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Introduction: We have conducted a nine-Mars Year (MY) consistent reaanalysis of the martian atmosphere covering the period MY 24–32 and making use of data from three different spacecraft. Remotely-sensed measurements of temperature, dust opacity, water ice and ozone from NASA's Mars Global Surveyor (MGS) and Mars Recconaisance Orbiter (MRO) and ESA's Mars Express (MEx) were assimilated [1] into a single model simulation, sampled two-hourly over the whole period. This forms a large, regular re-analysis dataset that is being made publicly available as an output of the EU UPWARDS project. The same analysis technique, with an improved model and higher resolution will be conducted with ESA Trace Gas Orbiter (TGO) data as it becomes available, further extending the martian climatology.

This data set is similar in approach to the earlier MACDA reanalysis [2], but MACDA only made use of Thermal Emission Spectrometer (TES) thermal and total column dust opacity data from MGS, had a lower vertical resolution and only covered the first third of the period now analysed (just under three MY). In addition, the model used here includes a full water cycle and a photochemical scheme, with trace gas fields advected by the model winds. The ozone assimilation and procedure being developed to better handle dust are described in more detail in companion abstracts [3, 4].

We illustrate the potential of this new dataset by comparing the solsticial pause [5, 6] in each year.

Mars global circulation model and analysis correction scheme: The assimilation technique makes use of the UK version of the Laboratoire de Météorologie Dynamique (LMD) Mars global circulation model (MGCM). This 4D-model differs mainly from the standard LMD MGCM [7] in using a spectral dynamical core and a semi-Lagrangian advection scheme. MGCM physical submodels have been developed in a collaboration between the LMD, the Open University, the University of Oxford and the Instituto de Astrofisica de Andalucia. The model was run at T31 resolution in the horizontal, corresponding to a resolution of 5° latitude by 5° longitude, with 32 vertical levels in the range 0–105 km.

Assimilation is performed using a form of the Analysis Correction Scheme [8] adapted for martian conditions and the type of remotely-sensed data that is primarily used to constrain the MGCM [1].

Observations: This reanalysis uses TES termal and total opacity data, as did MACDA [2], but addes the wáter ice opacity and vapour retrievals where available. It also uses ozone retrievals from Spectroscopy for Investigation of Characteristics of the Atmosphere of Mars (SPICAM) aboard MEx [described in more detail in 9] and termal, dust and wáter ice opacity from Mars Climate Sounder (MCS) aboard MRO.

Reanalysis output: The full dataset is illustrated in the form of the zonally-averaged total dust optical depth throughout the nine-year period of the re-anaysis in Figure 1.

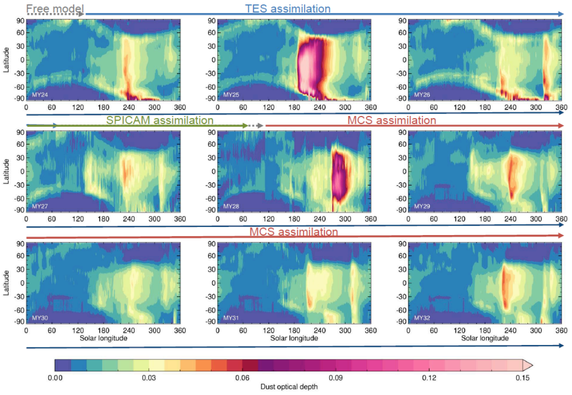

Figure 1: Longitudinally-averaged total dust optical depth from the reanalysis plotted for MY24—32 from top left to bottom right. The periods for which TES, SPICAM and MCS data were assimilated is shown by coloured arrows above the figures. A grey, dotted arrow indicates periods when no data was available to assimilate and the MGCM was effectively forecasting without coincident observational constraints.

Internannual variability and the solsticial pause: One of the most striking feaures of Fig. 1 above is the year-to-year variation in the martian dust loading, in particular in Northern Hemisphere Winter (the second half of the martian ear shown in the panels above.

Figure 2 shows the amplitude of the martian planetary wave activity versus latitude over the TES assimilation period of this figure and shows evidence of the martian solsticial pause, a clear reduction in the strength of the planetary waves centred on winter solstice (NH solstice is at L_S = 270°, SH solstice is at L_S = 90°) in each hemisphere and identified in the MACDA reanalysis by [3]. We will discuss the extent to which the pattern shown in Fig. 2 is reproduced through the new analysis and other evidence of interanual varaibility on Mars.

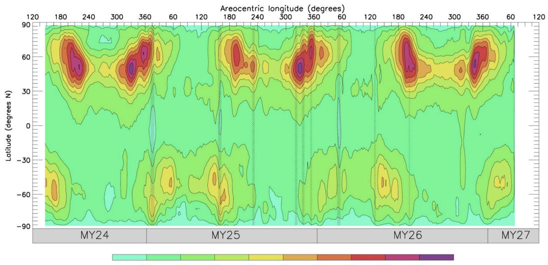

Figure 2: RMS temperature variability at 2.5 km altitude from the TES-period assimilation (mid-MY 24 to early MY 27), band-pass filtered to periods of 1.5–30 sols and with a 20-sol running mean applied. Hatching indicates no TES data. Figure adapted from [5].

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