**DATA ASSIMILATION FOR THE ATMOSPHERE OF MARS.** S. R. Lewis, P. L. Read, *University of Oxford, Department of Physics, Clarendon Laboratory, Parks Road, Oxford OX1 3PU, UK, (s.lewis1@physics.oxford.ac.uk).*

Given the quantity of data expected from current and forthcoming spacecraft missions to Mars, it is possible to propose the use of data assimilation as a means of atmospheric analysis for the first time for a planet other than the Earth. Several groups have described plans to develop assimilation schemes for Mars [1, 2]. Data assimilation is a technique for the analysis of atmospheric observations which combines currently valid information with prior knowledge from previous observations and dynamical and physical constraints, via the use of a numerical model. Despite the number of new missions, observations of the atmosphere of Mars in the near future are still likely to be sparse when compared to those of the Earth, perhaps comprising one orbiter and a few surface stations at any one time. Data assimilation is useful as a means to extract the maximum information from such observations, both by a form of interpolation in space and time using model constraints and by the combination of information from different observations, e.g. temperature profiles and surface pressure measurements which may be irregularly distributed. The procedure can produce a dynamically consistent set of meteorological fields and can be used directly to test and refine an atmospheric model against observations.

A sequential data assimilation scheme for the atmosphere of Mars has been implemented, derived from the analysis correction scheme, which was, until recently, used operationally for weather forecasting at the UK Meteorological Office [3]. The scheme has been interfaced with the Mars General Circulation Model (MGCM) currently under simultaneous development at Oxford and at Laboratoire de Météorologie Dynamique du CNRS in Paris [4]. The MGCM is typically run with a spectral truncation at wavenumber 31 in the horizontal, roughly equivalent to a $96\times48$ ($3.75^\circ$) grid, with 25 vertical levels from the surface to almost 100 km altitude.

The assimilation scheme has been calibrated and tested with a series of experiments using artificial data generated from independent models run under plausible Martian conditions and with sampling patterns typical of polar orbiting spacecraft [5, 6]. These experiments indicate that it is potentially possible to recover information about not only the zonal-mean atmospheric state but also stationary and traveling waves.

The Thermal Emission Spectrometer (TES) [7] aboard Mars Global Surveyor (MGS) has now begun to produce a sequence of thermal profiles from the Martian atmosphere. Temperature retrievals, from the surface to 40 km altitude, from TES observations during the aerobraking hiatus [8] were kindly made available by the TES team and have been assimilated using the scheme developed. The data were obtained during orbits 20–36, a 25 day period corresponding to $L_S$ =198.31°–213.42°.

A control model integration was conducted covering this period with a fixed, globally-uniform dust distribution with a total optical depth in the visible of $\tau = 0.5$ at 700 Pa, mixed

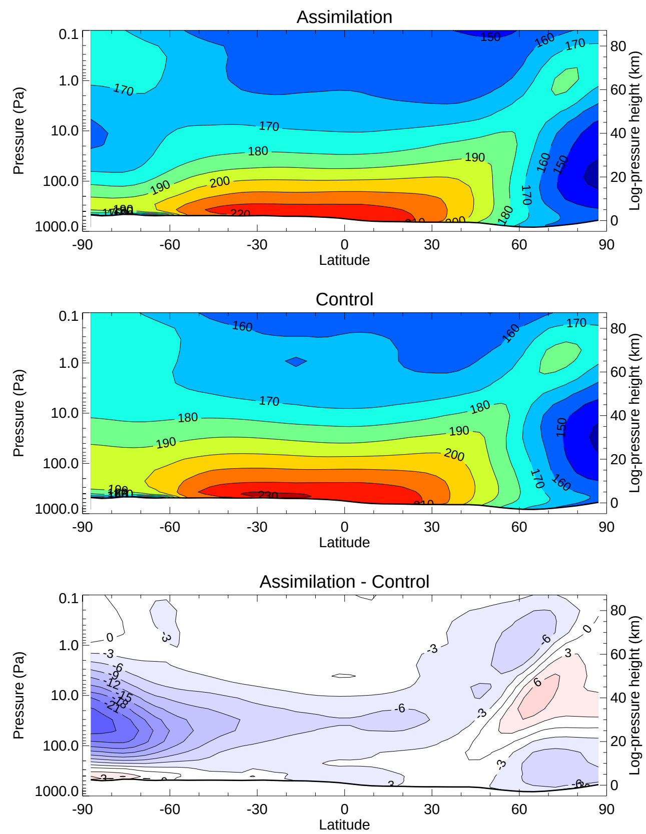


Figure 1: Zonal-mean temperature (K), $L_S$ =201.2°–213.5°. The assimilation is shown in the upper panel with the control model integration in the middle and the difference between them in the lower panel. The contour interval is 10 K in the upper two panels and 3 K in the lower.

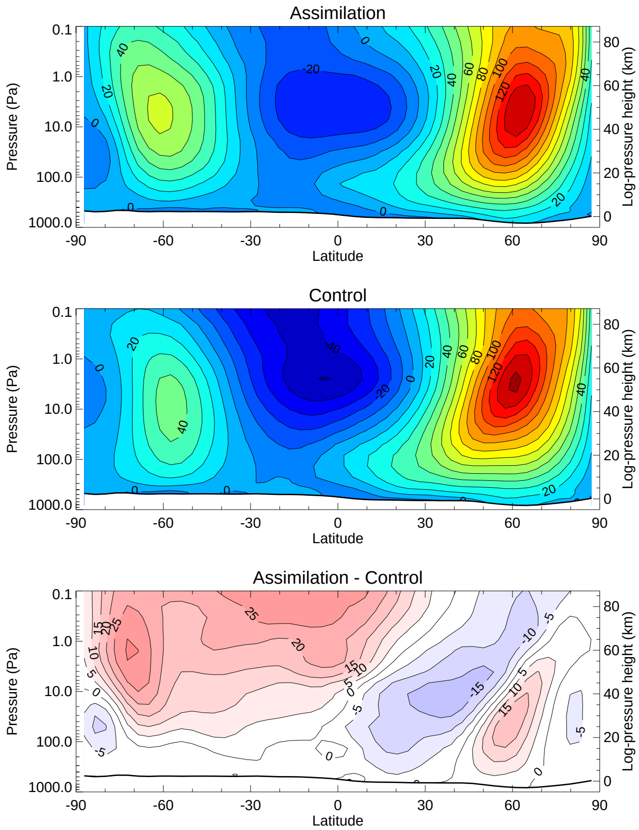


Figure 2: Zonal-mean zonal wind (m/s), $L_S$ =201.2°–213.5°, corresponding to the temperature maps in Fig. 1. The contour interval is 10 m/s in the upper two panels and 5 m/s in the lower.

up to about 40 km altitude. The same model was then used with the assimilation scheme and the results were compared. Zonal-mean temperatures for the last 20 days of the assimilation period are shown in Fig. 1. The control integration tends to over-estimate temperatures by a few degrees, particularly between 20 km and 40 km altitude. There is a larger disagreement of over 20 K above the south pole, which may be explained if there was less dust in this region in reality than was assumed in the control model. The corresponding winds, which are not observed directly but which are modified as a result of the dynamical balances in the model, are shown in Fig. 2.

The assimilation also shows evidence of modified wave behaviour. There are indications of a stronger stationary wavenumber two component in the northern hemisphere at mid- to high-latitudes. Traveling waves are more difficult to analyze, particularly as the MGS orbit at the time of the aerobraking hiatus was still highly elliptical with a period of 35 hours. Tests indicate that regular observations made from orbits with shorter periods, such as the 2 hour MGS mapping orbit, can be assimilated to recover information about typical traveling waves more successfully. However, the modified mean state in the assimilation does result in differences in the baroclinic waves in the northern, winter hemisphere; in particular, there was an increase in the amplitude of the zonal wavenumber one and three transient waves compared to the control experiment, which has an almost pure zonal wavenumber two transient component in the surface pressure field during this period.

Despite the fact that the orbital pattern at the time resulted in a dataset which was not ideal for assimilation, the trial assimilation of TES profiles from the aerobraking hiatus period appear successful and produce at least plausible results. Plans will be discussed for the assimilation of future data from MGS in its mapping orbit and from the Pressure Modulator Infrared Radiometer (PMIRR) [9] on the Mars Climate Orbiter spacecraft.

**Acknowledgments:** We thank Philip Christensen, Barney Conrath, John Pearl, Michael Smith and the TES team for giving us access to the TES temperature retrievals from the aerobraking hiatus period. This work was supported by grants from the UK Particle Physics and Astronomy Research Council.

**References:** [1] Banfield D. et al. (1995) *J. Atmos. Sci. 52*, 737–753. [2] Lewis S.R. and Read P.L. (1995) *Adv. Space Res. 16*, (6)9–(6)13. [3] Lorenc A.C. et al. (1991) *Quart. J. Roy. Meteor. Soc. 117*, 59–89. [4] Forget F. et al. (1999) *J. Geophys. Res.*, in press. [5] Lewis S.R. et al. (1996) *Plan. Space Sci. 44*, 1395–1409. [6] Lewis S.R. et al. (1997) *Adv. Space Res. 19*, 1267–1270. [7] Christensen P.R. et al. (1992) *J. Geophys. Res. 97*, 7719–7734. [8] Christensen P.R. et al. (1998) *Science 179*, 1692–1698. [9] McCleese D.J. et al. (1992) *J. Geophys. Res. 97*, 7735–7757.