Assimilating the Martian water cycle

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Assimilating the Martian water cycle

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Abstract

Water ice clouds have been shown to alter the thermal structure of the Martian atmosphere. Here we discuss the assimilation of total column water vapour and dust optical depth data from the Thermal Emission Spectrometer (TES) into the UK/LMD MGCM, and compare the predictions of cloud and temperature in the assimilation with observations.

1. Introduction

Water ice clouds play an important role in the global transport of water, as well as in determining the thermal structure of the atmosphere, particularly over the tropics [9]. The scattering of solar radiation and the emission of infra-red radiation by clouds have local cooling effects, while the absorption of solar and infra-red radiation can lead to warming. Which of these effects dominates depends upon the properties of the cloud, such as height, thickness and temperature. For example, the cold aphelion cloud belt absorbs infra-red radiation from the surface, leading to upper atmosphere warming, while the warmer polar hoods emit in the infra-red and cool the atmosphere [2].

In order for the model's prediction of clouds to be accurate, it is vital that the atmospheric temperature profile and water vapour abundance is modelled correctly. Data assimilation can help to constrain these parameters, allowing a consistent, four-dimensional mapping of the Martian atmosphere and water cycle to be obtained for the period of the observations. The assimilated record can be used to validate independent model results and investigate the interaction of water ice clouds with both the water cycle and atmosphere.

2. Modelling and data assimilation

To study the Martian water cycle, we use an MGCM which makes use of the most recent version of the LMD GCM physical schemes [1] with the UK spectral dynamical core and data assimilation scheme [4]. The model contains a cloud microphysics scheme, capable of simulating the nucleation, growth and sedimentation of ice particles [7]. The radiative effects of water-ice clouds are also included [6].

The assimilation scheme used in the model was developed by [3]. It is based on the Analysis Correction scheme of [5], and can analsye data distributed in both time and location. The scheme has already been successfully used to assimilate TES dust opacity and temperature data into the UK/LMD MGCM [4], as well as new data being returned from Mars Climate Sounder (MCS). Here, we assimilate 3D (horizontal and time-dependent) variations in dust opacities and total column water vapour abundances from TES [8]. The model vapour mixing ratios are vertically scaled in order for the total column value to match observations.

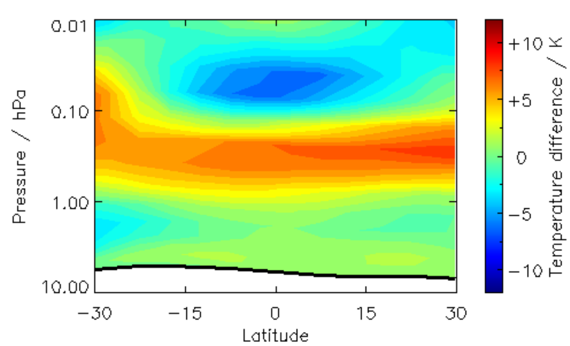

Figure 1: Zonally averaged temperature difference (vapour assimilation – free-running model) in the tropics, averaged over 5 sols around sol 160 ($L_S = 75°$) of Mars Year (MY) 25.

3. Preliminary results

Figure 1 shows the zonally-averaged temperature difference between an assimilation of both dust opacity and total column water vapour, and a free-running model. As can be seen, the assimilation has lead to an increased warming in the middle atmosphere around

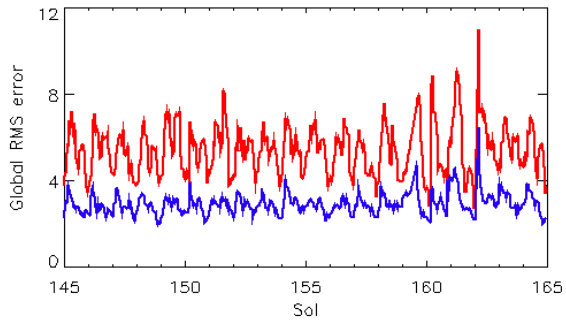

Figure 2: Global RMS error in total column water vapour (pr-μm) for sols 145-165 ($L_S = 68°$-$77°$) of MY 25. The red line is for the free-running model and the blue line is for the vapour assimilation.

the tropics. This is due to changes in the location and optical thickness of water ice clouds predicted in the assimilation compared to the free-running model. Such a warming has been shown previously by [9] who performed an assimilation using temperature and dust opacity data from TES. However, in this assimilation, the warming has successfully been accounted for without the need for temperature assimilation. Figure 2 shows the global RMS error in water vapour column for sols 145-165 of MY 25. In general, the RMS error is halved by performing the assimilation, with an average global RMS error of $\sim$3 pr-μm.

Work is currently still ongoing in order to improve the vertical scaling of the model's water vapour profile, which should lead to further improvements in cloud prediction. Additionally, work will begin on assimilating water ice data from both TES and MCS.

Acknowledgements

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