Data assimilation for the Martian atmosphere using MGS Thermal Emission Spectrometer observations

Conference or Workshop Item

DATA ASSIMILATION FOR THE MARTIAN ATMOSPHERE USING MGS THERMAL EMISSION SPECTROMETER OBSERVATIONS.

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Given the quantity of data expected from current and forthcoming spacecraft missions to Mars, it is now possible to use 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 [*Banfield et al.*, 1995; *Houben*, 1999; *Lewis and Read*, 1995; *Lewis et al.*, 1996, 1997; *Zhang et al.*, 2001]. 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 best 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 to refine an atmospheric model against observations.

The Thermal Emission Spectrometer (TES) aboard the Mars Global Surveyor spacecraft has already produced an extensive atmospheric data set, beginning during aerobraking and continuing into the current extended scientific mapping phase. Thermal profiles for the atmosphere below about 40 km, and total dust and water ice opacities can be retrieved from TES spectra in nadir viewing mode. This talk will describe assimilation of TES nadir retrievals into a Mars general circulation model (MGCM) [*Forget et al.*, 1999]. In this case, the assimilation scheme [*Lorenc et al.*, 1991] is able to combine information from thermal profiles with dust optical depths, making use of a model forecast containing information from the assimilation of earlier observations, to obtain a global, time-dependent analysis. Given sufficient thermal data, the assimilation procedure can indicate errors in the a priori dust distribution in the MGCM; in this case there are relatively cold regions above the poles compared to a model which assumes a horizontally-uniform dust distribution, see Figure 1. One major reason for using assimilation techniques is in order to investigate the transient wave behavior on Mars. Whilst the data from the 2-hour orbit MGS mapping phase is much more suitable for this purpose, even the longer (45–24 hour) period aerobraking orbit data may contain useful information about the synoptic-scale Martian circulation. Assimilations from the period of the regional Noachis storm demonstrate that the combination of thermal profile information with dust retrievals can have a beneficial impact on the analysis, though an accurate knowledge of the dust distribution is much less important under moderate conditions.

Ensemble techniques with models run from different initial conditions are one means which may be used to estimate the confidence which can be placed in such analyses. Figures 2 and 3 show the surface pressure at a single mid-latitude site (0°E, 47.5°N) from two ensembles, a control of independent MGCM integrations and a set of assimilations conducted from the same set of initial conditions. The diurnal tidal signature is clearly present in both figures, but the transient wave behaviour at longer periods is markedly different, with weak waves in the members of the control ensemble and stronger signals with periods of greater than one sol in the assimilation ensemble. The difficulties an assimilation might have in controlling surface pressure from atmospheric temperature data alone have been discussed previously [*Lewis et al.*, 1996]. Despite this stern test, the assimilations appear to produce a reasonably consistent picture, with a strong wave of period 6–7 sols which is absent at this time in all the members of the control ensemble.

MGS data are now available routinely from the science mapping orbit and a seasonally-evolving, global picture of the Martian atmosphere is under construction.

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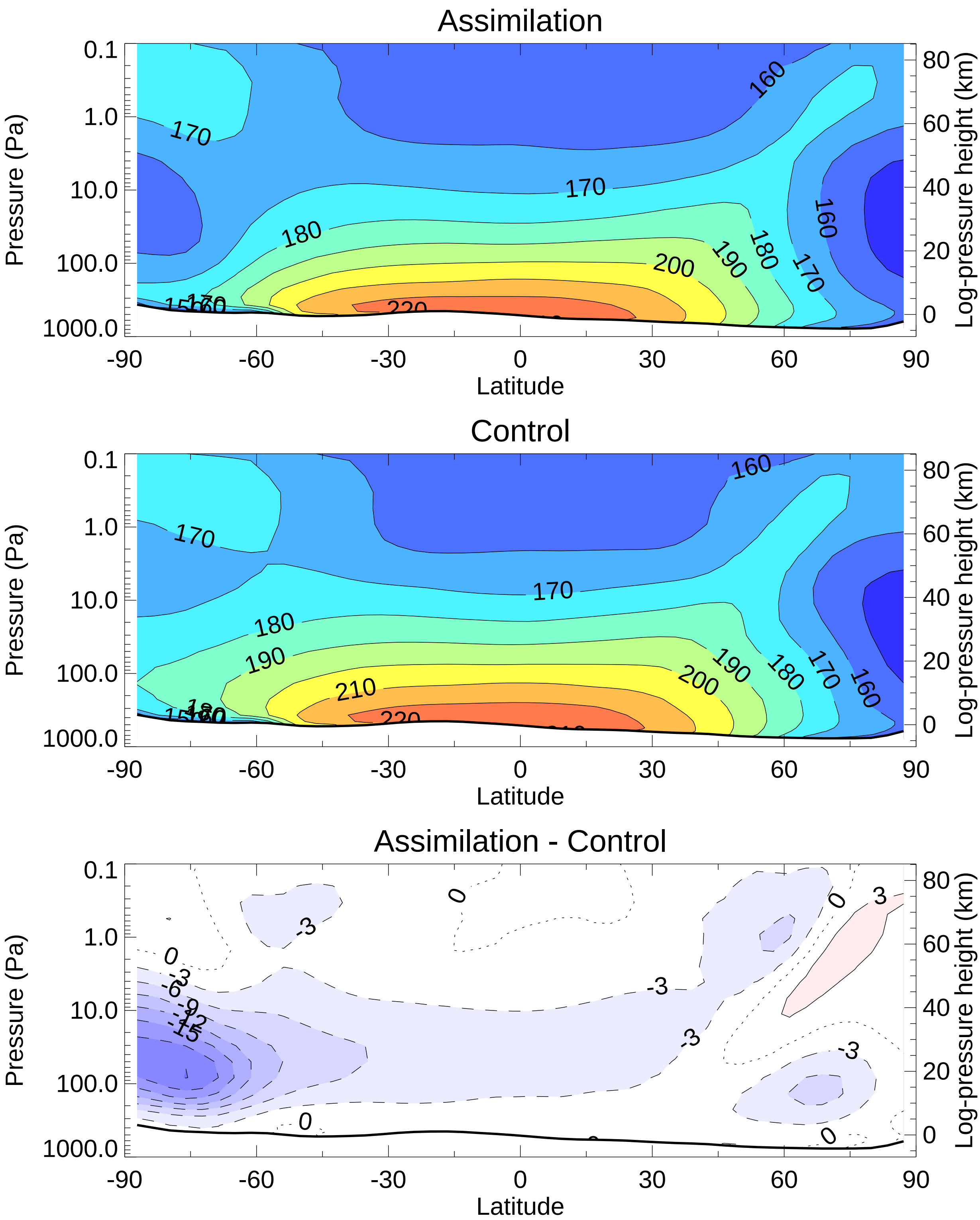

Figure 1: Zonal-mean temperature from a control model run, averaged over the period $L_S = 190°–200°$, compared with that from an assimilation with the difference shown in the lower panel.

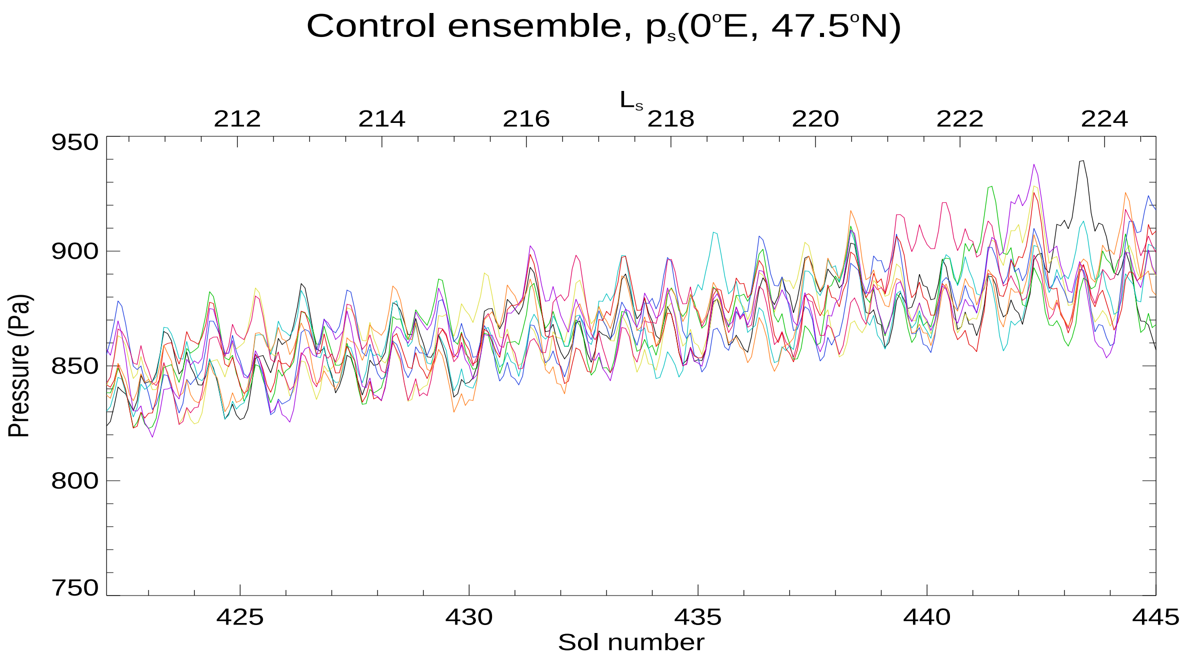

Figure 2: Surface pressure at a northern mid-latitude point (0°E, 47.5°N) for an ensemble of nine control integrations over the period $L_S = 210°$–$225°$.

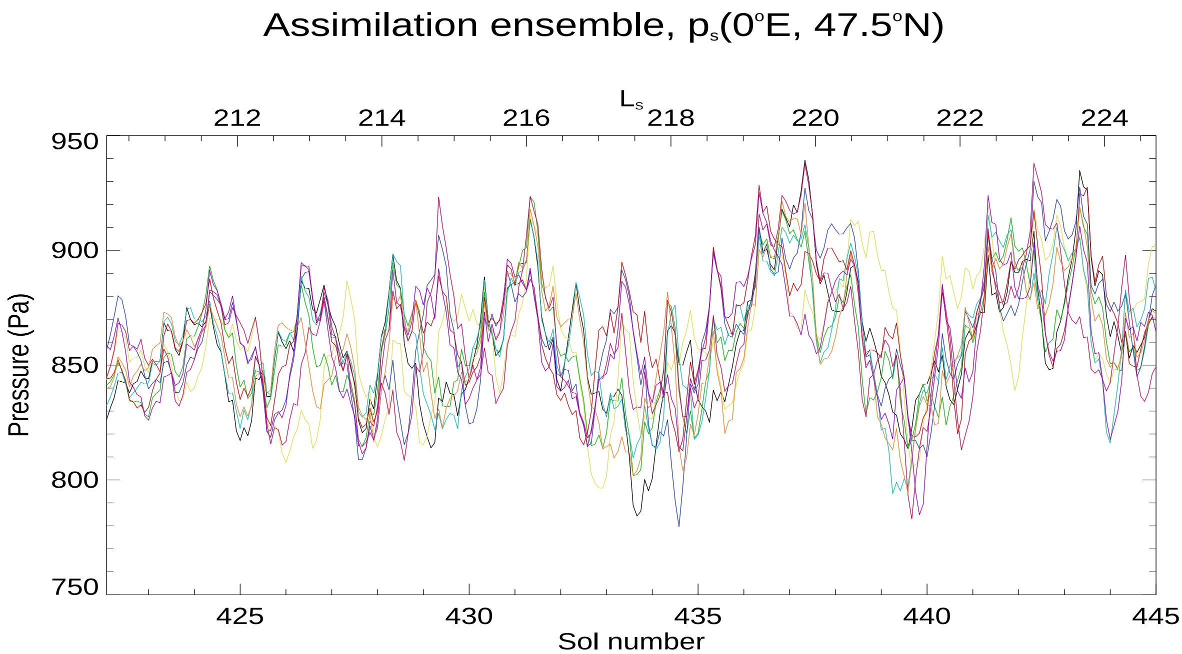

Figure 3: As Figure 2 for an ensemble of nine assimilations started with the same set of initial conditions as the control integrations at $L_S = 210°$.

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