TOWARDS ASSIMILATION OF EXOMARS TGO OBSERVATIONS INTO THE LMD MARS GCM

R. M. B. Young[1], S. Guerlet[1], E. Millour[1], F. Forget[1], and T. Navarro[1,2]
[1]Laboratoire de Météorologie Dynamique, Sorbonne Université, Paris, France (ryoung@lmd.jussieu.fr), [2]Department of Earth, Planetary, and Space Sciences, University of California, Los Angeles, California, USA.

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 400km 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 preparing to assimilate observations from the Atmospheric Chemistry Suite (ACS) thermal infrared channel (TIRVIM) on board TGO [1] into the LMD Mars General Circulation Model (GCM) [2]. The ACS/TIRVIM instrument will measure radiance spectra from which can be retrieved vertical profiles of atmospheric temperature, as well as surface temperatures and vertically-integrated amounts of dust and water ice, at various local times, latitudes and seasons. Our aim is to generate re-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.

The LMD Mars GCM 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. The data assimilation scheme is based on the Local Ensemble Transform Kalman Filter (LETKF) [3]. The LETKF is an ensemble-based assimilation scheme where we typically use 16 ensemble members and multiplicative inflation to adjust the background error covariance.

Assimilation of Martian atmospheric data provides a significant challenge for ensemble-based data assimilation schemes. Not only are the observed quantities available to assimilate – temperature, dust, and water ice – strongly inter-dependent, but Mars' atmosphere is markedly less chaotic than the Earth's at certain times of year [4]. The ensemble can converge over time, with bias and model deficiencies dominating errors in a way that cannot be alleviated by synoptic variability, and often the ensemble does not enclose new observations as they become available. The assimilation scheme behaves in a way that is distinctly non-terrestrial. However, such behaviour has been recognised and studied by users of Ensemble Kalman Filter techniques in other contexts, and various methods such as bias correction [5], additive inflation [6], parameter ensembles, and static error covariances exist to alleviate these problems. These are worth discussing for use in the Martian context.

Earlier work assimilated observations from the Mars Climate Sounder on NASA's Mars Reconnaissance Orbiter [7,8,9]. Figure 1 shows an example comparison between temperature analyses and MCS observations, varying the time between assimilations. We shall report on our recent improvements to the scheme, towards assimilating ACS observations once TGO's science activities begin, and on our progress in trying to overcome the various challenges of ensemble data assimilation in the Martian context.

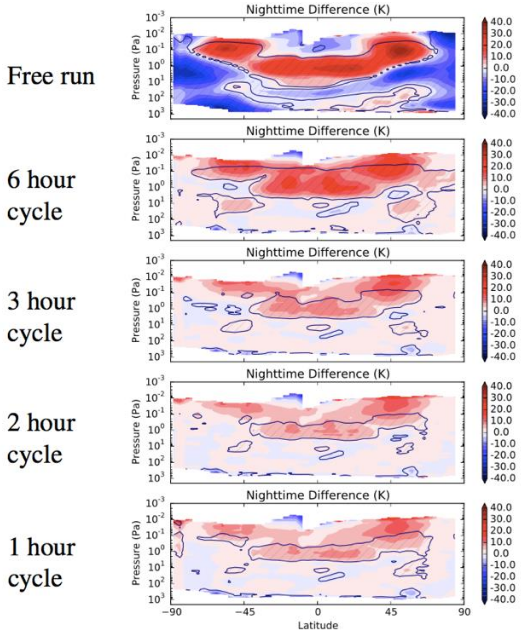

Figure 1: Difference between analysis mean and observed night-time (~3 am) temperatures for MCS observations binned over L_s =175−180° during MY29. The top panel has no assimilation, and the others vary the time between assimilations. In hatched regions the difference is larger than observational error.

References: [1] Korablev, O. et al. (2018), *SSR, 214*, 7. [2] Forget, F. et al. (1999), *JGR, 104*, 24155-24175. [3] Hunt, B. R. et al. (2007) *Physica D, 230*, 112-126. [4] Newman, C. et al. (2004), *QJRMS, 130*, 2971-2989. [5] Dee, D. P. and Da Silva, A. M. (1998), *QJRMS, 124*, 269-295. [6] Li, H. et al. (2009), *MWR, 137*, 3409-3419. [7] Navarro, T. (2016) *Ph.D. thesis*, LMD. [8] Navarro, T. et al. (2014) *GRL*, *41*, 6620-6626. [9] Navarro, T. et al. (2017) *ESS*, *4*, 1-31.