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Martian GCM with complete CO_2 clouds microphysics

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Abstract

Towards understanding Martian CO_2 cloud formation, abundance and features, including their formation and evolution in a Global Climate Model (GCM) is necessary. Their precise radiative impact on the climate throughout the history of the planet is especially of prime importance due to the backscattering of the infrared photons by the CO_2 ice crystals that might have contributed to a greenhouse effect.

The purpose of this work is to include a complete and validated CO_2 cloud scheme (developped by [1,2]) in the GCM of the Laboratoire de Météorologie Dynamique (LMD) [3]. We hereafter present the key steps of this coupling and the first results.

1. Introduction

Numerous observations (e.g. [4,5,6,*7,8]*), theoretical advances and modeling works [1,2,9,10,11,12] have improved our understanding of CO_2 cloud formation and dynamics on Mars. These clouds, less frequently observed than the water ice clouds, form in the troposphere at the poles during winter and at equatorial latitudes in the mesosphere (60 – 110 km). Atmospheric CO_2 condensation requires extremely low temperatures to produce supersaturation. Such low temperatures are reached during the polar night and have been observed at low latitudes in the mesosphere [5, 13, *14]*. These cold pockets are most likely produced by gravity waves propagating to the upper atmosphere [*12]*, at the altitudes of the temperature minima caused by the thermal tides.

Moreover, aerosol particles must be present for the CO_2 to condense on them by the mean of heterogeneous nucleation. At high mesospheric altitudes and such low pressures (typically 0.01 Pa), it is unknown whether dust lifted from the surface or particles coming from above (such as meteoritic smoke particles) prevail. CO_2 clouds are short-lived and do not last long after the favorable conditions vanish (about a dozen of minutes, [*2]*).

2. CO_2 clouds scheme for the GCM

We have adapted the CO_2 cloud microphysics scheme of *[1,2]* for his coupling with the LMD-GCM presented in [3]. The atmosphere is discretized in 32 layers up to about 120 km in the GCM and the timestep is about 7.5 minutes. During one such timestep, the CO_2 cloud scheme is called 50 times (i.e. every 9.5 seconds) and it includes includes heterogeneous nucleation on aerosols (dust, meteoritic smoke particles and water ice clouds), CO_2 ice nucleation and sublimation (as a function of CO_2 partial pressure and temperature) and sedimentation of the particles. For a better nucleation accuracy, the moments of the CO_2 ice particles population are distributed into 100 bin sizes.

3. Results

We have simulated an entire Martian Year, with a resolution of ~7.5 minutes, from the surface to about 120 km. The GCM outputs have been re-binned 15 sols at a time in altitude (13 10-km wide layers) and in local time (30 min resolution). The simulations show frequent CO_2 clouds at low latitude at mesospheric altitudes during the northen hemisphere spring and autumn (Ls 0-45 and Ls 150-190). Overall, nighttime clouds are higher (up to ~ 100 km) and are composed of smaller particles than daytime clouds (down to about ~40km). CO_2 clouds form with respect to the upward propagation of the thermal tide. Clouds are observed at the poles at mesospheric and tropospheric altitudes (even close to the surface) at the poles during their respective winters. Examples can be seen in figures 1,2 and 3.

4. Summary and Conclusions

A complete meteorology of CO_2 clouds inferred from the GCM will be presented and discussed at the conference. The sensibility with regards to various smulation parametrers will also be adressed.

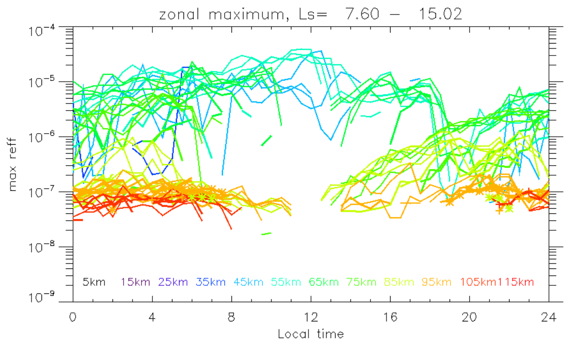

***Fig.1**: Distribution of CO_2 ice clouds particles effective radius as a function of local time and altitude (indicated by different colors). Every line represents a latitude, and the thicker the line, the closer to a pole the latitude is.*

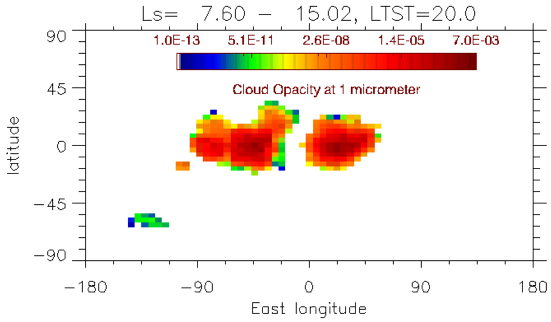

***Fig.2**: Map of maximum CO_2 ice clouds opacity at 1 µm, at a local time of 20 LTST, bewteen 7.6 and 15.02° LS.*

Acknowledgements

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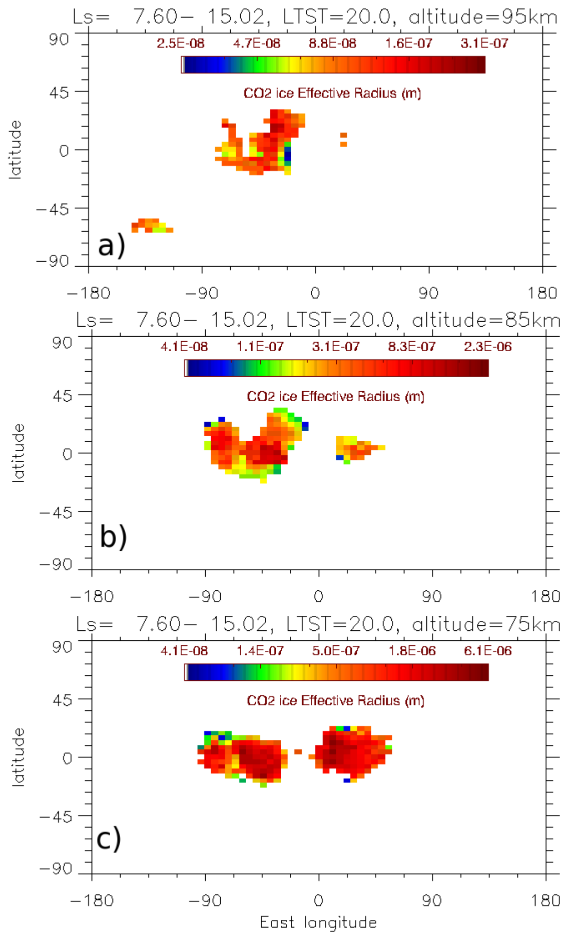

***Fig.3**: Maps of CO_2 clouds ice particles effective Radius. Local time is 20LTST and 3 altitudes are shown: 95km (a), 85km (b) and 75 km(a).*

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