# IMPACT OF THE REFINEMENT OF THE VERTICAL RESOLUTION OF THE LMD'S MARTIAN GLOBAL CLIMATE MODEL ON THE SIMULATION OF THE WATER CYCLE

*M. Vals[1], F. Forget[1], A. Spiga[1], E. Millour[1]*
*[1]Laboratoire de Météorologie Dynamique (Paris)*

**Introduction:** The martian atmosphere hosts a complex water cycle, which is mainly controlled by strong seasonal variations and plays a key role in the radiative transfer. The Martian Global Climate Model (GCM, see [1]) of the LMD (Laboratoire de Météorologie Dynamique) reproduces the main features of the whole processes charaterizing the atmosphere circulation. The water cycle simulated by the model comprises the sublimation and condensation of the water ice taking place on the surface, but also in the atmosphere, as water ice clouds. The representation of radiatively active water ice clouds has particularly been improved by recent implementations of detailed cloud microphysics ([2], [3]). These comprise the nucleation on dust particles, ice particle growth and scavenging of dust particles due to the condensation of ice. In spite of these significant improvements, some differences with the observations are persistent, as a lack of water ice clouds formed in the tropics at the aphelion belt, or the too strong water vapor release in the atmosphere at the North pole during the Northern Hemisphere Summer ([3]). In order, to solve these discrepancies, further studies, such as the refinement of the horizontal resolution (1°x1° instead of 4°x6°, [4]), and a parametrisation of sub-grid scale clouds, have been carried by Alizée Pottier, PhD-student at the LMD from 2013 to 2016.

Athough some corrections have been obtained, the global improvement of the simulated water cycle is not significant considering the numerical cost of such implementations. Moreover, recent studies have revealed the importance of the vertical resolution to reproduce particular processes such as the night-time convection detected under water ice clouds, and finally simulated by a mesoscale model (vertical resolution of 750m), see [5], [6]. Indeed, this kind of phenomenon cannot be resolved by the usual resolution of the GCM, which is around 2km at the considered altitude range, between 5 and 10km, whereas the convective layer is about 5km height. Therefore, further investigation focuses on the effect of a refinement of the vertical resolution of the model. The aim of the work presented here is eventually to study and compare the impact of a finer vertical resolution on the global consistency of the model. In the future, results will also have to be confronted to the new observations available (TGO).

**Refinement of the vertical resolution:** Two vertical resolutions are being tested with the LMD's martian GCM. The typical resolution adopted in the GCM is already refined near to the surface (from around 10 to 500m) in order to properly resolve the planetary boundary layer (PBL), however it gradually decreases from the top of the PBL up to the top of the atmosphere. It is then of about 2km around 10km altitude and 4km around 30km altitude.

The first higher resolution we are testing, referred to as 'high resolution', is about 800m around 10km altitude and 1.5km around 30km altitude. The second one, referred to as 'very high resolution', is about 500m around 10km and 650m around 30km altitude.

**Preliminary results:** Preliminary results have been obtained for both 'high' and 'very high' resolutions and mixing layers are well observed under night-time water ice clouds, on the contrary to what was obtained with the usual resolution (see **Figures 1**, **2** and **3**). Although some local features seem to be better reproduced thanks to such a refinement of the vertical resolution, the global impact on the water cycle is not obvious, as it can be seen for example in **Figures 4** and **5**, which reveal that the model still produces too much water vapour at North Pole during Summer in comparison to observations.

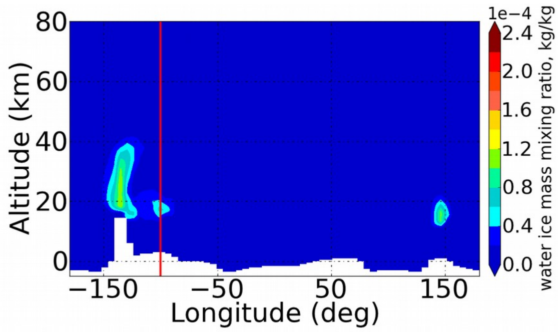


**Figure 1:** Slice of water ice mixing ratio (kg/kg) at latitude 20°, Ls=150° and LT=2AM, along the altitude above the martian aeroid, simulation obtained with the LMD's martian GCM, with the usual vertical resolution (about 2km around 10km altitude and 4km around 30km altitude)

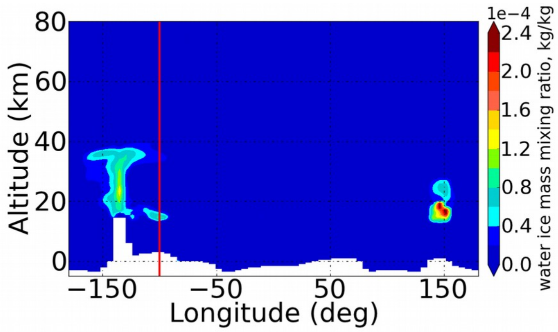


**Figure 2:** Slice of water ice mixing ratio (kg/kg) at latitude 20°, Ls=150° and LT=2AM, along the altitude above the martian aeroid, simulation obtained with the LMD's martian GCM, with the 'very high' resolution (about 500m around 10km and 650m around 30km altitude)

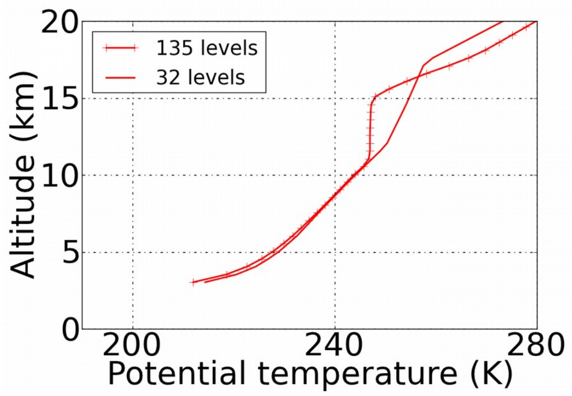


**Figure 3:** Potential temperature profiles along the altitude above the martian aeroid at Ls=150°, LT=2AM obtained respectiveley with usual vertical resolution (continuous line) and the 'very high' resolution (line with dashes)

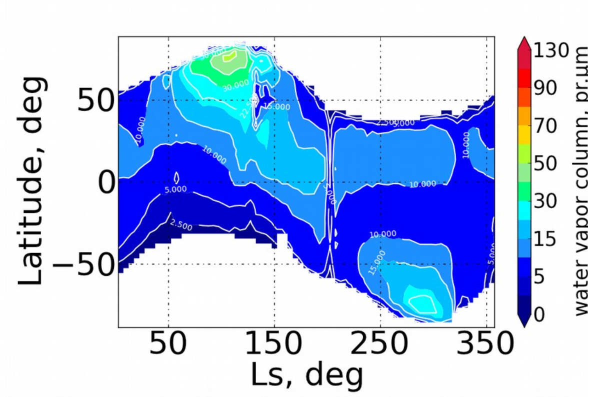


**Figure 4:** Annual cycle of the zonal mean of the water vapour ice column (pr.µm) observed at 2PM by the instrument TES on board Mars Global Surveyor

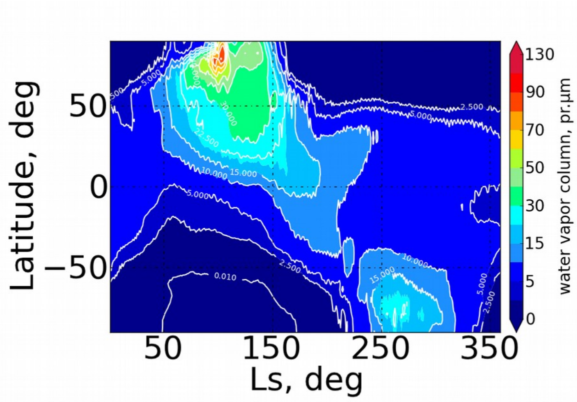


**Figure 5:** Annual cycle of the zonal mean of the water vapour ice column (pr.µm) obtained at 2PM by the LMD's martian GCM with the very high vertical resolution

**Objectives:** Further investigation will be carried on the effect of the finer vertical resolution on the water cycle. It will also be confronted to the implementation of the previously developped parametrization of sub-grid scale clouds. The study will also be extended to the impact on the global model, in particular on the simulation of the dust cycle, closely related to the water cycle. Results will be presented at the conference.

**References:**

[1] Forget, F., Hourdin, F., Fournier, R., Hourdin, C., Talagrand, O., Collins, M., Lewis, S. R., Read, P. L., and Huot., J.-P. Improved general circulation models of the Martian atmosphere from the surface to above 80 km. ***JGR***, 104:24,155–24,176, 1999.

[2] Madeleine, J.-B., Head, J. W., Forget, F., Navarro, T., Millour, E., Spiga, A., Colaïtis, A., Määttänen, A., Montmessin, F., and Dickson, J. L. Recent Ice Ages on Mars: The role of radiatively active clouds and cloud microphysics, ***GRL***, 41:4873–4879, 2014.

[3] Navarro, T., Madeleine, J.-B., Forget, F., Spiga, A., Millour, E., Montmessin, F., and Määttänen, A. Global Climate Modeling of the Martian water cycle with improved microphysics and radiatively active water ice clouds, ***JGR*** (Planets), 2014.

[4] Pottier, A., Forget, F., Montmessin, F., Navarro, T., Spiga, A., Millour, E., Szantai, A., and Madeleine, J.-B. Unraveling the martian water cycle with high-resolution global climate simulations. ***Icarus***, 2017.

[5] Wilson, R. J. and Guzewich, S. D. Influence of water ice clouds on nighttime tropical temperature structure as seen by the mars climate sounder. ***GRL***, 41(10):3375–3381. 2014GL060086, 2014.

[6] Spiga, A., Hinson, D., Madeleine, J., Navarro, T., Millour, E., Forget, F., and Montmessin, F. Snow precipitation on Mars driven by cloud-induced nighttime convection. ***Nature Geoscience***, 10:652–657, 2017.