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Martian Mesospheric CO_2 Ice Clouds in a 1D-Model

C. Listowski (1), A. Määttänen (2), A. Spiga (3), F. Montmessin (2), F. Lefèvre (4)
(1) LATMOS, UPMC, Guyancourt, France (constantino.listowski@latmos.ipsl.fr)
(2) LATMOS, CNRS/UVSQ,Guyancourt, France (3) LMD, UPMC, Paris, France (4) LATMOS, CNRS/UPMC, Paris, France

1. Introduction

Since the first probable observation of a CO_2 mesospheric cloud on Mars [1] their formation – out of the main component of the atmosphere (95%) – has not been fully addressed yet by studies dealing with CO_2 ice cloud modeling in general (e.g [2][15]). Their formation process may be constrained by various recent observations from which effective sizes of crystals have been derived ([8][10][11][14]). Moreover, temperatures far below the CO_2 condensation point have been revealed by the SPICAM instrument in the mesosphere, suggesting a strong potential for triggering CO_2 ice condensation in extremely supersaturated environment ([3][10]). Mesoscale modeling has shown that locations where gravity waves are able to propagate through the martian atmosphere up to the mesosphere are strongly correlated with locations of CO_2 ice cloud observations [13]. These elements strongly suggest an interesting way to model the formation of CO_2 mesospheric clouds within a 1D-model, by creating highly supersatured cold pockets with the help of gravity waves.

2. Modeling the clouds

2.1 Microphysical model for CO_2 crystals

We use a microphysical model previously developed by [9] for water ice clouds on Mars, that we have adapted for a CO_2 (95%)/N_2(5%) gas mixture. A hybrid radius grid is used and prevents numerical diffusion during crystal growth. The growth rate of CO_2 ice crystals is as described by [6]. It is adapted to a near-pure vapor condensation with high supersaturations as encountered in the martian mesosphere. We adopt classical nucleation theory assuming that nucleation is only heterogeneous, as it most probably is on Mars, for surface as well as for mesospheric conditions [7,8].

2.2 Inputs: gravity waves and dust

We use temperature profiles perturbed by gravity waves (Fig. 1) as presented in [13] who use [12] where thermal tides are properly described. They seem to be a prerequisite to explain CO_2 cloud formation in the martian mesosphere [5]. However small scale perturbations (gravity waves) are needed for temperature excursions below the CO_2 condensation point. We investigate various supersaturations at pressure levels between 5.10^{-2} and 10^{-3} Pa (~70-100 km).

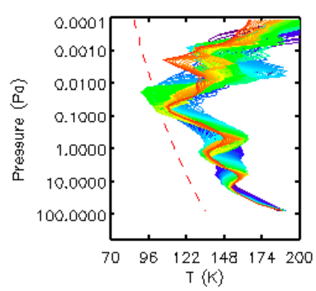

Figure 1 *Example of temperature profile perturbed by a gravity wave with a maximum supersaturation of s=20. Dashed line is CO_2 condensation temperature. Colorscale (blue to red) stands for the time (~4 hours in total).*

We use a dust bed in equilibrium (sedimentation vs. vertical turbulent mixing at kd=1000 m^2 s^{-1}) or alternatively add dust particles to simulate the presence of an aerosol detached layer originating either from dust lifted from the ground or due to micrometeoritic material.

3. Results and perspectives

3.1 Daily mesospheric clouds

Given a dust bed in equilibrium it is possible to reproduce the effective size of clouds as observed by OMEGA ([8][11][14]) for relatively high supersaturations: S~60 (Fig. 2 & 3). The cloud evaporates fast after the cold pocket has vanished. Note that the opacities (0.01) cannot be explained with a simple dust bed in equilibrium: an additional source of dust particlez is needed.

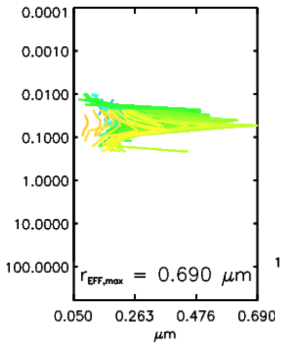

Figure 2
Crystal radius (µm) profile (y-axis is pressure in Pa). Cloud obtained at ~70 km altitude with the temperature profile of Figure 1. Maximum supersaturation is 20.

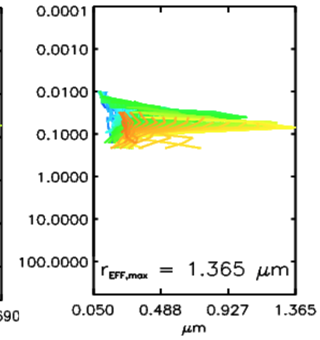

Figure 3
Crystal radius (µm) profile (y-axis is pressure in Pa) Cloud obtained with a temperature profile reaching a maximum supersaturation of 70.

3.2 Night mesospheric clouds

With a gravity wave added to a nighttime temperature profile, and causing supersaturations S>100 (Fig. 4) at pressures below 10^{-2} Pa, a dust bed in equilibrium leads to effective radii r_{eff}~80 nm (Fig. 5). It corresponds to effective radii observed with SPICAM [10]. However, a supply of condensation nuclei may be necessary to explain the larger effective sizes observed (r_{eff}~ 130 nm), as well as the opacities.

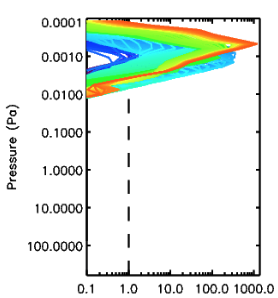

Figure 4
Simulated night profile of the CO_2 saturation ratio, with a gravity wave. A maximum value of S~ 1000 is reached at ~100 km (p<10^{-3} Pa).

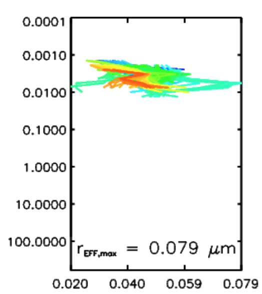

Figure 5
Cloud formed (due to the cold pocket Fig. 4) out of the high altitude residual particles in the equilibrium dust bed.

3.3 Perspectives

We will further discuss the possibility to reproduce observed effective crystal radii and opacities at the same time for both type of clouds. Also, the probable influence of radiative heat transfer in the energy budget of the crystals will be discussed.

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