# Water ice clouds in a martian global climate model using data assimilation

## Conference or Workshop Item

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## Abstract

The water cycle is one of the key seasonal cycles on Mars, and the radiative effects of water ice clouds have recently been shown to alter the thermal structure of the atmosphere. Current Mars General Circulation Models (MGCMs) are capable of representing the formation and evolution of water ice clouds, though there are still many unanswered questions regarding their effect on the water cycle, the local atmosphere and the global circulation. We discuss the properties of clouds in the LMD/UK MGCM and compare them with observations, focusing on the differences between the water ice clouds in a standalone model and those in a model which has been modified by assimilation of thermal and aerosol opacity spacecraft data.

## 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 [10, 11]. The scattering of solar radiation and the emission of infra-red radiation by clouds have local cooling effects, while the absorption of solar and infrared 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 (ACB) 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 [4].

## 2. The LMD/UK MGCM

To study the martian water cycle, we use an MGCM which makes use of the most recent version of the LMD GCM physical schemes [3, 8] with the UK spectral dynamical core and data assimilation scheme [6]. Examples of water ice cloud and vapour distributions from the model are shown in Figure 1, which can be compared to the Thermal Emission Spectrometer (TES) retrievals in Figure 2 (note that the simulation begins earlier and ends later than the observations, and observations aren't present over the winter poles). The model results were obtained with 3D (horizontal and time-dependent) variations in dust opacities resulting from an assimilation of TES observations.

As can be seen, the model predicts the appearance of the ACB during northern hemisphere spring and summer (as per observations), as well as polar hood clouds during winter, of which only the equatorward edges can be seen in Fig 2. The appearance of a planet-encircling dust storm (which began at $L_S = 185°$ of Mars Year 25) can be seen to reduce cloud opacity at all latitudes, particularly over the north polar cap.

There are, however, also differences present. The predicted cloud opacities over the equator during northern hemisphere winter are greater than those observed, which can be linked to the model vapour abundances also being greater than observations at this season. Also, while the polar hoods are present at times and locations similar to recent MCS results [1, 2], their opacities, as well as latitudinal and temporal distribution, differ. For example, in observations the north polar hood extends all the way to the pole and the south polar hood disappears between $L_S$ =70°–100°, but these features are not present in the model results.

## 3. Data assimilation

Data assimilation combines the benefits of both observation and modelling, and allows a consistent, four-dimensional mapping of the martian atmosphere to be obtained for the period of the observations. This is especially beneficial in regions where observational data is sparse, for example over the winter poles. Even if only one or two observables are assimilated (e.g. temperature, dust opacity), the resultant assimilation will still provide an analysis of all model variables. The assimilated record can be used to validate model results, and investigate the interaction of water ice clouds with

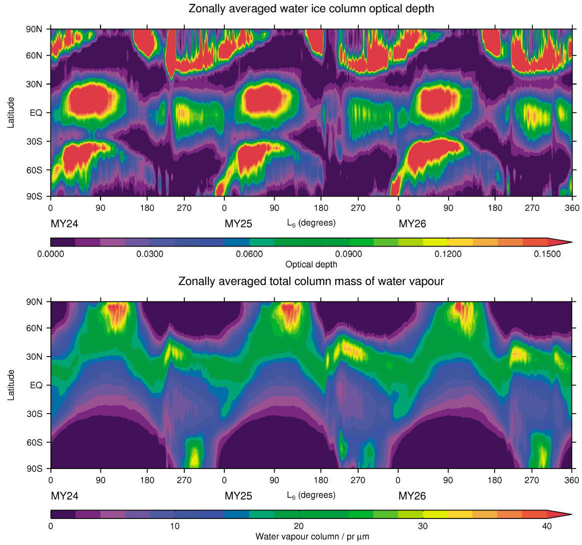


Figure 1: Zonal averages of (top) water ice optical depth, and (bottom) water vapour column abundance, from a model run using the LMD/UK MGCM and assimilated dust opacities from TES observations [6].

both the water cycle and atmosphere. The assimilation scheme used in the model was developed by [5]. It is based on the Analysis Correction scheme of [7], and can analsye data distributed randomly in both time and location. The scheme has already been successfully used to assimilate TES results into the LMD/UK MGCM, and will also be able to assimilate new data being returned from Mars Climate Sounder.

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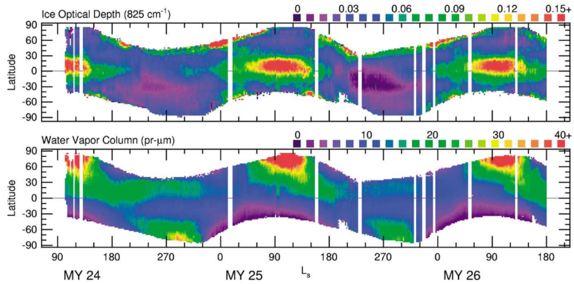


Figure 2: TES zonal averages of (top) water ice optical depth, and (bottom) water vapour column abundance. Data were taken during daytime (local time ∼14:00), and are binned by 5° of $L_S$ [9].