A COMPARISON OF THE U.K. AND LETKF TES ANALYSES

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Introduction:

A reanalysis uses data assimilation to optimally combine past observations and an atmospheric model to create a four-dimensional depiction of the state of the atmosphere. The U.K. Reanalysis (Lewis et al., 2007) of Thermal Emission Spectrometer (TES) retrievals provides a comprehensive dataset of Martian climate spanning several Martian years. Recently, new analyses employing the Local Ensemble Transform Kalman Filter (LETKF) assimilation system have been created for both TES and Mars Climate Sounder (MCS) data for several time segments (Hoffman et al., 2010; Greybush et al., 2011). Here we conduct a preliminary comparison of the two reanalyses for a 30-sol time period in the NH Martian autumn during Mars Year 24. This investigation provides a demonstration that the ensemble data assimilation techniques are performing reasonably for the Martian atmosphere, as well as encourages a discussion of the relative merits of both products.

Models and Assimilation Systems:

Table 1 contains a side-by-side comparison of the model and assimilation systems used in the two reanalysis products. The LETKF as applied to the MGCM is described in detail in Greybush et al. (2011). As an ensemble data assimilation system, the LETKF provides significant advances over previous assimilation techniques (Kalnay et al., 2007), and is competitive with state-of-the-art systems for terrestrial numerical weather prediction. In particular, the background error covariance is determined from an ensemble of atmospheric states, and consequently is flow-dependent and time evolving. Correlations among variables are determined from the ensemble rather than relying on prescribed relationships, which permits the winds and surface pressure to be updated simultaneously by temperature observations, or the dust field to be updated by surface brightness temperature (Wilson, 2011), for example. The LETKF naturally provides uncertainty estimates for the analysis, and has tools for observation error estimation (Li et al., 2009) and bias correction.

Table 1: Model and Assimilation Systems

Parameter	**U.K. Reanalysis**	**LETKF Reanalysis**
Assimilation Scheme	Analysis Correction Scheme (Lorenc et al., 1991), which is similar to nudging	Local Ensemble Transform Kalman Filter (LETKF; Hunt et al., 2007)
Update Frequency	Continuously (every model time step)	Assimilation cycle is 0.25 sol
Temporal Availability	Every 2 Mars hours	Every 6 Mars hours, more frequently as desired
Atmospheric Model	Oxford-LMD Mars model (Forget et al., 1999)	GFDL MGCM (Wilson et al., 2002; Hoffman et al., 2010)
Model Resolution	72 x 36 x 25 levels	60 x 36 x 28 levels
Vertical Coordinate	Sigma	Hybrid Sigma-Pressure
Temperature Data	PDS TES Profiles, with vertical averaging	PDS TES Profiles at TES levels

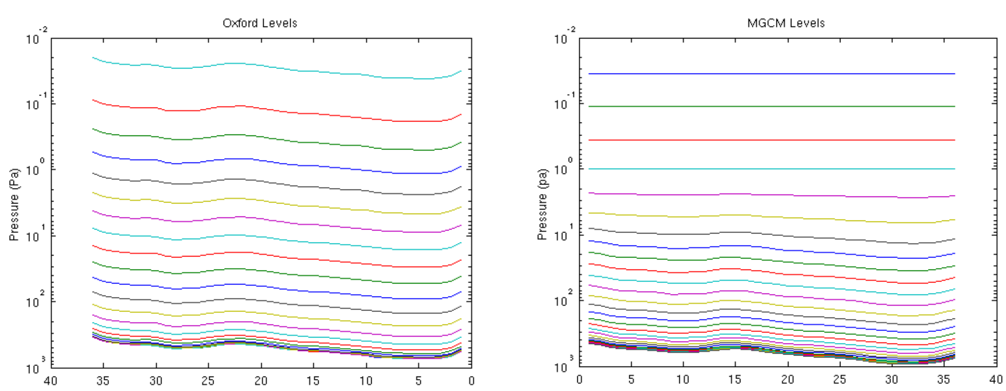

Figure 1: Schematic comparing vertical resolution of the Oxford-LMD Mars model versus the GFDL MGCM. The Oxford model is purely sigma coordinate, whereas the MGCM transitions to pressure coordinates at higher altitudes.

Dust Methodology	TES dust opacities directly inserted.	Initially, fixed dust opacity varied among ensemble members. Eventually, updated from observations.
Variables Updated	T, U, V, surface pressure, dust	T, U, V, surface pressure
Uncertainty Estimate	None	From Ensemble
Localization Cutoff Radius	1200 km	1460 km (400 km * 3.65)
Availability	Entire TES Period	Intervals from MY 24, MY 25 for TES, MY 29 for MCS

Observations:

Thermal Emission Spectrometer (TES) retrievals from the Mars Global Surveyor spacecraft are initially obtained from the Planetary Data System (PDS; Smith et al., 2001). Observations are available between 1997 and 2006. Temperature retrievals are located on 19 vertical pressure levels up to 40 km in altitude. Temperature observation errors (including both instrument error and errors of representativeness) are estimated at 3 K (with the method of Li et al., which assumes no vertical error correlations, we estimated 2.7 K), although the characteristics are not well known. Dust opacity is reported as a column value, but can be unreliable when surface temperatures are below 220 K or opacities are too large.

Comparison of Analyses:

The analyses are compared during a 30-sol time period during the NH autumn of MY 24. Both analyses must be interpolated to a common grid for direct comparison. Fig. 2 provides a sample snapshot comparison of the temperature difference between two analyses. The analyses are compared to each other, as well as to TES observations, and additional results will be presented at the workshop. One method of comparison is to initialize the MGCM from each reanalysis, and then compare 2-10 sol forecasts against independent (in time) TES observations. Additional insights can be gained by considering independent information from radio science profiles (Hoffman et al., 2011). In addition to time and zonal mean statistics, snapshots from both analyses will be analyzed to ascertain amplitude and phase of travelling waves, and see if there is an agreement.

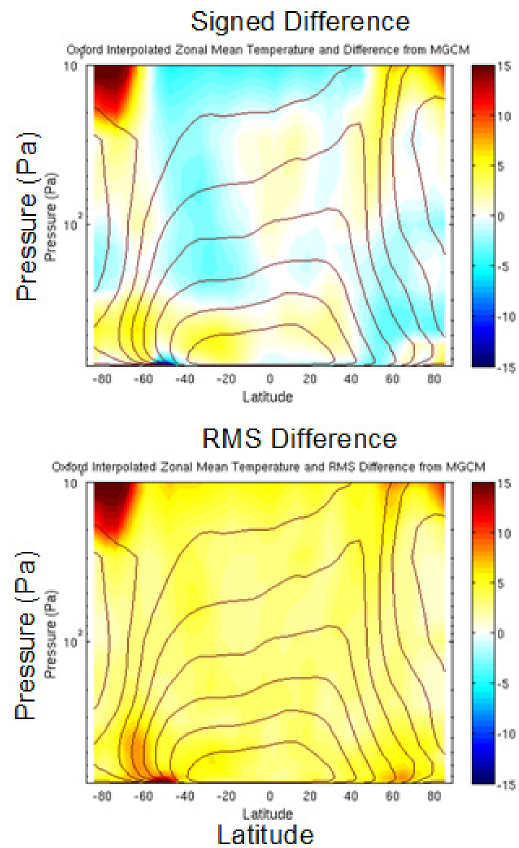

Figure 2: Signed (top) and RMS (bottom) zonal mean difference in temperature between the U.K. Reanalysis and LETKF Reanalysis at a snapshot near Ls = 185°, shown at TES vertical coverage (surface to near 40 km). Larger differences near the poles at upper levels are due to a model bias that should be corrected with the addition of topographic wave drag to the MGCM (Wilson 2011).

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