Modelling Radiatively Active Water Ice Clouds in the Martian Water Cycle

Conference or Workshop Item

How to cite:

For guidance on citations see FAQs.

© 2011 The Authors

https://creativecommons.org/licenses/by-nc-nd/4.0/

Version: [not recorded]

Link(s) to article on publisher’s website:

Copyright and Moral Rights for the articles on this site are retained by the individual authors and/or other copyright owners. For more information on Open Research Online's data policy on reuse of materials please consult the policies page.
Modelling Radiatively Active Water Ice Clouds in the Martian Water Cycle

Conference or Workshop Item

How to cite:

For guidance on citations see FAQs.

© 2011 The Authors

Version: Version of Record

Link(s) to article on publisher's website:

Copyright and Moral Rights for the articles on this site are retained by the individual authors and/or other copyright owners. For more information on Open Research Online's data policy on reuse of materials please consult the policies page.
Modelling radiatively active water ice clouds in the Martian water cycle

L. Steele1, S. R. Lewis1, M. R. Patel2 and R. J. Wilson3
1Department of Physics & Astronomy, The Open University, MK7 6AA, UK
2Planetary and Space Sciences Research Institute (PSSRI), The Open University, MK7 6AA, UK
3Geophysical Fluid Dynamics Laboratory, Princeton, New Jersey, USA

Email: L.Steele@open.ac.uk

Introduction
Aerosols, both water ice and dust, play a key role in the Martian climate. However, our understanding of the interactions between the dust and water ice, 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, cirrus clouds 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].

Figure 1 shows the difference in visible dust opacity averaged over Mars month 5 for both dust schemes. As can be seen, the 2005 dust scheme shows increased opacity, particularly in the southern hemisphere poleward of around 40° S.

As has been seen, the distribution of dust in the MGGCM has a large impact on atmospheric temperature. It would also therefore be expected to influence the temporal and spatial distribution of clouds, though such simulations have not yet been carried out.

Effects of water ice clouds in MGGCM 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 MGCMs.

The current LMD MGCM [5] 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 MGCM radiation scheme, so absorption of visible/infrared radiation by the water ice clouds is not taken into account. This absence of radiation has been identified as being potentially significant in the equatorial and mid-latitude regions of Mars, where the planet-clouding cloud belt [5] forms [8].

Figure 2 shows the different in visible dust opacity between simulations run with different TES dust schemes (2005 – 2003), averaged over L = 190° – 150°.

Figure 3 shows the effect of this increased dust opacity on the atmospheric temperature. The inclusion of the newer dust scheme results in increased middle atmosphere warming, particularly over the poles, and especially over the north pole. The increased temperature can be attributed to the adiabatic warming of the air that is sinking over the poles. The increased dust in the atmosphere from the 2005 scheme leads to stronger meridional circulation, and hence increased polar warming.

Figure 4. Plots of the meridional mass streamfunction (MMS) averaged over an entire Martian year are shown in Figure 4. The MMS from both the simulations and the modelled data, show a strong dominance of the northerly circulation, though the MMS from both the simulations and the modelled data, show a strong dominance of the northerly circulation, and test the sensitivity of the model to varying dust opacity.

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 MGCM to the distribution of dust, we have run simulations using the LMD MGCM. The two dust schemes used in the independent simulations are derived from assimilations of TES total dust opacity. They are based on earlier and revised retrievals, henceforth donated as 2003 and 2005 dust schemes. As can be seen in the plots, both simulations used identical initial conditions.

Sensitivity of the model to dust distribution
As well as comparing the two simulations with each other, we have also carried out comparisons with observations from the MCD, and modelled data from the MCD, which is used as a convenient summary of model experiments from the LMD MGCM. Figure 5 shows mean vertical profiles of temperature and pressure from the MCD. Figure 6 shows the difference in vertical profiles between observations from the MCD and modelled data. As can be seen, the profiles from the assimilation using TES dust and thermal retrievals are in much better agreement, particularly below around 40 km.

Figure 5. Mean vertical profiles of temperature at varying latitudes from (a) MY24 simulation using 2003 dust scheme; (b) MY24 simulation using 2005 dust scheme; and (c) modelled data from the MCD v3. (Panels (d) and (e)) are from [6].

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 the LMD MGCM, which includes the new LMD physics routines. A unique data assimilation system [10] will be used to obtain a complete, dynamically self-consistent reconstruction of the extratropical circulation for the whole period of the MCS mission. A series of diagnostic studies will be made to characterise the climatological and synoptic meteorology of Mars over seasonal and interannual timescales, including detailed case studies of events such as the formation of cycloonic weather systems.

Acknowledgements
The authors thank L. Montabone and D. Muホールand for their assistance with the model simulations.

References: