Study of ice cloud formation and evolution in the Tropical Cloud Belt with a detailed microphysical model

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Introduction

Water ice clouds are an important player in the Martian climate. They not only influence the water cycle, but also have a radiative influence on the temperature [1] and cause dust depletion, as dust particles are condensation nuclei for the ice particles. A better understanding and description of these processes requires a microphysical study.

We here present some case studies of the formation and evolution of Martian water ice clouds in the Tropical Cloud Belt (TCB) with the one-dimensional detailed microphysical model MARSBOX and compare the results with SPICAM data.

Model description

MARSBOX is a recently developed microphysical model for Martian ice clouds based on the state-of-the-art model for terrestrial Polar Stratospheric Clouds PSCbox [2, 3]. Two types of particles are considered: dust particles and dust coated with ice (ice particles), with, for both, a size-resolved distribution discretized in geometrically increasing size bins. We here run the model with 30 bins. The microphysical processes taken into account are: heterogeneous nucleation of dust particles by surface diffusion of water vapor, and condensation/sublimation of water vapor on/from ice particles. The vertical transport is described by gravitational sedimentation and eddy diffusion. The model has a timestep of $1/10 solhr$ and an internal variable timestep, of minimum $0.1s$ and maximum $1/10 solhr$ determined by the speed of the microphysical processes.

To initialize the model, we assume that no ice is present. For the dust initialization, we consider a log-normal size distribution, while the vertical distribution is determined by an adapted size dependent Conrath formula [4]. The total amount of dust is fitted such as to obtain a prescribed optical thickness, using a simplified fit [5] of the thickness obtained from the Mars Global Surveyor mission. The model is then run for 20 sols without formation of ice particles, to reach a steady state.

Simulations and results

The atmospheric temperature, pressure and total water budget, are required as input for every vertical layer and at every timestep. MARSBOX then calculates the fraction of the water budget which is ice and which is vapor, and the amount, size distribution and composition (fraction of dust and ice) of the ice particles. The model also computes the extinction profile and optical depth of the ice cloud using Mie theory at present.

We will present simulations with the input fields from the MGCM GM3 [6] over a few places of interest in the TCB. For these simulations we take an effective radius $r_{eff} = 0.5\mu m$ and effective width $\nu_{eff} = 0.4$ for dust and a contact angle $m = 0.98$ for the nucleation.

As example, we show in figure 1 the daily mean over the period $L_s = 100° - 110°$ of the optical thickness, for the wavelength $\lambda = 300nm$, of a cloud above Elysium Mons (left) and Syrtis Major (right). We see that a small variation in the GM3 input temperature ($T \rightarrow T - 2K$) gives a good comparison with the SPICAM data [7]. This figure also illustrates the cloud evolution throughout the day and shows that clouds, depending on their geographical location, do not reach their maximum at the same period of the day.

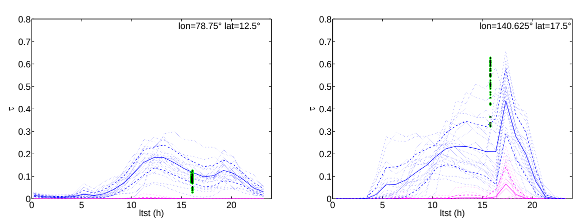

Figure 1: Comparison between the daily optical thickness of MARSBOX and SPICAM on Elysium Mons (left) and Syrtis Major (right) for the GM3 input temperature T (magenta) and $T - 2K$ (blue). The solid lines give the mean, the dashed lines the variability and the dotted lines are the individual results. The green bullets and black crosses are SPICAM results, assuming a cloud altitude of respectively $15km$ and $25km$

The model is not only very sensitive to variations in the input fields, but parameters such as the initial effective radius r_{eff} and effective width ν_{eff} of the size distribution of dust and the contact parameter m also have an important influence on the results. As illustrated in figure 2 and 3 for the location already considered at Syrtis Major, r_{eff} does not only induce a small variation in the optical thickness (which is still in agreement with the results from SPICAM), but also in the amount, the size distribution, and therefore the effective radius of the ice particles.

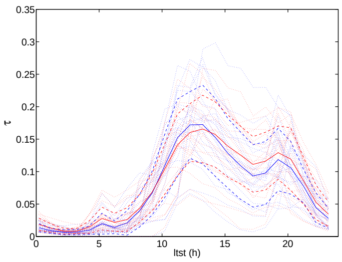

Figure 2: Optical thickness above Syrtis Major for the dust effective radius $r_{eff} = 0.5\mu m$ (blue) and $r_{eff} = 1.0\mu m$ (red)

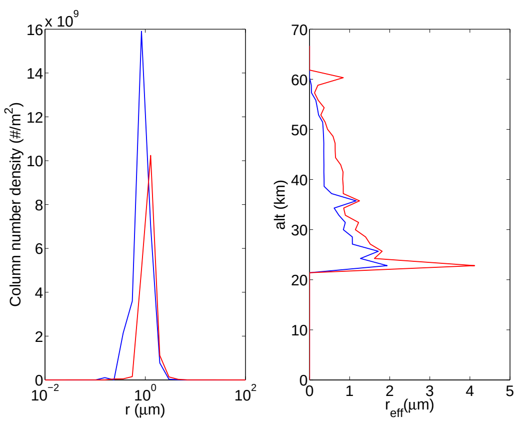

Figure 3: Size distribution (left) and vertical profile of the effective radius (right) for ice particles at 11.2solhr, for a dust effective radius of $r_{eff} = 0.5\mu m$ (blue) and $r_{eff} = 1.0\mu m$ (red)

We will also show how sensitive the model is for the parameters ν_{eff} and m with respect to the main properties of the ice particles.

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