DATA ASSIMILATION FOR MARS: AN OVERVIEW OF RESULTS FROM THE MARS GLOBAL SURVEYOR PERIOD, PROPOSALS FOR FUTURE PLANS AND REQUIREMENTS FOR OPEN ACCESS TO ASSIMILATION OUTPUT.

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Introduction

The Thermal Emission Spectrometer (TES) aboard Mars Global Surveyor (MGS) has produced an extensive atmospheric data set, both during the initial aerobraking hiatus and later from the scientific mapping phase of the mission which lasted almost three complete Martian seasonal cycles. Thermal profiles for the atmosphere below about 40 km, and total dust and water ice opacities, have been retrieved from TES spectra (Conrath et al., 2000; Smith et al., 2000).

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 the successive corrections method which has proved simple and robust in trial studies with artificial data under Martian conditions (Lewis et al., 1996, 1997).

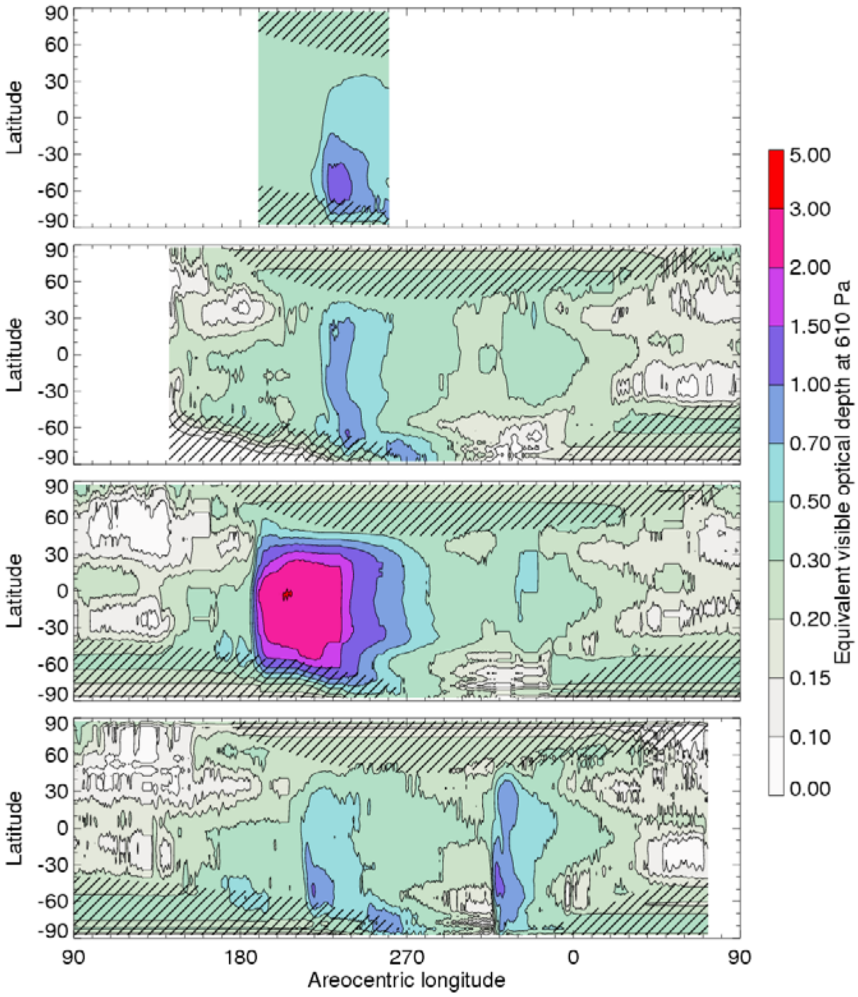

Figure 1: Assimilated dust optical depth at 610 Pa from the full assimilation period. Each panel shows one Martian year, Mars Years 23-26 from upper panel down, with summer solstice at the left-hand edge. The hatched regions indicate where there are few, if any, total opacity observations (mean surface temperature below 160 K)

Assimilation Period

The full period for which assimilated data is available is illustrated by Fig. 1, which shows the assimilated dust optical depth in the visible, at a standard reference pressure of 610 Pa. This now includes the aerobraking hiatus period (MY23, Ls=190–260), during which time the orbital period was being reduced from 45 to 24 hours and the configuration was more difficult for atmospheric assimilation. Lewis et al. (2006) describe the aerobraking phase assimilation in more detail. Following this, data are available throughout almost three Martian years of 2-hour, mapping phase orbits (MY24, Ls=141 to MY27, Ls=72). The Mars Year (MY) numbering scheme used here is that of Clancy et al. (2000).

As seen in Fig. 1, the MGS mapping phase covers an intriguing period with a relatively clear year, followed by a year featuring the large 2001 global dust storm. A final year initially appeared similar to the first, but then a second period of regional dust activity developed, close to the time of the Beagle 2 and MER landings. Initial studies of dust storm variability in these data include Montabone et al. (2005, and this issue).

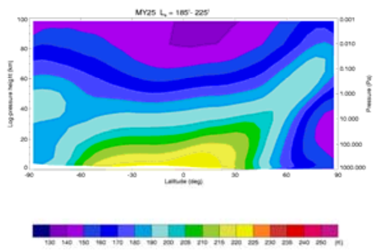

Figure 2: Zonal mean temperature for Ls=185-225 in MY25, the period of the global dust storm.

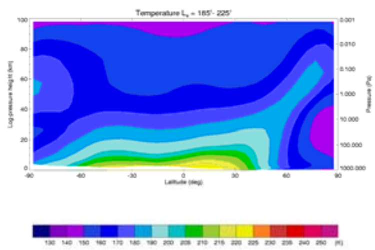

Figure 3: As Fig. 2, but for Ls=185-225 in MY26.

The 2001 Global Dust Storm

The impact of a global dust storm on the MGCM is illustrated by Figs. 2–7, which show a similar period in MY25, the year of the 2001 global dust storm, and MY26, the following year which had smaller, regional dust activity. The impact of the MY25 storm on temperature, wind and mean meridional circulation is clear. The later two quantities are not directly observed (nor is temperature above 40 km in this data set), but evolve in a consistent way during the assimilation as part of the full model state.

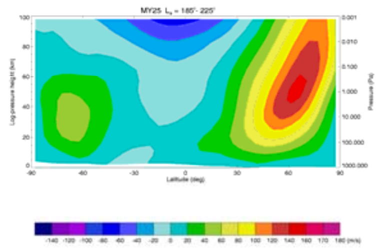

Figure 4: Zonal mean eastward wind for the period corresponding to Fig. 2.

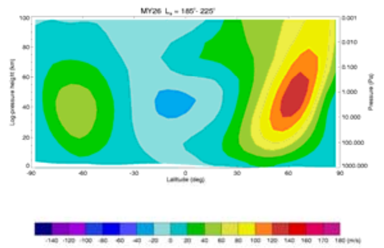

Figure 5: As Fig. 4, but for MY 26.

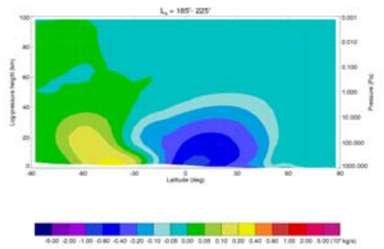

Figure 6: Mean meridional circulation during the 2001 global dust storm period of Fig. 2. Note the nonlinear contour interval.

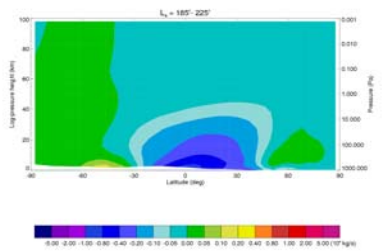

Figure 7: As Fig. 6, but for MY26.

Tides, Stationary and Transient Waves

One major motivation for using assimilation techniques is in order to investigate the transient wave behaviour on Mars, which is difficult to interpret when the observations are made asynchronously from a single orbiting spacecraft. Montabone et al.

(2006) discuss the analysis and validation of stationary waves in the assimilation. Lewis and Barker (2005) described the thermal tide behaviour, an analysis which is extended by Figs. 8 and 9 to show the diurnal and semidiurnal tidal amplitudes respectively throughout the MGS mapping phase. The correlation between the semidiurnal tide and optical depth (Fig. 1) is striking (e.g. Wilson and Hamilton, 1996).

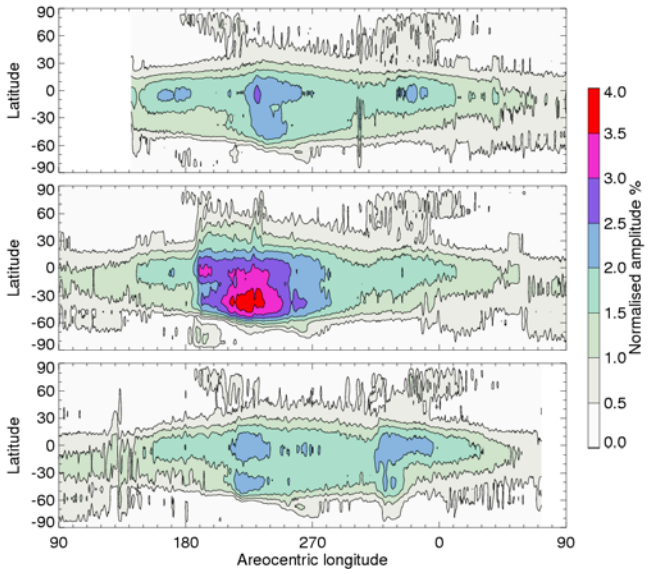

Figure 8: The normalised amplitude of the surface pressure signature of the diurnal tide, shown as a function of latitude and time during the MGS mapping phase, the same period as the lower three panels of Fig. 1 (Mars Year 24, Ls=141 to Mars Year 27, Ls=72).

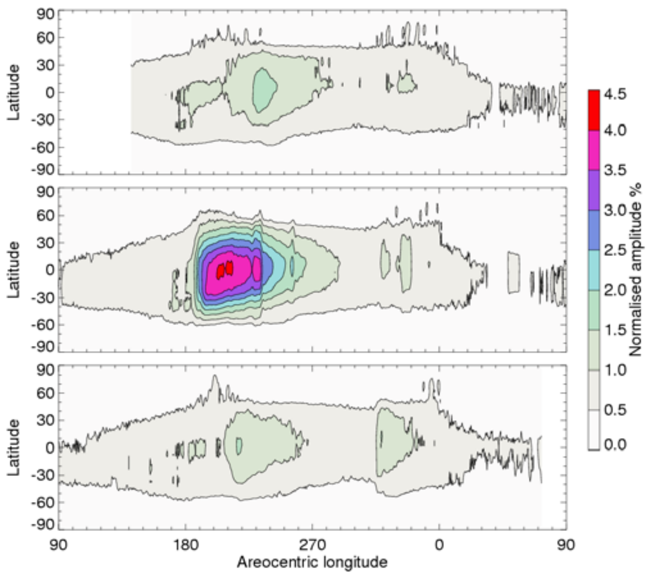

Figure 9: The normalised amplitude of the semidiurnal tide shown over the same period as in Fig. 8.

Entry Profiles

The assimilation of the MY26 data from Ls=320 onwards permits a detailed comparison with the Spirit and Opportunity landers, for which accelerometer entry profiles are available (see Withers, 2003, for analysis details), and for the entry location of the ill-fated Beagle 2 mission, see Fig. 10. In these cases, the assimilation is more consistent with the moderate dust loadings of the European Mars Climate Database (EMCD) “Viking dust scenario” than the clearer “MGS scenario” (based on the early MGS observations), in accordance with the slightly raised dust levels of this period, Fig. 1. The EMCD was used here to provide an ensemble of independent GCM runs. While the assimilation does not mimic small-scale features of the accelerometer retrievals, this could not be expected given that the assimilation profiles are from a global model, which represents large-scale processes but not small-scale waves explicitly.

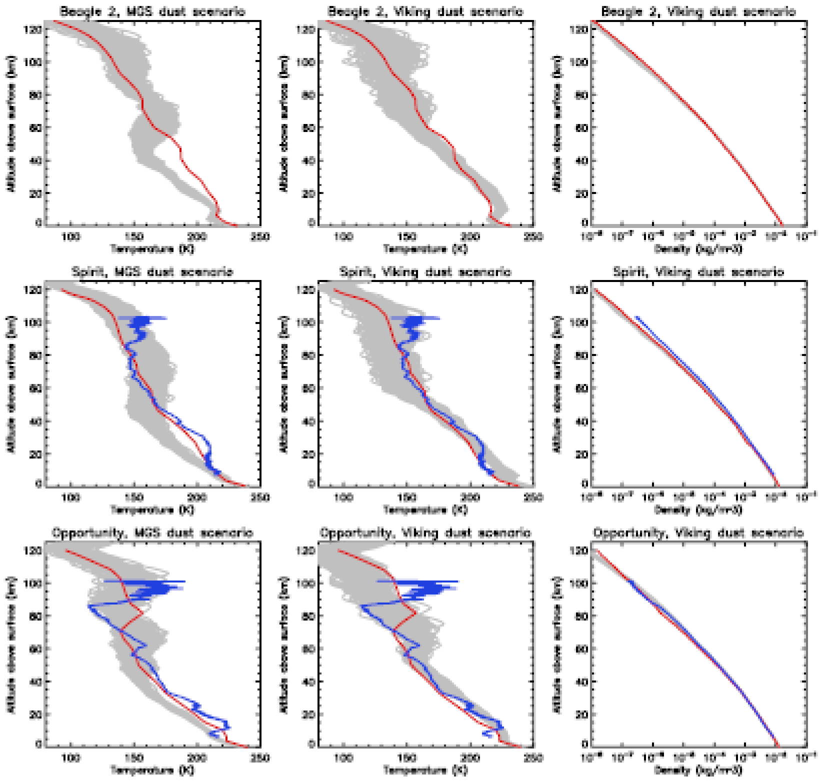

Figure 10: Entry profiles corresponding to Beagle 2, Spirit and Opportunity Mars landers. Grey lines are ensembles from version 3.1 of the European Mars Climate Database (left column “MGS scenario”, centre and right columns “Viking dust scenario”), the red lines are individual profiles interpolated to the same time and location in the assimilation and the blue lines are accelerometer retrievals supplied by P. Withers.

Future Plans

The assimilation technique described here has proved robust and reliable for the entire TES/MGS period. Recent developments in data assimilation for the Earth, e.g. 4D-Var and the ensemble Kalman filter, might allow an improved analysis to be conducted, and this is the subject of current study. The forthcoming data from Mars Climate Sounder on Mars Reconnaissance Orbiter will provide a new opportunity to assimilate an extended atmospheric data set from a single orbiting satellite, a configuration that has already proved successful in the present study.

We intend to make the results of these assimilations more easily accessible to the wider scientific community. This presents a practical challenge, since even the 2-hourly data set from a single, relatively moderate resolution model which has been run for several Mars Years is many tens of Gbytes. One option which will be pursued is the production of climate statistics (as in the EMCD, Lewis et al., 1999), but this results in the loss of detailed information describing transient atmospheric waves, for example. Possible solutions will be discussed, as will the selection of atmospheric fields and diagnostics of most interest to other researchers.

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