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Data assimilation of temperature and aerosols on Mars

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Abstract

The latest results of data assimilation on Mars using the Laboratoire de Météorologie Dynamique (LMD) Mars Global Climate Model (MGCM) and (Mars Climate Sounder) MCS observations are presented, with the estimation of both temperature and aerosols and an emphasis on the prediction and forecasting of the Martian atmosphere.

1. Introduction

Data assimilation is a technique widely used in geoscience, especially meteorology and weather forecast. It enables to optimally reconstruct a best estimate of the atmospheric state by combining instrumental observations and theoretical information provided by a numerical model.

Data assimilation on Mars has been studied for 20 years [1], using nudging and Kalman Filter techniques by various teams. This work updates the development of a data assimilation chain by coupling the LMD MGCM with the Local Ensemble Transform Kalman Filter (LETKF) [2] assimilation framework [3].

2. Data assimilation description

2.1 Motivation

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.

- One of the main objectives of the Trace Gas Orbiter (TGO), that will be launched in 2016, 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 MGCM parameters or characterize instrumental errors.

2.2 Atmospheric Model

The model used in this data assimilation scheme is the MGCM developed at LMD [4]. It includes a semi-interactive dust scheme guided by dust scenarios, a water cycle that includes radiatively active water ice clouds with interaction between dust and clouds.

2.3 Data assimilation scheme

The principle of data assimilation is to successively alternate two steps: analysis and forecast (figure 1). 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 numerical 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.

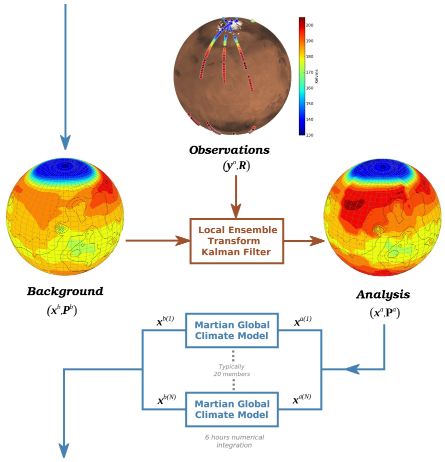

Figure 1: Diagram of the functioning of the LETKF over one cycle

3. Results

The present work shows the assimilation of observations from the Mars Climate Sounder (MCS) on board Mars Reconnaissance orbiter.

When compared to Earth, the specificities of the Martian atmosphere (low atmospheric density, water in trace quantities, absence of oceans) give Mars a very predictable weather. For a large portion of the year, instabilities in the Martian atmosphere do not grow [5]. This makes assimilation on Mars more difficult because the main source of disagreement between model and observations are biases (whether these are model or observational biases), rather than flow instabilities [6]. In order to tackle this issue, the approach in this work is to use observations to get an estimate of the two main aerosols that are strong forcings of the Martian atmosphere, rather than just the atmospheric flow. These aerosols are:

- Dust loading of the atmosphere, which controls most of its thermal structure, through dust radiative effects.

- Water ice clouds, whose radiative effects are known to be possibly as significant as the ones of dust, depending on the time of the year.

The estimation of aerosols in three dimensions in the Martian atmosphere and their evolution in time compensates for a bias that exists for simulations without assimilation, given the fact that it is a challenge to impose a realistic distribution of aerosols in a Martian GCM. It has the potential to greatly improve our capability to predict the future state of the atmosphere on a few days time-scale (figure 2), paving the way to an operational weather forecast on Mars.

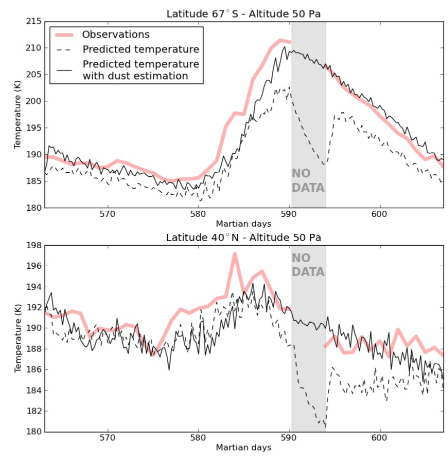

Figure 2: The impact on temperature prediction with and without estimation of dust during a regional dust storm.

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