Distribution of SO2 content at the night side of Venus' upper mesosphere

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Introduction:

Venus has a dense CO_2 atmosphere with a thick cloud layer (50-70 km) consisting of sulfuric acid (H_2SO_4) aerosols. Sulfur oxides (SO_x) are directly associated with those aerosols and plays an important role in chemistry of the atmosphere. Any change of its content within or above the clouds has an influence on photochemical processes in the mesosphere (70-100 km). Recent ground-based observations [1-4] and continuous monitoring from the Venus Express orbiter [5-7] have shown high temporal and spatial variability of SO_2 abundance mostly on the day side: from 20 to 500 ppbv above the clouds. There is a lack in the detailed analysis at the night-time mesosphere where photo dissociation of sulfur dioxide is replaced by interaction with the global subsolar/antisolar circulation and chemical reactions with atoms of Cl, OH, O etc.

In this paper we present vertical distribution of SO_2 content at the night side of Venus upper mesosphere that resulted from stellar occultations made by the SPICAV UV spectroscopy. This mode of occultation occurred for the entire VEx mission, and it gave us possibility to observe yearly variations for period 2006-2014 at altitudes 85-100 km. In parallel, we have reprocessed the terminator dataset from the UV solar occultations at the same altitude range [5] up to 2014. Like this, we have got whole the night-time coverage of SO_2 distribution from the sunset to the sunrise twilights of the upper mesosphere.

Experiment:

SPICAV UV channel operated in the spectral range 118-320 nm with a resolution 1-2 nm at nadir or stellar/solar occultation modes [8]. Here we deal with measurements of SO_2 atmospheric absorption in stellar and solar occultation modes. In the case of stellar occultation the instrument observes night-side mesosphere while in solar occultation it probes evening/morning twilights at altitude range 85-100 km. SPICAV can register SO_2 absorption bands at 190-220 and 270-300 nm and CO_2 bands at 120-210 nm.

In the occultation mode an instrument registers the solar (or a stellar) flux out of planetary atmosphere and a flux, having passed through different levels of the atmosphere. The ratio of the second flux to the first one determines the atmospheric transmission at a fixed tangent altitude. This transmission (a relative quantity) is interpreted as due to the extinction from aerosols and gases that can be identified by their spectral signature, and their quantity along the line of sight (LOS) of the instrument (Fig. 1).

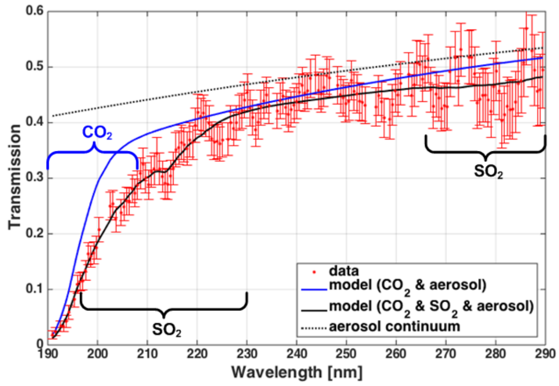

Fig. 1. An example of measured transmission spectrum (red dots with error bars) from a stellar occultation at altitude 90 km (orbit 1073, LT 2:00am, Lat 37.81°N). Molecular absorptions of CO_2 (in blue) and SO_2 (in black) are detected together with aerosol continuum (black dashed): $N_{CO2}=3\cdot10^{23}$ cm^{-2}; $N_{SO2}=8\cdot10^{16}$ cm^{-2}.

Solar occultation. In the solar occultation mode the vertical FOV varied from 0.5 to 15 km, depending on the instrument's CCD recording algorithm and on a distance to the planet's limb. For our study we selected orbits with an altitude FOV less than one scale height of the atmospheric density (i.e. <4 km). It reduced the importance of the stray light, which comes from different parts of the atmosphere in the case of a wide FOV. At present, we have processed 330 sessions of solar occultation occurring from 2007 to 2014, in the latitude range 30°S-90°N, and in conditions of sunrise (06:00am of Venus local time) or sunset (06:00pm). Most of the observations took place close to the Northern pole with a short distance to the planet's limb (< 2000 km), due to peculiarities of the VEX's polar orbit.

Stellar occultation. The stellar occultation technique is similar to the solar one with the difference that a star is observed as a respectively weak point source and the night side of the atmosphere is probed. The instrument's FOV is directed to an UV star with maxima of radiance at wavelengths 100-300 nm. During the VEX mission stellar occultation mode occurred regularly with ~60 different target stars, covering latitudes from 70°S to 70°N and local time on Venus from 07:00pm to 05:00am. In order to avoid detection of the Sun brightening from the day-side atmosphere we selected observations with a solar-zenith angle more than 100°. Thus, we have collected statistics with 210 sessions of stellar occultations from June 2006 to May 2014.

Results:

Figure 1 (see above) demonstrates a clear detection of SO_2 absorption on a background of CO_2 and aerosol abundances. This is a case of a rather large mixing ratio of sulphur dioxide at altitude 90 km: 270 ppb. Nevertheless, in some observations we retrieved rather low values – down to 10 ppb. It shows a high variability of SO_2 content in Venus' upper mesosphere either from solar occultation or from stellar one. On average, the volume mixing ratio increases with altitude from 10-30 ppbv at 85 km to 100-300 ppbv at 100 km (Fig. 2).

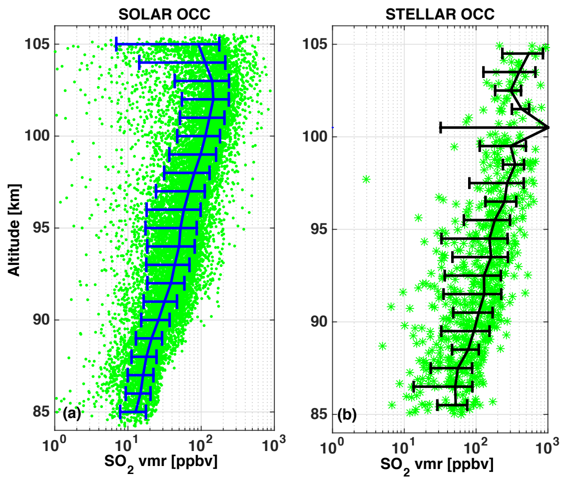

Fig. 2. Altitude distribution of SO_2 mixing ratio from SPICAV UV solar (a) and stellar (b) occultations. Solid lines are weighted mean values with standard deviations. Error bars of individual dots (not shown) are less than the dispersion of the data.

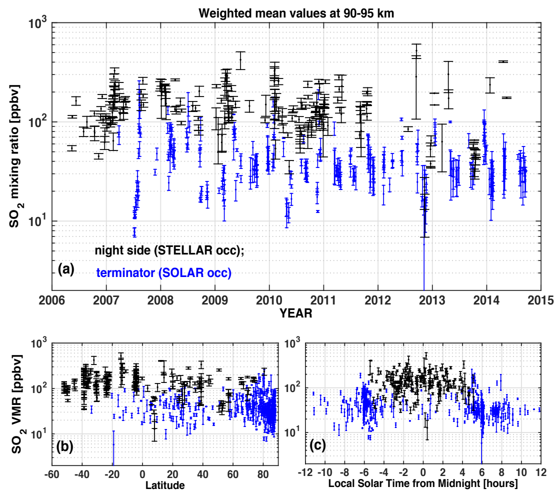

Fig. 3. Time (a), latitude (b) and Local time (c) diagrams of SO_2 variations at altitude level 90-95 km (blue – solar occultations, black – stellar occultations).

Time variations of SO_2 show a few peaks with values >100 ppb from both regimes of occultation (Fig. 3a). These events are local in time and they are not revealed on the latitude diagram (Fig. 3b). We can also look on the Local time diagram where average SO_2 content around midnight are 2-4 times higher than at the evening/morning twilights (Fig. 3c). Additional analysis is going on together with properties of aerosol particles [9], in order to establish correlations between SO_2 peaks and particles sizes and densities.

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