TRANSPORT-DRIVEN FORMATION OF AN OZONE LAYER AT THE MARS WINTER POLES

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Introduction:

Cross-hemispheric circulation of the atmosphere is a major feature of the Martian troposphere and Venusian thermosphere. On Mars, it is driven by the latitudinal gradient of insolation at the surface, which generates a global summer-to-winter Hadley cell reversing orientation during equinoxes and maximizing intensity at solstices. On Venus, it is driven by a longitudinal gradient between the dayside and the nightside and takes place above the super-rotating mesosphere and troposphere. This subsolar-to-antisolar (SSAS) circulation is known to induce major observational features, such as the vast O_2 and NO emission zones observed close to midnight. Recently, SPICAV onboard Venus Express has detected for the first time the presence of ozone on Venus, accounting for a thin thermospheric layer at about 100 km. Concomitantly, a similar feature was recently identified on Mars with SPICAM, with the presence of a >10 km thick ozone layer in the southern winter hemisphere near the pole.

Ozone on Mars:

Ozone on Mars has been reported since the early 70's and has now been well characterized thanks to the SPICAM instrument onboard Mars Express [1] which operates in the ultraviolet range (110 to 320 nm) where ozone possesses a distinctly broad absorption band (the Hartley band) peaking around 250 nm. The observations discussed here have been obtained while SPICAM was acquiring UV spectra in a stellar occultation mode. This mode allows to infer ozone vertical profiles at a specific location. Five years of data have been compiled so far, yielding the space and time coverage displayed in Figure 1.

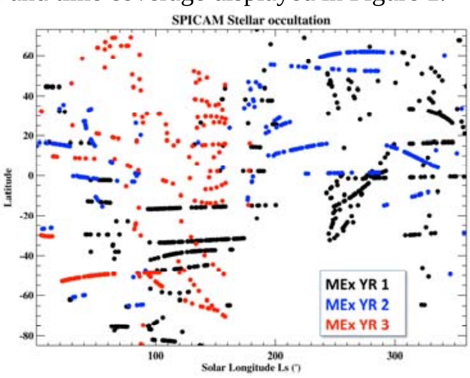

Figure1: Ls vs. latitude distribution of the SPICAM stellar occultation for 2.5 Mars years.

A preliminary assessment of ozone vertical distribution was given in [2]. The profiles showed the presence of two ozone layers: (1) one located near the surface, the top of which is visible below 30 km altitude, and (2) one layer located in the altitude range 30 to 60 km, a feature that is highly variable with latitude and season. This layer is first seen after $L_s = 11°$, and the ozone abundance at the peak tends to increase until L_s 40°, when it stabilizes around 6–8 10^9 cm^{-3}. After southern winter solstice (L_s 100°), the peak abundance starts decreasing again, and this ozone layer is no longer detected after L_s 130°. A model [3] predicted the presence of these ozone layers, the altitude one being only present at night.

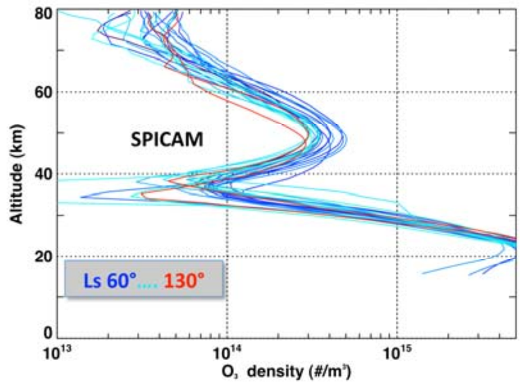

Figure 2: A subset of SPICAM ozone concentrations (molecules/m^3) profiles collected near 75°S between Ls 60° and 130°. The layer of interest appears distinctly between 40 and 60 km.

A new type of ozone layer:

Different from the ozone layer otherwise observed on Mars which extends from the surface and is controlled by reaction with HOx radicals, a new type of layer has been recently identified that is only observed at the winter poles of Mars. This layer is located at 50 km and is confined to the deepest polar regions, typically poleward of 60° (Figure 2). Due to the asymmetric coverage of SPICAM occultations between the two hemisphere, it was not possible to probe the north polar region as deeply as in the south. This polar ozone layer follows a distinct seasonal evolution (reproduced in Figure 3), only existing during southern fall/winter in the south (and conversely in the north), and peaking in abundance around solstices. Such seasonal behavior suggests a potential control by global circulation whose typical pattern around solstices is dominated by a single Hadley cell extending from the summer mid-latitudes to the winter polar regions.

We hypothesize that this layer is related to O atoms produced in the summer hemisphere and carried via global circulation towards the polar night where they can recombine, yielding the newly detected O_2 emission feature evidenced by OMEGA [4], showing an O_2 production zone at around 45 km. The transport of O atoms allows further recombination of O_2 molecules with O, resulting in a local source of ozone.

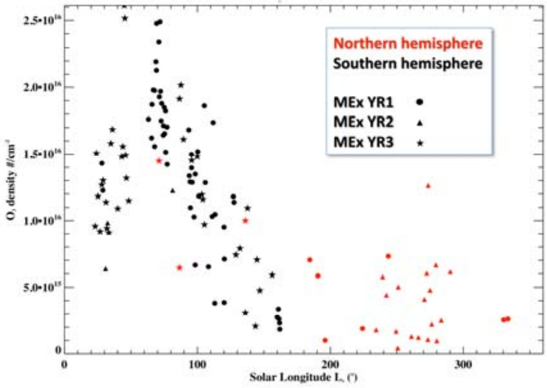

Figure 3: Seasonal evolution of polar ozone observed by SPICAM at 50 km.

Preliminary comparison with the results of the LMD/LATMOS 3D photochemical model indicates that the model is qualitatively able to reproduce this polar ozone feature (see comparison displayed in Figure 4). However, the model tends to overestimate ozone abundances at the peak level by a factor of 2 to 3. Further analysis is needed to identify the reasons for the observed differences, but several lines of evidences point towards an overly intense transport in the model.

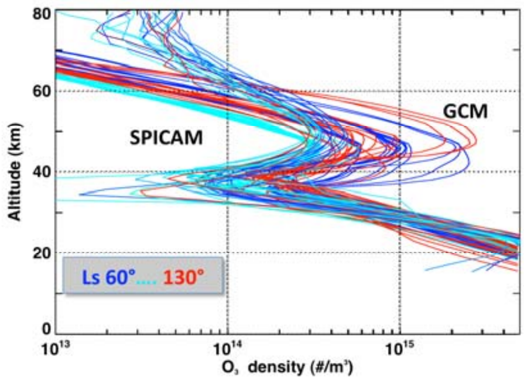

Figure 4: Comparison between SPICAM and LMD GCM predictions.

The combination of SPICAM ozone data and OMEGA O_2 emission will provide a unique and nearly direct access to the absolute strength of the circulation in the polar region.

References:

[1] Perrier et al., *JGR Planets*, 2006.
[2] Lebonnois et al., *JGR Planets*, 2006.
[3] Lefèvre et al., *JGR Planets*, 2004
[4] Bertaux et al., *Mars atmosphere Workshop*, 2010.