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Ozone in the Martian atmosphere observed by TGO/NOMAD-UVIS solar occultations

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Introduction: The NOMAD-UVIS instrument on board the ExoMars Trace Gas Orbiter has been investigating the Martian atmosphere with the occultation technique since April 2018 [1]. In the solar occultation mode, it is mainly devoted to studying the climatology of ozone and aerosols content [2,3,4].

We analyzed almost two Mars Years of ozone vertical distributions acquired at the day-night terminator, corresponding to more than 8300 solar occultations, acquired between April 2018 (MY 34, L_S=163°) and November 2021 (MY 36, L_S=132°).

Retrieval method(s): As in the work of [5], the NOMAD-UVIS ozone retrievals proved more difficult than expected due to the presence of spurious detections of ozone caused by instrumental effects, high dust content, and very low values of ozone. This led us to compare the results from three different retrieval approaches:

- an onion peeling method (OP);
- a full occultation Optimal Estimation Method (FOEM), and
- a direct onion peeling method (DOP).

The OP method is similar to that used for Mars and Venus stellar occultations [6,7]. The FOEM and DOP approaches are based on ASIMUT-ALVL, the BIRA-IASB radiative code [8,9].

The main challenge was to find reliable criteria to exclude spurious detections of O_3, and we finally adopted two criteria for filtering: i) a detection limit, and ii) the $\Delta\chi^2$ criterion. Both criteria exclude spurious O_3 values especially near the perihelion, where based on the simulations from a general circulation model, we do expect very low values of ozone.

Comparison of filtering methods between UVIS and SPICAM:

We compared the results of filtering with SPICAM-UVIS observations. The SPICAM team applied very similar criteria for filtering their data to the ones implemented here [5]. Even if the two instruments observed during different Martian Years, the agreement on the filtered O_3 retrievals is very good, and both filtering approaches lead to very similar results (see **Figure** 1).

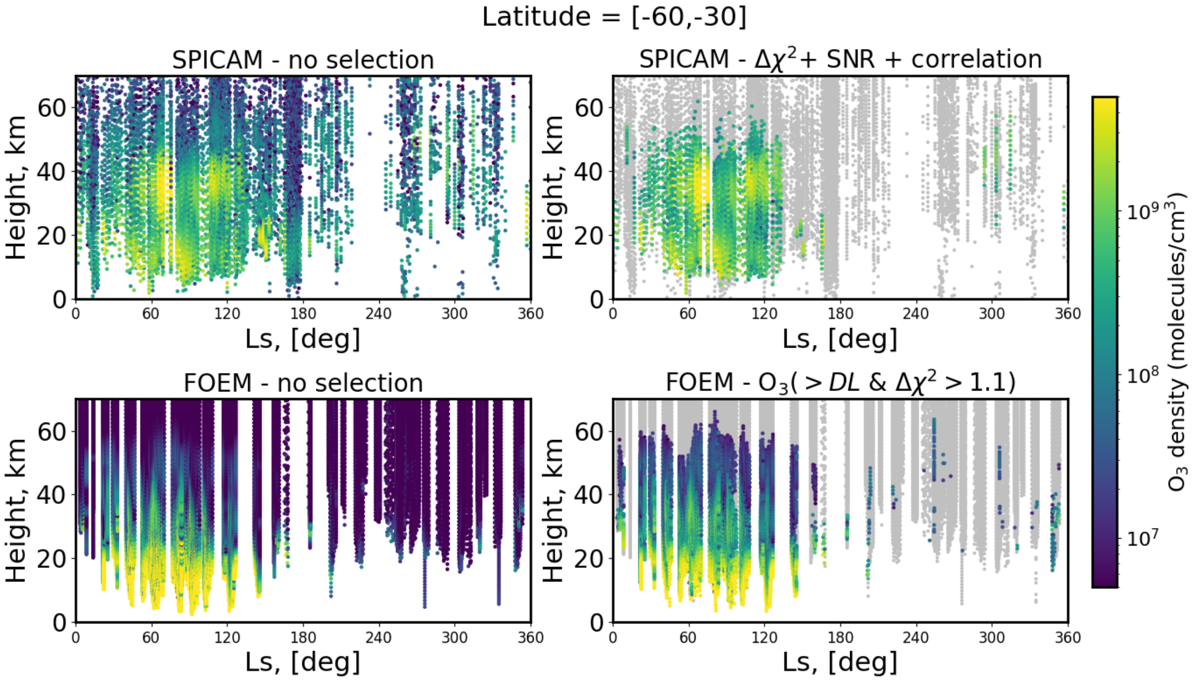

Figure 1: An example of the effect of the selection criteria for SPICAM-UV and NOMAD-UVIS observations for a latitude band (-60°;-30°). Left panels show the ozone vertical distribution before applying the filtering; right panels shows O_3 profiles after the selection criteria.

The O_3-H_2O relationship: Water vapor was observed by the infrared channel of the NOMAD SO. The results from a first analysis can be found in [10], while an extended dataset is presented in a companion abstract [11]. Water vapor and ozone are measured simultaneously, which allows us to investigate the water-ozone correlation, the key to addressing the atmospheric chemistry on Mars.

We present correlation plots of O_3 vs. H_2O at high latitudes (60°-90°, both hemispheres), and at the equator (30°S-30°N). It is important to notice that during a solar occultation experiment at the terminator, ozone may exhibit rapid changes due to photolysis that are uncorrelated to water vapor. As an example, we show the 60°N-90°N latitude region (**Figure 2**): a clear anti-correlation is observed at lower altitudes, up to 40 km. O_3 is roughly proportional to $(H_2O)^{-1.0}$ up to 30 km and a variation with L_s seems also present.

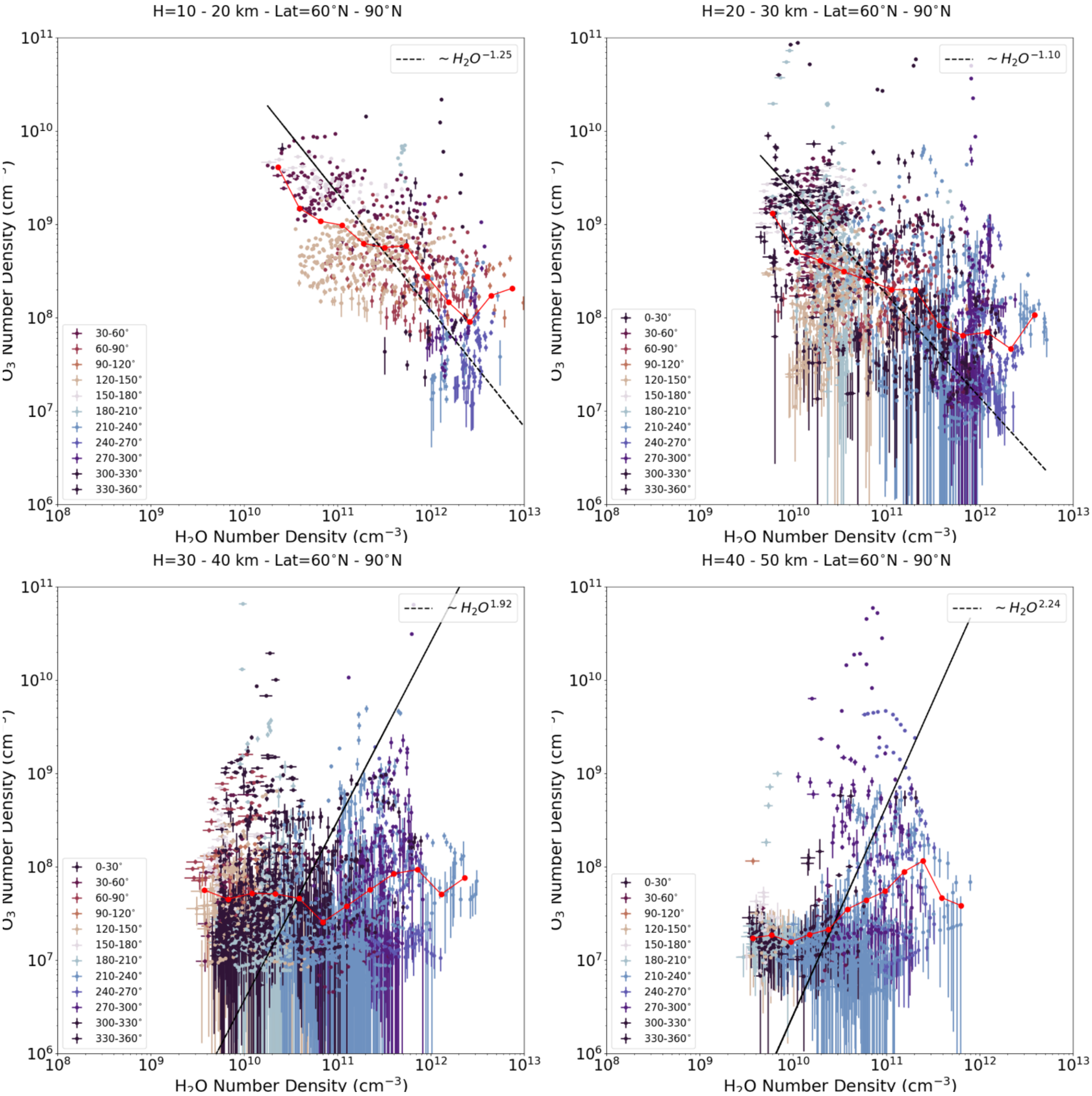

Figure 2: O_3 (cm^{-3}) vs. H_2O (cm^{-3}) vertical profiles measured simultaneously by NOMAD-UVIS at high latitudes in the Northern hemisphere (60°N-90°N). (a) 10 – 20 km; (b) 20 – 30 km; (c) 30 – 40 km; (d) 40 – 50 km. Colours indicate the Ls interval. The black line shows the function $O_3 = H_2O^x$, with x varying with the altitude range.

Impact of gradients at the Martian terminator: Rapid variations in species concentration at the terminator have the potential to cause asymmetries in the species distributions along the line of sight (LOS) of a solar occultation experiment. Ozone, in particular, displays steep gradients across the terminator of Mars due to photolysis [12]. Nowadays, most of the retrieval algorithms for solar and stellar occultations rely on the assumption of a spherically symmetrical atmosphere. However, photochemically induced variations near sunrise/sunset conditions need to be taken into account in the retrieval process in order to prevent inaccuracies.

We investigated the impact of gradients along the LOS for the retrieval of ozone under sunrise/sunset conditions. We used the diurnal variations in the ozone concentration obtained from photochemical model calculations together with an adapted radiative transfer code.

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