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The Polar Upper Atmosphere of Venus Based on Observations from SOIR/VEX and the VExADE experiment.

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Abstract

The VExADE observations have provided *in situ* measurements of the mass density of the thermosphere for altitudes above 165 km and latitudes above 82° [1, 2].

Venus upper atmosphere CO_2 density vertical profiles have been obtained from solar occultations performed by the SOIR high resolution spectrometer [3] onboard VEX. Temperature, total density and total pressure profiles have been derived for altitude range of 70 to 170 km and at different latitudes.

Here, a dataset is compiled to obtain a SOIR dataset, called Venus Atmosphere SOIR measurements at the Terminator (VAST), which is compared to the VExADE mass density measurements over the polar areas. The aim of this study is to better constrain VAST density profiles using VExADE densities in order to construct an empirical model of the polar Venusian thermosphere in the 70-200 km altitude range.

1. Introduction

Carbon dioxide is the main component of Venus' atmosphere, with a mean volume mixing ratio (VMR) of 96.5 % up to an altitude of 120 km. Above this, its VMR decreases with altitude because of diffusive separation and of CO_2 photo-dissociation by solar ultraviolet radiation. As the main constituent of the Venus atmosphere, CO_2 is of great interest in order to describe the physics of the atmosphere.

The region probed by SOIR and the VExADE experiment are overlapping and is a place where dynamical processes change rapidly with altitude. The effects of the superposition in the Venus upper atmosphere of a relatively stable subsolar-to-antisolar circulation cell driven by solar heating (above 120 km) and a highly variable retrograde superrotating zonal flow (above the cloud tops) are observed in the highly variable density at high altitude.

2. The VExADE *in-situ* measurements of mass density.

The VExADE experiment has been designed to sample *in situ* the mass density of the thermosphere of Venus. It uses the atmospheric drag-induced perturbations of the orbital motion and of the attitude of the Venus Express spacecraft when passing through the upper atmosphere of the planet on the low-altitude part of its orbit. The radio-tracking data of the spacecraft (provided by the VEX Radioscience experiment, VeRa) are used to precisely reconstruct the orbital drag acceleration from which is derived an estimate of the actual mass density of the thermosphere at the orbit periapsis [1]. During the same low-altitude passes, the monitoring of the torque asserted by the atmosphere on the spacecraft [2] has been performed, providing a profile of the mass density along the periapsis pass. To date, seven VExADE drag experiments have been performed, probing the altitude range of 165 to 200 km and the latitude range of 82 to 90° (Fig. 1). Both radio-tracking and torque datasets have provided reliable density estimates, which are in remarkably good agreement [2], and which are lower than VTS3 predicted densities by a mean factor of 0.6 [1, 2].

3. SOIR-VAST CO_2 profiles

SOIR is one of the three channels of the SPICAV/SOIR instrument [3]. It is an infrared spectrometer covering the 2200 to 4400 cm^{-1} region that performs solar occultation observations. The vertical size of the instantaneously scanned atmosphere at the limb tangent point for Northern measurements is a few hundreds of meters[4]. The altitude range probed by SOIR varies from 70 to 170 km, the lower boundary being to total absorption of sunlight by Venus' clouds, and the upper boundary, the detection of the strongest CO_2

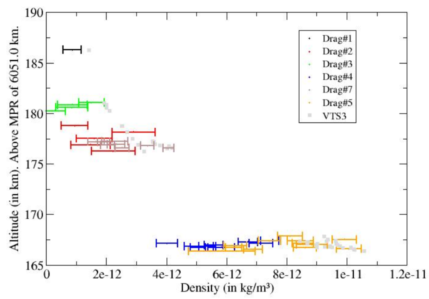

Figure 1: Venus Polar thermosphere mass density observed by the VExADE experiment.

band. During an occultation, four different diffraction orders are measured quasi-simultaneously within 1 s, allowing us to study CO_2 at different altitude ranges [5]. Only part of the SOIR dataset from which CO_2 information can be retrieved has been considered in this study to define the VAST. The selected measurements are obtained on morning or evening terminator side for a wide range of latitudes and within the 2006 to 2011 period. The associated individual CO_2 density and temperature profiles are presented in Figure 2, and show a general good agreement for a systematic decrease of CO_2 density (associated with temperature decrease) around 125 km.

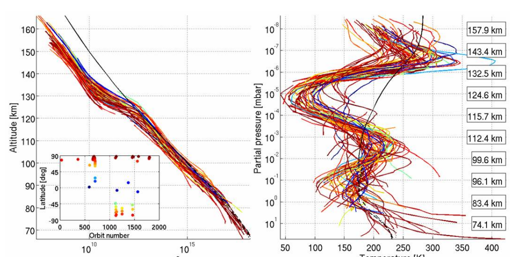

Figure 2: CO_2 density and temperature profiles used to define the VAST compilation.

4. VExADE vs VAST mass density

The VAST CO_2 density profiles at polar latitudes (80-90°) have been used to derive mass density profiles (Fig. 3), assuming the CO_2 VMR values of the VTS3 model above 100 km altitude. Although, the altitude range does not completely overlap between the VExADE and VAST density measurements, the VExADE data indicate higher density than expected from interpolating the VAST profiles abovee 165 km. In turn, it suggests either erroneous assumptions made when estimating the mass density from the VAST CO_2 profiles or an increase of temperature above about 160 km altitude. It illustrates how VExADE data can be used to improve for the VAST mass density/temperature profiles in their highest altitude part. Moreover, the VExADE torque measurements can also be used to test the assumption of morning-evening symmetry made to construct mean mass density profile from SOIR-VAST data [5]. The torque data have indeed provided profiles of mass density along the terminator for some periapsis passes [2].

5. Perspectives

Preliminary results of this study have shown the interest to merge different sets of data for constructing an empirical model of the polar Venusian thermosphere within the altitude range of 70-200 km [5, 6]. Such a model would be useful to better understand the dynamics of the Venusian polar thermosphere as well as to plan VEX future operations, such as aerobraking maneuver.

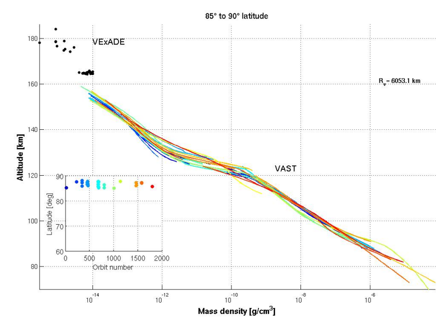

Figure 3: Comparison of VExADE densities (black dots) and density profiles (colored curves) from VAST polar latitude dataset.

Acknowledgements

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