The destabilizing effect of water ice clouds in Mars climate models: Challenges and Solutions. Alizée Pottier[1], F. Forget[2], F. Montmessin[1], T. Navarro[2], J.-B. Madeleine[2], E. Millour[2], and A. Spiga[2], [1]Laboratoire Atmosphères, Milieux, Observations Spatiales (11 boulevard d'Alembert, Quartier des Garennes, 78280, Guyancourt, France, alizee.pottier@latmos.ipsl.fr), [2]Laboratoire de Météorologie Dynamique (Tour 45-55, 3ème étage, case postale 99, 4 place Jussieu, F 75252 Paris Cedex 05) .

Introduction: Much effort has been put into a better understanding of the martian water cycle. The use of Global Climate Models has been proven useful in such a study. The GCM of the Laboratoire de Météorologie Dynamique (LMD) is part of that effort. It includes a full water cycle, complete with its polar caps as source and sink, water vapour and ice tracers, cloud formation and sedimentation processes.

It has been shown recently that radiatively active clouds are necessary to have an accurate Mars seasonal cycle representation. Water ice clouds take a key part in the radiative equilibrium of the planet. Indeed, they absorb incoming solar radiation and thermal infrared emission. They explain some thermal inversions that are observed[1,2,3]. The temperature distribution in the equatorial region cannot be fully understood without radiatively active clouds[4].

Furthermore, clouds play a major role in the transport of water during the martian seasonal cycle[5].

Thus, invaluable insights about the martian climate and water cycle can be inferred from a GCM with radiatively active clouds. Consequently, water ice clouds were recently made active in the LMD GCM.

Radiatively active clouds in a GCM: challenges. The global circulation of the martian atmosphere is modified[6]. Active clouds help reduce some temperature bias that were present in the model with inactive clouds, even if some problems remain[6] (see figure 1). The clouds warm the middle atmosphere between the tropics, and that is in agreement with MCS observations[7] . The Hadley cell is also stronger.

There are two major challenges.

Most global climate models[8,9,6,4] that have taken into account the radiative effect of clouds have found that their simulations of the water cycle was significantly degraded (figure 3b). This was shown to result from the fact that during summer solstice at the North Pole, which is critical for the global water budget, a too thick polar hood develops, which has a strong negative impact on the total amount of water fueling the cycle. The clouds block the incoming solar radiation and less water ice is sublimated. In most cases, the water cycle is too dry. This might come from the inability, at the time, to model with the GCM supersaturation of water vapor, which was recently discovered on Mars[10].

There is also a positive feedback loop between the temperature of the air, its water vapor content and the water ice clouds that may appear. Consequently, the radiatively active water ice clouds tend to make the model more unstable. Clouds, vapor and temperature are strongly coupled[9].

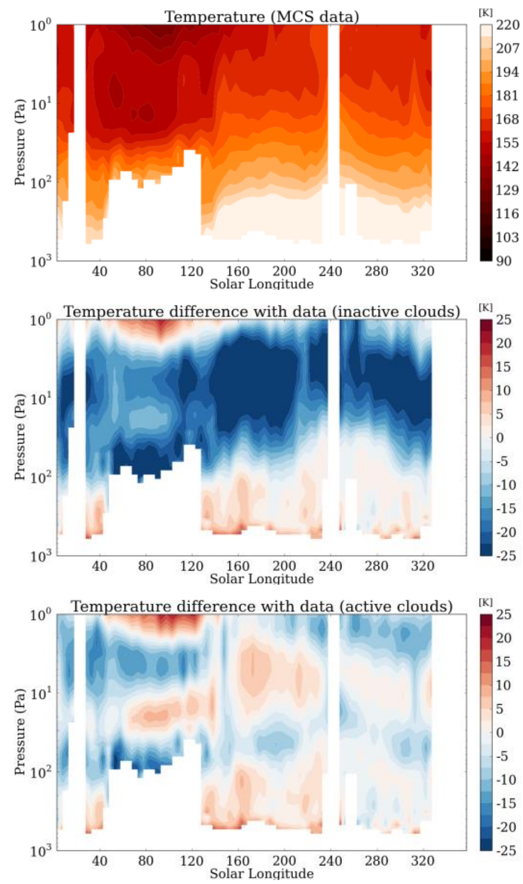

Figure 1.a. MCS data, MY 29, equator, diurnal zonal mean temperature. **1.b.** Temperature difference between a GCM with inactive clouds and MCS diurnal data, MY29. **1.c.** Temperature difference between a GCM with active clouds and MCS diurnal data, MY29.

We will now describe the latest developments in the GCM to solve the aforementioned problems.

A new microphysical scheme. The latest microphysical scheme of the model includes nucleation, condensation and scavenging. The scheme relies on the hypothesis that martian water ice clouds form on condensation nuclei, which are the airborne dust particles[11] . The possibility of supersaturation is included by computing analytically the growth rate of ice crystals.

One of the major results of this inclusion was the disappearance of the persistence of the polar hood during northern summer[12] (see figure 2). The model is consequently wetter and closer to observations (see figure 3).

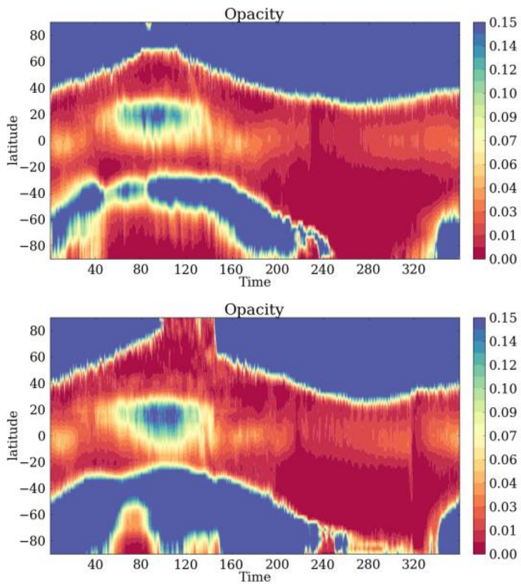

Figure 2. Zonally averaged cloud opacity. **2.a.** GCM without microphysics: thick cloud cover of the northern polar area during its spring and summer. **2.b.** GCM with microphysics: clearer sky there.

The model remains very sensitive to parameters like surface ice albedo and thermal inertia, as well as poorly known microphysical parameters such as the nucleation contact angle and the assumed width of the particle size distribution (it does predict the effective radius of the particles, but not the width of the distribution). Scavenging of dust by clouds is not enough to explain the detached layers observed by MCS, which must be parametrized on their own[13].

Cloud resolution and subgrid scale nebulosity. So as to reduce the impact of the positive feedback loop, the need to include a finer representation of the clouds in model cells arose. Indeed, as GCM grid cells are quite thin in height and very broad in terms of ground coverage, clouds covering a whole model cell are very unlikely at the spatial resolution of the GCM.

That is why the inclusion of partial cloud cover in cells is currently studied. Earth models use a probability density function for water vapor mixing ratio, but it might not fit the particular martian environment, very dry, and prone to extreme temperature changes. We need to understand well how martian clouds behave first. High resolution model runs are currently performed to reach this goal (see figure 4), with a maximum of 1° per 1° resolution, which means 60 per 60 km at the equator of Mars.

From these we deduce a way to take into account subgrid scale nebulosity. We will present our ideas and preliminary results during the conference.

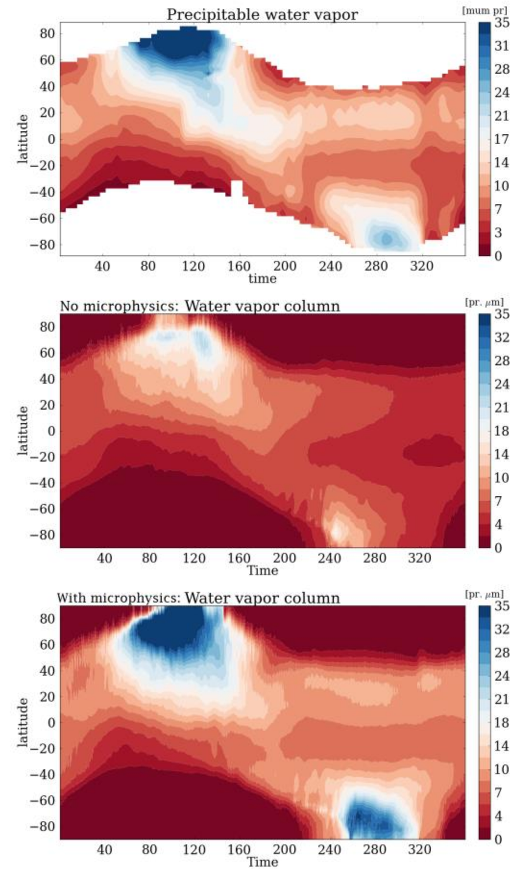

Figure 3. Water vapor column (precipitable µm). **3.a.** TES data, MY 26. **3.b.** GCM without microphysics. **3.c.** With microphysics.

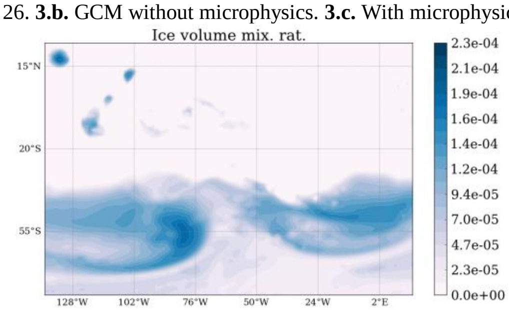

Figure 4. A high resolution (1° per 1°) snapshot of water ice mixing ratio at a height of 10 km. Zoom on the Tharsis area and below.

References:

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