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# Martian GCM with complete CO<sub>2</sub> clouds microphysics

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## Abstract

Towards understanding Martian CO<sub>2</sub> 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<sub>2</sub> ice crystals that might have contributed to a greenhouse effect.

The purpose of this work is to include a complete and validated CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> clouds are short-lived and do not last long after the favorable conditions vanish (about a dozen of minutes, [2]).

## 2. CO<sub>2</sub> clouds scheme for the GCM

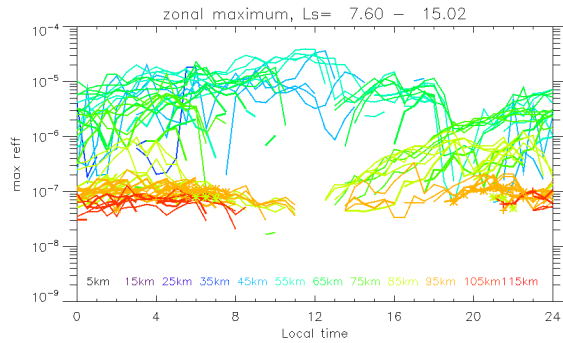
We have adapted the CO<sub>2</sub> cloud microphysics scheme of [1,2] for his coupling with the LMD-GCM presented in [3]. The atmosphere is discretized in 32 layers up to about 120 km in the GCM and the timestep is about 7.5 minutes. During one such timestep, the CO<sub>2</sub> cloud scheme is called 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<sub>2</sub> ice nucleation and sublimation (as a function of CO<sub>2</sub> partial pressure and temperature) and sedimentation of the particles. For a better nucleation accuracy, the moments of the CO<sub>2</sub> ice particles population are distributed into 100 bin sizes.

## 3. Results

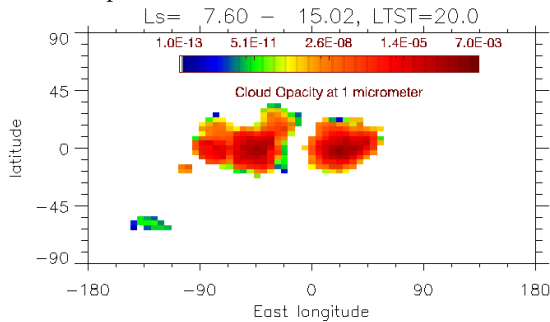
We have simulated an entire Martian Year, with a resolution of ~7.5 minutes, from the surface to about 120 km. The GCM outputs have been re-binned 15 sols at a time in altitude (13 10-km wide layers) and in local time (30 min resolution). The simulations show frequent CO<sub>2</sub> clouds at low latitude at mesospheric altitudes during the northern 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<sub>2</sub> 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<sub>2</sub> clouds inferred from the GCM will be presented and discussed at the conference. The sensibility with regards to various simulation parameters will also be addressed.



**Fig.1:** Distribution of CO<sub>2</sub> 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.



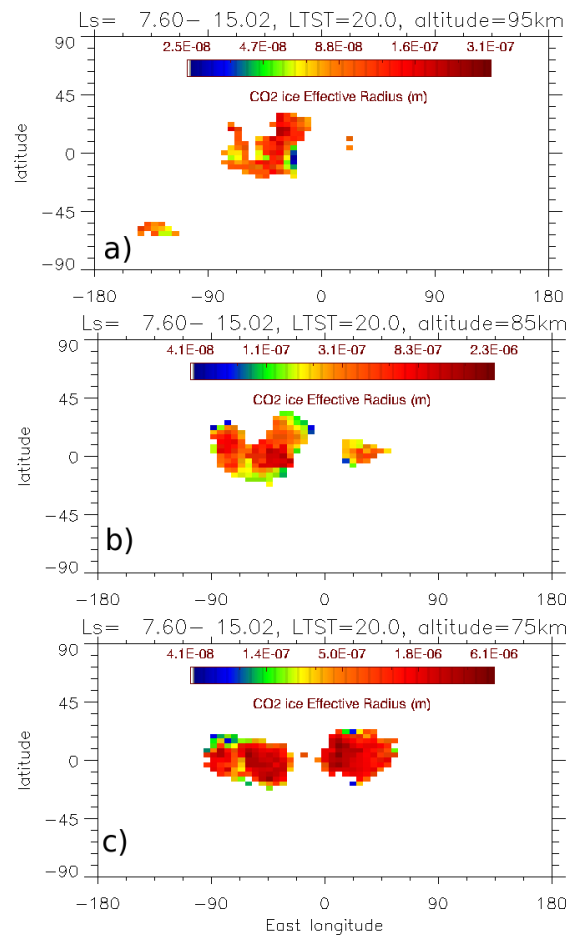
**Fig.2:** Map of maximum CO<sub>2</sub> ice clouds opacity at 1  $\mu\text{m}$ , at a local time of 20 LTST, between 7.6 and 15.02° LS.

## Acknowledgements

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## References

[1] Listowski, C. et al., 2013, Near-pure vapor condensation in the Martian atmosphere: CO<sub>2</sub> ice crystal growth, *JGR*, 118, 10, 2153-2171 ; [2] Listowski, C. et al., 2014, Modeling the microphysics of CO<sub>2</sub> ice clouds within wave-induced cold pockets in the martian mesosphere, *Icarus*, 237, 239-261; [3] Forget, F. et al., 1999, Improved general circulation models of the Martian atmosphere from the surface to above 80 km, *JGR*, 104, E10; [4] Clancy and Sandor, 1998, CO<sub>2</sub> ice clouds in the upper atmosphere of Mars, *GRL*, 25, 4, 489-492 ;[5] Montmessin, F. et al., 2006, Subvisible CO<sub>2</sub> ice clouds detected in the mesosphere of Mars, *Icarus*, 183, 2, p. 403-410; [6] Montmessin, F. et al., 2007, Hyperspectral imaging of convective CO<sub>2</sub> ice clouds in the equatorial mesosphere of Mars, *Journal of Geophysical Research*, 112, E11;



**Fig.3:** Maps of CO<sub>2</sub> clouds ice particles effective Radius. Local time is 20LTST and 3 altitudes are shown: 95km (a), 85km (b) and 75 km(a).

[7] Määttänen, A. et al., 2010, Mapping the mesospheric clouds on Mars: MEX/OMEGA and MEX/HRSC observations and challenges for atmospheric models, *Icarus*, 209, 2, 452-469; [8] Vincendon, M. et al., 2011, New near-IR observations of mesospheric CO<sub>2</sub> and H<sub>2</sub>O clouds on Mars, *JGR*, 116; [9] Määttänen, A. et al., 2005, Nucleation studies in the Martian atmosphere, *JGR*, 110, E2; [10] Määttänen, A. et al., 2007, Two-component heterogeneous nucleation kinetics and an application to Mars, *J. of Chemical Physics*, 127, 13; [11] Colaprete, A. et al., 2008, CO<sub>2</sub> clouds, CAPE and convection on Mars: Observations and general circulation modeling, *PSS*, 56, 2; [12] Spiga, A. et al., 2012, Gravity waves, cold pockets and CO<sub>2</sub> clouds in the Martian mesosphere, *GRL*, 39, 2 ; [13] Schofield, J. T. et al., 1997, The Mars Pathfinder Atmospheric Structure Investigation/Meteorology, *Science*, 278, 5344; [14] Forget, F. et al., 2009, Density and temperatures of the upper Martian atmosphere measured by stellar occultations with Mars Express SPICAM, *JGR*, 114, E1