Spatial variation of Methane and other trace gases detected on Mars: interpretation with a General circulation model F. Forget[1,2] , B. Haberle[2], F. Montmessin[2] , [1]LMD, IPSL (Universite Paris 6, BP99, 75252 Paris Cedex 05 France; forget@lmd.jussieu.fr), [2]NASA Ames Research Center, USA,

Introduction: Several teams have recently reported the detection of methane in the Martian atmosphere [1-3]. Although the detection is at the limit of the instrument capacities, one of the most surprising findings by some of these teams is the apparent strong spatial variations observed in spite of the fact that a gas like methane was expected to have a relatively long lifetime in the Martian atmosphere and thus be well mixed. To better quantitatively understand how such spatial variations can form on Mars, we have performed multiple realistic 3D general circulation model simulations in which gases with different sources, lifetime or sinks are released and transported in the Martian atmosphere.

The model: The main tool used for our study is the LMD General Circulation Model [4] which is designed to represent the details of the Martian climate and circulation with high accuracy. In addition, some experiments have been performed with the NASA Ames GCM to test our results with an independent model. Tracers are transported by the general circulation winds using a performant finite volume transport scheme [5] and mixed by the atmospheric turbulence (especially in the boundary layer) and convection. A recent improvement of the model is the ability to take into account the non-volatile gas enrichment in the polar night when CO2 is condensing (and depletion over the subliming cap). For this purpose, an exact mathematical representation of the gas motion in GCM "sigma" coordinates has been written, and a parameterization of the vertical mixing due to non-condensible gas buoyancy motions has been included.

Simulations: Several long simulations (~10 years) have been performed. 1) Gases with various lifetime ranging from 10^3s to 10^{10}s (like methane in theory) and infinity are released from localized sources and transported in an atmosphere initially free of these gases 2) same simulations but starting with an atmosphere already saturated and in equilibrium with the sources and sinks (case of continuous sources outgassing for a very long time) 3) Like 1 but assuming that the main gases sinks are globally located at the surface (case of heterogeneous reaction with the solid surface) 4) Like 1 but assuming that the gases sinks is related to solar radiation (case of photolysis induced chemistry) and 5) Like 1 and 2 but assuming a global source.

Preliminary results: First, we find that gases with lifetime shorter than 10^7s (~100 sols) do exhibit strong spatial variations with a strong maximum near their localized source (Figure 1). Therefore gas with lifetime of a few tens of days or less released from a non global source should be expected to show large spatial (longitudinal) variations. Gases with longer lifetime tend to be well mixed after a while. However, spatial structures can be created if the source is not continuous, because the atmosphere is then far from being in equilibrium with the gases. For instance, Figure 2 shows that after about two third of a year, a gas with a very long lifetime of 10^{10}s (~320 Earth years; like methane in theory) can be twice more abundant near its source than in the rest of the atmosphere. This suggest that remote observations could detect strong spatial variations not because the chemical lifetime of the gas is short, but because the sources are not constant in time (local events, seasonal cycle, etc…).
Finally, after many years, we found that the main source of spatial variations for long lifetime gas is the seasonal CO2 cycle and the corresponding enrichment in the polar night as detected by [6] in the case of Argon.

Further results will be presented at the conference.

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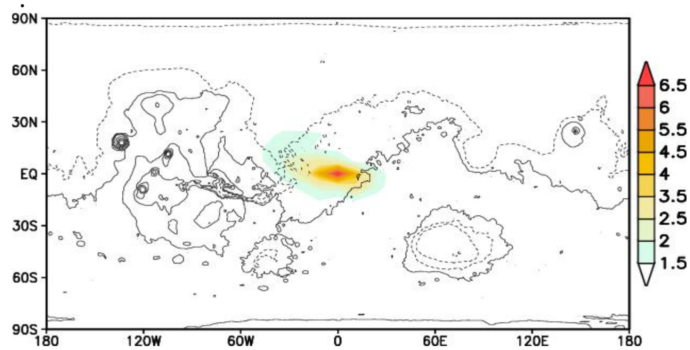

Figure 1: Relative column abundance of a gas with localized source at 0°N 0°E and lifetime of 10^7s (~100 days) after 10 years. The gas column abundance has been scaled with surface pressure to remove the topography effects and normalized to the global mean abundance.

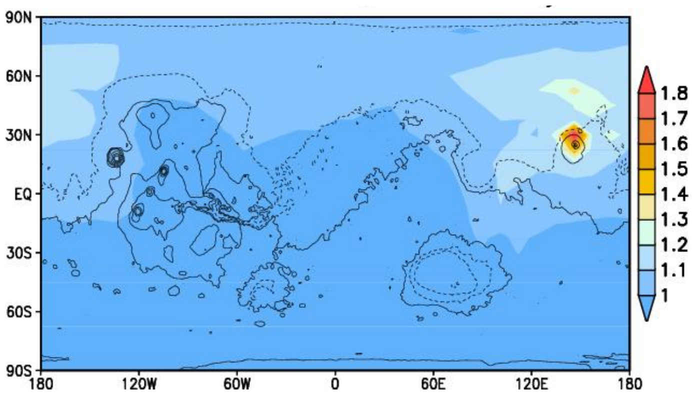

Figure 2: Same as Fig. 1 but for a gas released from the Elysium area with a lifetime of 10^{10}s (320 Earth years; like methane in theory) and after 0.6 Martian years. The local maximum above the source is still significant in spite of the very long lifetime of the gas.

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[3] Krasnopolsky et al. Icarus 172 p. 537-547 (2004)
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[6] Sprague et al. Science 306, pp1364 (2004)