# Ozone vertical distribution on Mars from SPICAN/MEX UV occultations

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# OZONE VERTICAL DISTRIBUTION ON MARS FROM SPICAM/MEX UV OCCULTATIONS

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**Introduction:** We have achieved a four-year climatology of the O3 vertical distribution using SPICAM UV occultations. The climatology confirms the overall behaviour of O3, but reveals some discrepancies in comparison with a global climate model. By definition, solar occultations are acquired at sunset or sunrise, probing a local time where the rapid changes in insolation can have a large effect on the atmospheric state. Classically, the so-called onion-peeling method has been used as the necessary hypothesis on the atmospheric structure in the vertical inversion of the occultations; the atmosphere is supposed spherically symmetric. However, for photochemically active species, such as $O_3$, this hypothesis is a great simplification, since $O_3$ distribution exhibits large gradients between the day and night sides of the planet, which may induce errors when not accounted for. We are presenting here a simple way to overcome the problem when comparing models and observations; direct comparison of slant profiles (i.e., without doing the vertical inversion).

**Method and data:** The full retrieval method of the profiles, including ozone, in solar occultation was described in [1], using a similar analysis as the aerosol and ozone profiles in stellar occultation described in [2,3]. Details on the SPICAM instrument can be found in [4].
The UV channel measures spectra between 118 and 320 nm. The occultation technique is self-calibrated, since the spectra are normalised with the observed solar spectrum to acquire atmospheric transmissions. The transmission spectra are fitted with the Beer-Lambert law taking into account extinction by gaseous species ($CO_2$ and $O_3$) and aerosols. Aerosol extinction is modeled with the so-called alpha-model, providing access to the Ångström coefficient, which depends on the size of the aerosols.

**Ozone climatology:** The UV occultation dataset gives access to a climatology of ozone vertical distribution and to the local time variations. We will present the global results and a comparison to the LMD Mars Global Climate Model. We will also focus on certain case studies, such as the 3D mapping of the southern polar vortex, where a transport-induced ozone layer has been observed [5]. This layer can now be probed in both stellar and solar occultations thanks to the full dataset (Figure 1).

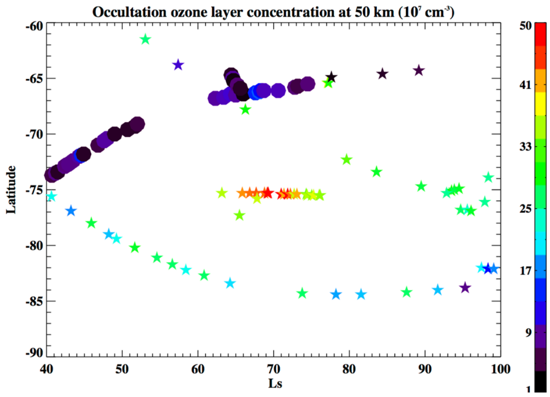


**Figure 1:** Ozone concentration at 50 km at the south winter pole with SPICAM occultations (circles: solar, stars: stellar). Color scale goes from $1x10^7$ to $50 x10^7$.

**Ozone gradients at the terminator:** The rapid variation of ozone due to photolysis at sunrise and sunset inhibits us from using the classical way of comparing the local density profiles acquired in solar occultation at the terminator with local profiles extracted from a model. The spherical symmetry hypothesis made in the onion-peeling vertical inversion method is not valid for photochemically active species (e.g., ozone) around terminator (see Figure 2). We are testing here a method commonly used in the Earth community, which uses directly the slant profiles (ozone concentration integrated along the line-of-sight of the instrument) for the comparison. These profiles do not suffer from the hypotheses necessary in vertical inversion.
We are considering a subset of six SPICAM occultations. For each occultation, we have used the 1D version of the LMD MGCM to model the ozone vertical and horizontal distribution with high solar zenith angle (or local time) resolution around the terminator (Figure 2). The clear dissymmetry of the ozone distribution around the terminator is visible in Fig. 2. We then integrate these model results following the lines-of-sight of the occultation (calculated from the observation

geometry) to construct the modeled slant profiles (left panel of Figure 3).

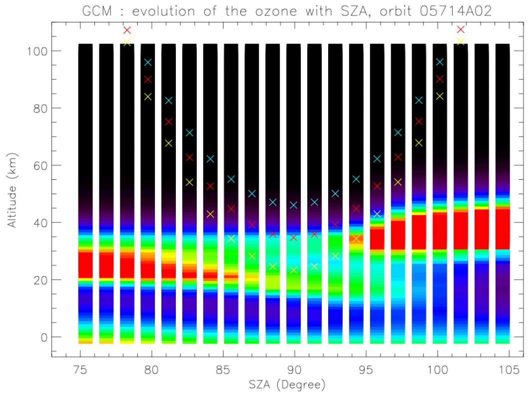


**Figure 2:** Inhomogeneity of ozone around the terminator and its consequences on the analysis: Modeled ozone profiles (colors) around the terminator during the occultation as a function of the solar zenith angle and examples of three LOS of SPICAM (symbols).

In four out of six studied occultations, the agreement between the modeled and observed slant profiles is quite good (for an example, see left panel of Fig. 3). However, some cases display clear differences: sometimes the observed ozone densities are clearly smaller than the ones extracted from the model (not shown). Instead of being of a bias due to the comparison, this might also be simply due to the model not performing as it should in these cases (i.e., the model underestimates the ozone destruction via $HO_x$ radicals due to too small water vapor concentrations).

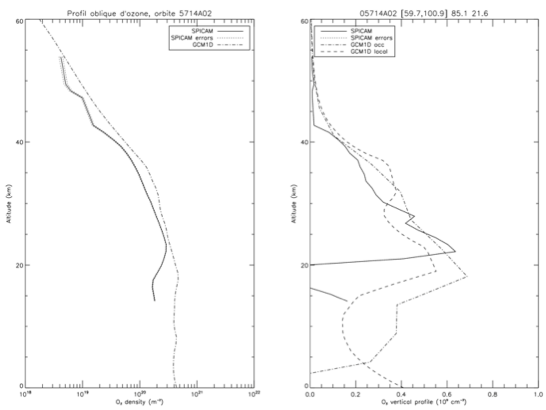

**Figure 3:** Left: Ozone concentrations integrated along the line-of-sight (slant profiles) from the model (dash-dot line) and the observations (solid line). Right: Ozone vertical profiles from SPICAM (solid line) and the model (dash-dot line) after vertical inversion of the slant profiles, and comparison to the modeled local profile at the terminator (dashed line).

We also tested the possibility to acquire improved results on the local vertical profile comparison by performing the onion-peeling vertical inversion of the previously described slant profiles. The comparison of the model with SPICAM is slightly better in some cases (see right panel of Fig. 3), but naturally the differences where SPICAM observes clearly less ozone than predicted by the model (not shown) persist. In any case, the vertical inversion method we use even for inverting the LOS-integrated model profiles includes the spherical symmetry hypothesis, and thus the comparison of the local profiles is biased.

Thus, here the most pertinent comparison is the one between the slant profiles. To completely avoid the problem of the spherical symmetry hypothesis, the heterogeneity of the atmosphere (for temperature, density/pressure and photochemically active trace gas concentrations) should be fully accounted for within the vertical inversion method. This will be achieved within the UPWARDS project (see abstract Piccialli et al., this conference, [6]).

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