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Combination of SOIR/VEX observations and VTGCM simulations to decipher the mesosphere and lower thermosphere of Venus

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Abstract

SOIR [1] is a high resolution spectrometer flying on board the ESA Venus Express mission [2]. It performs solar occultations of the Venus high atmosphere, and so defines unique vertical profiles of many of the Venus key species. Here we focus on carbon dioxide while the temperature, the total density and the total pressure are derived from the observed CO_2 density vertical profiles. A striking permanent temperature minimum at 125 km is observed. The dataset is processed in order to obtain a Venus Atmosphere from SOIR measurements at the Terminator (VAST) compilation for different latitude regions and extending from 70 up to 170 km in altitude. The results are compared to the literature as well as recent VTGCM results.

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 as CO_2 is photo-dissociated on the dayside of the planet by solar ultraviolet radiation, forming carbon monoxide and excited oxygen atoms. As the main constituent of the Venus atmosphere, carbon dioxide is of great interest in order to describe the physics of the atmosphere at the terminator.

The region probed by SOIR is a place where dynamical processes change rapidly with altitude. The global circulation of the Venus upper mesosphere and thermosphere is estimated to be a combination of two distinct flow patterns: (1) a relatively stable subsolar-to-antisolar (SS-AS) circulation cell driven by solar (EUV-UV-IR) heating (above 120 km), and (2) a highly variable retrograde superrotating zonal (RSZ) flow (above the cloud tops). The effects of the superposition of these 2-wind components in the Venus upper atmosphere are observed in measured temperature, density, and nightglow distributions. However, the dynamical processes driving this variability are still poorly understood.

2. The SOIR instrument

SOIR is one of the three channels of the SPICAV/SOIR instrument [1]. It is an infrared spectrometer covering the 2200 to 4400 cm^{-1} region [3]. SOIR performs solar occultation observations. The vertical size of the instantaneously scanned atmosphere at the limb tangent point varies from a few hundreds of meters for the Northern measurements to tens of kilometers for the Southern measurements. The altitude range probed by SOIR varies from 70 km up to 170 km. The lower boundary corresponds to total absorption of sunlight by Venus' clouds, and the upper boundary to the detection of the strongest CO_2 band. During an occultation, four different diffraction orders are measured quasi-simultaneously within 1 s. It allows us to study either the same species at different ranges of altitudes, as it will be the case here for CO_2, or different species to obtain volume mixing ratios [4,5,6].

3. The VAST data

Although the SOIR dataset now contains 478 observations (Jan. 2012) from which 465 can be used to retrieve information on CO_2, only a subset has been considered in this study to define the Venus

Atmosphere from SOIR measurements at the Terminator (VAST). The selected measurements are obtained on morning or evening terminator side for a wide range of latitudes and were obtained between 2006 and 2011 [6]. The 59 individual CO_2 density and temperature profiles are presented in Figure 1.

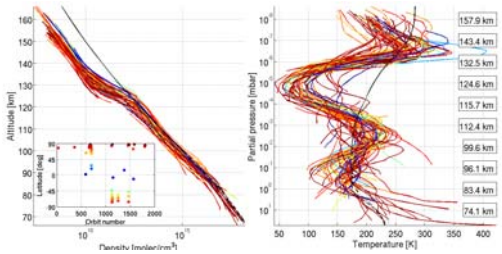

Figure 1: CO_2 density and temperature profiles used to define the VAST compilation.

The dataset is divided as a function of latitude in 5 regions (0°-30°, 30°-60°, 60°-70°, 70°-80°, 80°-90°) and a North-South hemisphere symmetry is supposed, as well as morning and evening symmetry. The VAST data have been compared to literature data (Figure 2) and show a general good agreement. They show a systematic decrease of temperature around 125 km [6].

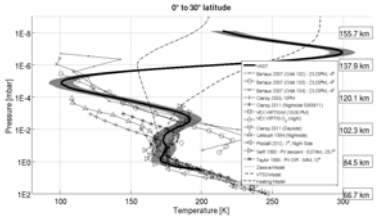

Figure 2: Comparison of VAST and literature data.

4. VTGCM

The Venus Thermospheric General Circulation Model (VTGCM) is a 3-D finite-difference hydrodynamic model of the Venus upper mesosphere and thermosphere (above the cloud tops) [7,8,9,10]. Briefly, the VTGCM solves the time-dependent primitive equations for the upper atmosphere: neutral temperatures, key neutral-ion densities, and three-component neutral winds. Nightglow emission distributions (e.g. NO UV and O_2 IR) are also simulated. The model domain covers a 5° by 5° latitude-longitude grid, with 69 evenly-spaced log-pressure levels in the vertical, extending from approximately 70 to 300 km (70 to 200 km) at local noon (midnight). The most recent version of the VTGCM code [10] addresses the dayside and nightside thermal structure, and its variations, for comparison to available observations. Comparisons of VTGCM terminator CO_2 densities/temperatures are made with VAST profiles in this paper.

5. Summary and Conclusions

The use of VTGCM to analyze and interpret the VAST data has contributed to a better characterization of the Venus middle and upper atmosphere RSZ and SS-AS wind components. VAST will be further refined and improved with further CO_2 measurements expanding the sampling periods and locations available for data-model comparison.

Acknowledgements

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