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Atmospheric data assimilation using the LMD Mars GCM with an ensemble Kalman Filter

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1. Introduction

Data assimilation is a technology widely used in geosciences, especially meteorology and weather forecast. It enables to optimally reconstruct a best estimate of the atmospheric state by combining various instrumental observations and theoretical information provided by a model. In Earth atmosphere science, it is systematically used to provide climatologies derived from space-based observations.

The very first Martian data assimilation project was carried out by [9], who applied the Analysis Correction Scheme to their Mars Global Climate Model (MGCM) .

More recently, ensemble methods have been used for Martian data assimilation. The Local Ensemble Transform Kalman Filter (LETKF) has been coupled to the GFDL MGCM [5] and used with observations from the Thermal Emission Spectrometer (TES) [4]. The Data Assimilation Research Testbed (DART) has been used to apply an ensemble Kalman filter to the MarsWRF GCM with TES radiance data [7].

The purpose of this work is to develop a data assimilation chain by coupling the Laboratoire de Météorologie Dynamique (LMD) MGCM with the LETKF assimilation framework of the University of Maryland [6].

2. Motivations

There are various possibilities and applications presented for data assimilation. In this specific case, the reasons to develop such an assimilation are numerous :

The reconstruction of atmospheric fields is *per se* a strong motivation. It provides a best estimate of the known atmosphere and could be seen as a useful tool for atmospheric science community.

Data assimilation could help to characterize the local conditions for landers and rovers on the Martian ground on a daily basis .

One main objective of the Trace Gas Orbiter (TGO) is to detect the presence and origin of trace gas in the Martian atmosphere. A data assimilation chain using data from the Atmospheric Chemistry Suite (ACS) on board TGO can be used to backtrack winds to locate the sources of such trace gases.

Another asset of data assimilation is the possibility to point out disagreements between model and observations. It is a very powerful tool to estimate GCM parameters or characterize instrumental errors.

3. The model

The model used in this data assimilation scheme is the MGCM developed at LMD [2]. It includes a semi-interactive dust scheme driven by dust scenarios, a thermal plume model [1], a water cycle that includes radiatively active water ice clouds [10] with interaction between dust and clouds, a photochemical model [8] and an extension to the thermosphere, up to 600 km [3].

4. Data assimilation scheme

The principle of data assimilation is to successively alternate two steps: analysis and forecast. In the analysis step, an *a priori* estimate of the system state, called the background, is used to obtain a new estimate (called the analysis) by being combined to observations. The forecast, or propagation step, consists of applying the forward model to the analysis to get a new background after time integration (of typically 6 hours).

The assimilation scheme used is LETKF, which consists of an approximation of the Kalman Filter. It uses an ensemble, that is to say a set of a large enough number of forecast members that samples the variability of the system. The analysis step then consists of applying the filter to the background ensemble to create a new ensemble, the analysis. Observations are localized, that is to say their influence is limited and weighted in space within an arbitrary range. An adaptative inflation is used, i.e. the spread of the analysis ensemble is automatically corrected after the analysis step [11].

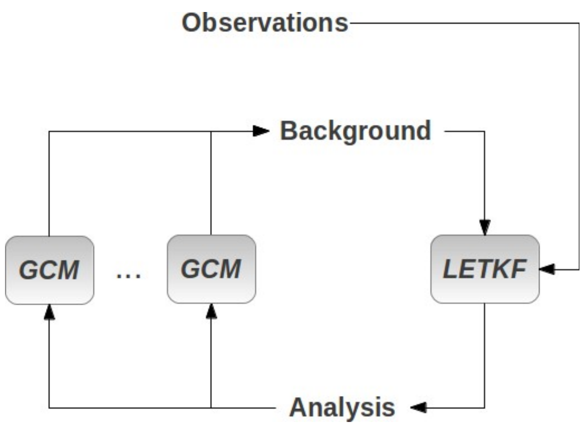

Figure 1: Simple schematics of an ensemble data assimilation framework.

5. Development strategies

The development of a data assimilation chain is strongly incremental. After the validation of the assimilation with synthetic observations derived from the model itself (“twin experiments”), we plan to assimilate temperature from the Mars Climate Sounder (MCS) on board Mars Reconnaissance Orbiter as well as from the Planetary Fourier Spectrometer (PFS) on board Mars Express, thus taking advantage of the combination of the different local times between PFS and MCS measurements. The next goal is to directly assimilate dust and ice from MCS data.

Beyond this preparatory assimilation, the goal is to prepare the real-time assimilation of data from ACS on board TGO whose orbital insertion is expected in the second half of 2016. Ultimately, the direct assimilation of ACS radiances instead of temperatures will be attempted with the help of a direct model.

References

[1] Colaitis, A. et al.: A Thermal Plume Model for the Martian Convective Boundary Layer,J. Geophys. Res. (in revision)

[2] Forget, F. et al.: Improved general circulation models of the martian atmosphere from the surface to above 80 km, J. Geophys. Res-Planet., Vol. 104, 1999

[3] González-Galindo, F. et al: A ground-to-exosphere Martian general circulation model: 1. Seasonal, diurnal, and solar cycle variation of thermospheric temperatures, J. Geophys. Res., Vol. 114, 2009

[4] Greybush, S. et al.: Ensemble Kalman filter data assimilation of Thermal Emission Spectrometer temperature retrievals into a Mars GCM, J. Geophys. Res., Vol. 117, 2012

[5] Hoffman, M.J., et al.: An ensemble Kalman filter data assimilation system for the martian atmosphere: Implementation and simulation experiments, Icarus, 2010

[6] Hunt, B. R., Kostelich E. J. and Szuniogh, I.: Efficient data assimilation for spatiotemporal chaos: A local ensemble transform Kalman filter, Elsevier PhysD, Vol. 230, 2006.

[7] Lee C., et al.: Demonstration of ensemble data assimilation for Mars using DART, MarsWRF, and radiance observations from MGS TES, J. Geophys. Res., Vol. 116, 2011

[8] Lefèvre, F. et al.: Three-dimensional modeling of ozone on Mars, J. Geophys. Res., Vol. 109, 2004

[9] Lewis, S. R. and Read, P. L.: An operational data assimilation scheme for the martian atmosphere. Adv. Space Res. 16(6), 9–13. 1995

[10] Madeleine, J.-B et al.: The influence of radiatively active water ice clouds on the Martian climate, Geophys. Res. Lett., vol. 39, 2012

[11] Miyoshi, T.: The Gaussian Approach to Adaptive Covariance Inflation and Its Implementation with the Local Ensemble Transform Kalman Filter, AMS, vol. 139, 2011