Modelling Radiatively Active Water Ice Clouds in the Martian Water Cycle

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Modelling radiatively active water ice clouds in the Martian water cycle

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Introduction

Aerosols, both water ice and dust, play a key role in the Martian climate. However, our understanding of the interactions between these aerosols, the surface (solar ice caps, frost) in the atmosphere (vapour, ice clouds) and the distribution and properties of dust is currently incomplete. Water ice clouds have been observed at many locations in the Martian atmosphere, and they occur in many different forms, such as polar hood clouds, ice caps, sublimation fogs and ground fogs. The largest spatial distribution of clouds belongs to the aphelion cloud belt, which appears during northern hemisphere spring and summer each year in a zonal band between around 10° S and 30° N [1, 2].

In this poster, we demonstrate the potential impact of water ice clouds on a Mars Global Circulation Model (MCGM), and test the sensitivity of the model to varying dust opacity. We use independent model experiments and assimilations of the Mars Environmental Spectrometer (TES) retrievals and validate the model against Mars Climate Sounder (MCS) observations.

Effects of water ice clouds in MCGM simulations

It is known that cirrus clouds in the Earth’s atmosphere can scatter and absorb incoming solar radiation, and absorb and emit thermal infrared radiation, causing a warming of the atmosphere [3,4]. Therefore, due to the presence of water ice clouds in the Martian atmosphere, it is necessary to take into account their radiative effects in MCGMs.

The current LMD MCGM [9] run in the UK uses a spectral dynamical core, and includes a simplified water cycle in which there is atmospheric transport of water vapour and ice, a bulk cloud scheme, and interaction with the Martian regolith [6,7]. However, in the model run in the UK, the water ice opacity is not yet coupled with the MCGM radiation scheme, so absorption of visible/infrared radiation by the water ice clouds is not taken into account. This assumption has been identified as being potentially significant in the equatorial northern atmosphere of Mars around aphelion, when the planet-bridging cloud belt forms [8]. As can be seen in Figure 1, it appears as though the downward infra-red radiation emitted by the aphelion cloud belt is introducing a warming of the atmosphere not accounted for in the model.

Sensitivity of the model to dust distribution

Due to the radiative effects of dust, its temporal and spatial distribution will have a large effect on other atmospheric properties. To test the sensitivity of the MCGM to the dust distribution, we have used a set of simulations with the seasonal and interannual evolution of zonally averaged equatorial temperature bias over the course of the MGS mapping mission; white, red and black contours indicate variable depth of assumed dust distribution, 185° K isotherm and approximate height of cloud condensation level respectively. (a) Seasonal evolution of zonally averaged equatorial temperature bias over the course of the MGS mapping mission; white, red and black contours indicate variable depth of assumed dust distribution, 185° K isotherm and approximate height of cloud condensation level respectively. (b) Seasonal evolution of zonally averaged equatorial temperature bias at 0.5 Hpa [8].

Plots of the mean temperature (in kelvin) and the mean time-averaged temperature for a Martian year for (a) modelled data from the MCD; (b) MY24 simulation using 2005 dust scheme; (c) MY24 simulation using 2003 dust scheme, and (d) MY25 assimilation using TES thermal and dust retrievals.

As well as comparing the two simulations with each other, we have also carried out comparisons with observations from the MCS and modelled data from the MCD, which is used as a convenient summary of model experiments from the LMD MCGM. Figure 5 shows mean vertical profiles of temperature at varying latitudes from (a) MY24 simulation using 2005 dust scheme; (b) MY24 simulation using 2003 dust scheme; (c) MY25 assimilation using TES thermal and dust retrievals; and (d) modelled data from the MCD v3. (Panels (d) and (e) are from [8]).

Project aims

The project will model the Martian water cycle, including radiatively active water ice clouds, to interpret new observations from MCS. We will be using the latest version of this LMD MCGM, which includes new LMD physics routines. A unique data assimilation system [10] will be used to obtain a complete, dynamically self-consistent reconstruction of the extraterrestrial circulation for the full Martian year. A series of diagnostic studies will be made to characterise the Martian climate and interannual variability, including detailed case studies of events such as the formation of cyclonic weather systems. The assimilation results can be used to test the validity of the new cloud schemes introduced to the model, improving our understanding of the Martian water cycle.

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References: