A FIVE MARS YEAR CLIMATOLOGY FROM DATA ASSIMILATION USING MGS/TES AND MRO/MCS OBSERVATIONS.

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Introduction:

The Thermal Emission Spectrometer (TES, Christensen et al., 2000) on board Mars Global Surveyor (MGS) has produced an extensive atmospheric data set during its scientific mapping phase between 1999 and 2004, before eventually starting to fail. Nadir thermal profiles for the atmosphere below about 40 km altitude, and total dust and water ice opacities, have been retrieved from TES spectra (Smith et al., 2004), covering almost three complete Martian seasonal cycles, from L_s=141° in MY 24 through L_s=82° in MY 27.

These data have been analysed by assimilation into a Mars general circulation model (MGCM), making use of a sequential procedure known as the Analysis Correction scheme (Lorenc et al., 1991), a form of successive corrections method which has proved simple and robust under Martian conditions, even during the less-than-ideal MGS aerobraking period (Lewis et al., 2007).

A first version of our Mars re-analysis using only MGS/TES has been validated against independent MGS/radio occultation temperature profiles (Montabone et al., 2006a), and has been used to study the variability of dust storms (Montabone et al., 2005), thermal tides (Lewis and Barker, 2005), the effects of tropical water ice clouds (Wilson et al., 2008), Martian weather predictability (Rogberg et al., 2010), and the climatology of northern and southern hemisphere baroclinic waves (Read et al., this issue), among other topics.

One limitation of TES is that only a few limb profiles are available. Our first re-analysis, therefore, does not include observations of temperature above about 40 km altitude, nor 3D information on dust opacity (the vertical distribution of dust opacity is analytically prescribed using the so-called "Conrath" distribution").

In September 2006, a new NASA spacecraft, Mars Reconnaissance Orbiter (MRO), started its mapping phase. The Mars Climate Sounder (MCS) on board MRO is a radiometer with one visible channel and eight far-infrared channels, which can produce limb and near-nadir observations (McCleese et al., 2007). 3D retrievals of temperature, dust and water ice opacities from MCS observations (Kleinböhl et al., 2009) can now be assimilated using the same scheme we used for TES, with the advantage of the extension in altitude (thermal profiles can extend higher than 80 km altitude, although errors become larger), the increased vertical resolution (doubled with respect to TES), and the direct information on the vertical distribution of dust and water ice.

Overall, the application of our data assimilation scheme to observations from TES and MCS can span almost five complete seasonal cycles, including MY 24, 25, 26 (and early MY 27) from TES and MY 28, 29 (at the time of writing) from MCS. This represents a multi-annual climatology for Mars, which has the advantage of being a complete, balanced, four-dimensional best-fit to observations for all the atmospheric variables, including those for which no direct measurements are available (e.g. wind and surface pressure). It represents, therefore, a unique opportunity to study the inter-annual variability of the Martian weather and climate with respect to all its components, such as the dust cycle, the water cycle, the CO_2 cycle, the atmospheric tides and other prominent waves, such as high latitude baroclinic waves (see other dedicated abstracts in this issue, e.g. Liam et al., Read et al., Ruan et al.).

GCM(s) and Data Assimilation:

TES and MCS retrievals (temperature, dust and water ice opacities) are assimilated into the Martian Global Circulation Model (MGCM) which is in use at the University of Oxford and at the Open University (Milton Keynes), in the UK. This model consists of a spectral dynamical solver and a tracer transport scheme developed in the UK. Its package of state-of-the-art physical parameterization routines is shared with the LMD Mars GCM, and has been developed in a collaboration led by LMD, with the University of Oxford, the Open University and the Instituto de Astrofisica de Andalucia (Spain). There exist two main versions of this model; the oldest (v3) version is based on the physics package mainly described in Forget et al., 1999, while the newest (v5) version is based on the improvements to the physics package reported, for instance, in Forget et al., this issue. Our first version of the TES re-analysis was carried out using the MGCM v3. We are currently producing a new version of this re-analysis based on the MGCM v5, which will hopefully improve some of the issues described, for instance, by Montabone et al., 2006a. We are using the MGCM v5 for the assimilation of MCS observations.

The data assimilation scheme that is used with both TES and MCS retrievals is the sequential Analysis Correction scheme (Lorenc et al., 1991), adapted and tuned for Martian data assimilation. In the first instance, we are carrying out the assimilation of MCS observations in the way described in Montabone et al., 2006a for TES, although different settings are required, for instance, to take into account different vertical resolutions and extensions. Only 2D, vertically-integrated dust opacities are assimilated so far, and the vertical distribution of the dust is still provided by the Conrath analytical function. This first approach will allow us to build a consistent climatology of five Martian years observed by two different instruments. Short-term plans to include a full 3D advection of dust (and water ice) will allow to use the full capability of the MCS dataset (see below), although careful validation will be required.

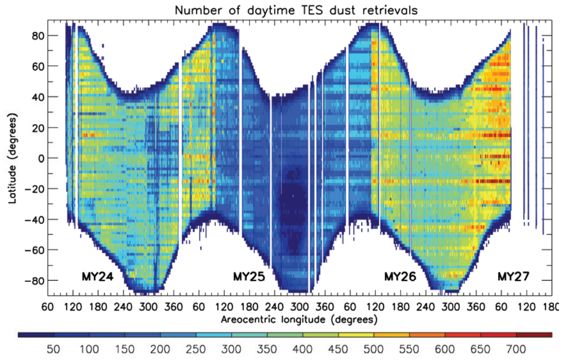

Figure 1: Number of available (daytime) MGS/TES dust optical depth retrievals, binned in 2° latitude and 1° areocentric longitude. Data cover most of MY24, MY25, MY26 and part of MY27.

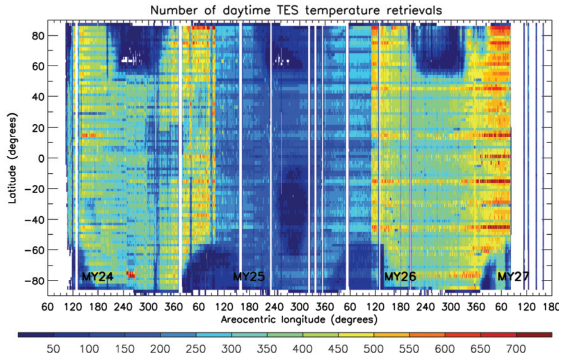

Figure 2: Same as Fig. 1, but for the number of available daytime temperature retrievals. Daytime retrievals are those in the local time range [6h, 18h].

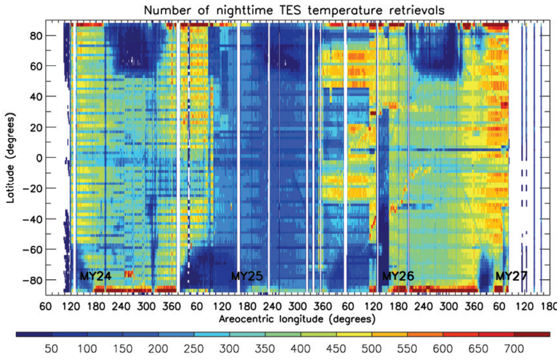

Figure 3: Same as Fig. 2, but for the number of available nighttime temperature retrievals. Nighttime retrievals are those in the local time ranges [0h, 6h] and [18h, 24h]

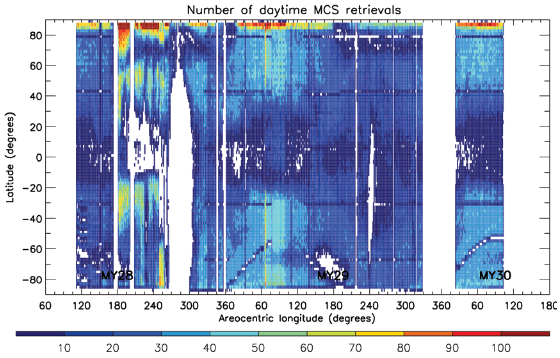

Figure 4: Number of available daytime MRO/MCS retrievals, binned in 2° latitude and 1° areocentric longitude. Data cover most of MY28, MY29, and part of MY30. Daytime retrievals are those in the local time range [6h, 18h].

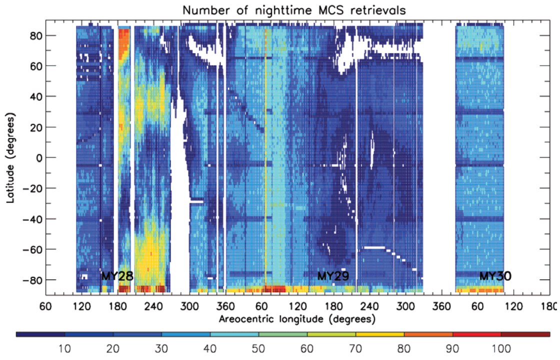

Figure 5: Same as Fig. 4, but for available MCS nighttime retrievals. Nighttime retrievals are those in the local time ranges [0h, 6h] and [18h, 24h]

Atmospheric Thermal Structure and Dynamics:

In this contribution we present the first results of a complete assimilation of both datasets and highlight the challenges of combining TES and MCS data assimilation to produce a climatology that spans five Martian years. Particular attention will be devoted to the inter-annual variability of the atmospheric thermal field, in response to dust storm activity. Given the fact that data assimilation provides balanced results for all atmospheric variables, an insight into the dynamics will also be provided, looking in particular at the high latitude winds and polar jets.

Future Improvements of Data Assimilation:

TES observations did not provide information on the vertical distribution of dust opacity, but this information is available in the MCS observations. We are currently in the process of combining the Analysis Correction scheme and the tracer advection scheme in our model, with the final goal of transporting assimilated dust and water ice fields consistently (see also Ruan et al., this issue). This will improve the performance of the data assimilation in periods and locations where the coverage of dust and water ice retrievals is currently poor (e.g. the polar nights for TES, or the tropical region for MCS), produce a consistent atmospheric state including the aerosols, and help to improve parameterizations of dust lifting and water ice cloud formation.

Availability of the Data Assimilation Products:

We intend to make our data assimilation products available to the community for both science and engineering-oriented purposes. The British Atmospheric Data Centre (BADC, http://badc.nerc.ac.uk/) will host our main re-analysis data which, in the short term, will be limited to the MGS/TES data assimilation. People may contact the corresponding author in order to register their interest and be updated about the status of the project.

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