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Preliminary assimilation of observations from ACS/TIRVIM on board ExoMars TGO into the LMD Mars GCM

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Abstract

We present preliminary results from data assimilation of observations from the thermal infrared instrument TIRVIM, part of the Atmospheric Chemistry Suite on board ESA-Roscosmos' ExoMars Trace Gas Orbiter. These assimilations focus on atmospheric temperatures retrieved from the first few months of nadir data. We use the Local Ensemble Transform Kalman Filter technique to assimilate observations into the LMD Mars General Circulation Model.

1. Introduction

The ExoMars Trace Gas Orbiter (TGO), a collaborative project between the European Space Agency (ESA) and Roscosmos (Russia), was successfully inserted into Mars orbit on 19 October 2016, and reached its final science orbit on 7 April 2018. TGO began taking observations as part of commissioning operations in March 2018.

At the Laboratoire de Météorologie Dynamique (LMD) we are responsible for data assimilation of observations from the Atmospheric Chemistry Suite (ACS) thermal infrared instrument (TIRVIM) on board TGO [4]. This instrument measures vertical profiles of temperature as well as dust and water ice integrated content, at various local times, latitudes and seasons. Our aims are to generate analyses of the Martian atmosphere in a semi-operational way, provide these to the community in the short term, and use them to better understand Mars' climate.

2. Observational data

TIRVIM is a thermal infrared spectrometer with spectral range 1.7–$17\,\mu\mathrm{m}$, whose main purpose is to continuously monitor the Martian environment in nadir in support of solar occultation measurements by ACS's near-infrared and mid-infrared channels [4]. Its primary observations are vertical profiles of atmospheric temperature, but it also produces surface temperatures and column-integrated dust, water ice, and other aerosol opacities.

We use the first few months of nadir data from TIRVIM. These have been calibrated and then retrieved using a line-by-line radiative transfer model [2]. We focus on assimilation of atmospheric temperatures, with assimilation of the other available data to follow. The observations cover various local times of day with full coverage in longitude every 7–10 days, over $\pm 75^\circ$ latitude, with vertical coverage between $\sim 5-45\,\mathrm{km}$ altitude.

3. Model and assimilation

The LMD Mars General Circulation Model (GCM) [1] is a detailed model of Mars' atmosphere that includes representations of the dust cycle, water cycle, boundary layer, subsurface, aerosols, upper atmosphere, and other parametrizations relevant to the Martian environment.

Assimilation of observations into the LMD Mars GCM is achieved using the Local Ensemble Transform Kalman Filter [3, 6]. The LETKF is an ensemble-based assimilation scheme where we typically use 16 ensemble members and multiplicative inflation to adjust the background ensemble error covariance.

Assimilation of Martian atmospheric data provides a significant challenge for ensemble-based data assimilation. Quantities available to assimilate are strongly inter-dependent, and Mars' atmosphere is less chaotic than the Earth's, so the ensemble can converge over time, with bias dominating the ensemble in a way that cannot be alleviated by synoptic variability.

4. Previous work

Work up to now has assimilated temperature, dust, and water ice observations from the Mars Climate Sounder on NASA's Mars Reconnaissance Orbiter [5, 6]. Figures 1 and 2 show example comparisons between temperature analyses and MCS observations, varying the time between assimilations. The errors are reduced visibly as the time between assimilations is reduced to 2 hours (Fig. 1), and error diagnostics (Fig. 2) show that a 1 hour cycle improves this even further.

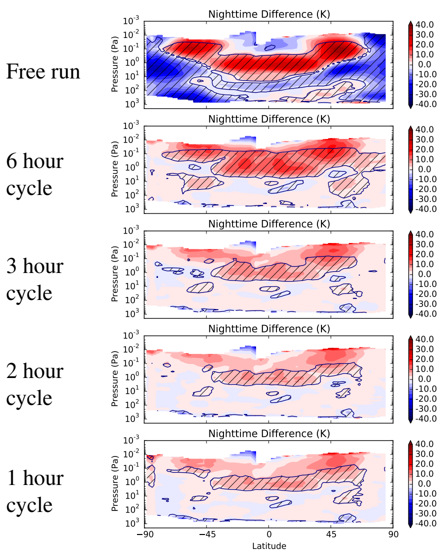

Figure 1: Difference between analysis mean and observed night-time ($\sim$3 am) temperatures for MCS observations binned over $L_s = 175-180°$ during MY29. The top panel has no assimilation, and the others vary the time between assimilations. In hatched regions the difference is larger than observational error.

5. Summary and Conclusions

The LMD Mars data assimilation scheme is ready to analyse data from the TIRVIM instrument, part of the ACS suite on board ExoMars TGO. We shall present our preliminary analysis of the first few months of assimilated atmospheric temperature observations.

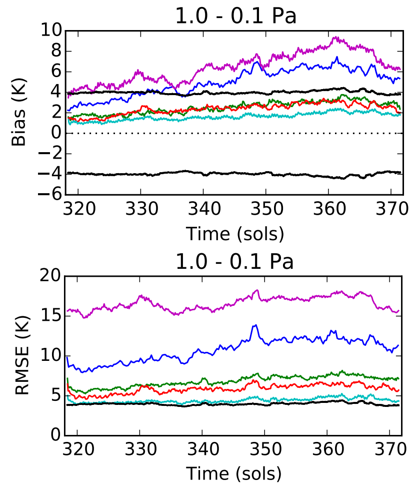

Figure 2: Temperature bias and RMS error in the analysis mean compared with raw observations, globally and diurnally averaged over 10–1.0 Pa between $L_s = 150-180°$ during MY29 (same period as Fig. 1). We show the pressure range where the assimilation is poorest. Lines show the free run and 6, 3, 2, and 1 hour assimilation cycles. Black lines show observational error.

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