EPSC Abstracts
Vol. 10, EPSC2015-807-1, 2015
European Planetary Science Congress 2015

Studying the Venus terminator thermal structure observed by SOIR/VEx with a 1D radiative transfer model

A. Mahieux (1,2,3) , J. T. Erwin (3), S. Chamberlain (1), S. Robert (1), A. C. Vandaele (1), V. Wilquet (1), I. Thomas (1), R. V. Yelle (3)

(1) Belgian Institute for Space Aeronomy, Brussels, Belgium

(2) Fonds National de la Recherche Scientifique, Brussels, Belgium

(3) Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona, USA

Abstract

The SOIR instrument on board Venus Express routinely measures the CO_2 number density profiles in the mesosphere and thermosphere region at the Venus terminator using the solar occultation technique. Assuming the hydrostatic equilibrium, we derive temperature profiles, which show a permanent cold layer at 125 km, surrounded by two warmer layers at 100 km and 140 km. We developed a 1D conductive radiative transfer model to study the mean SOIR thermal profile, considering the main species, and carefully modelling the radiative terms. In order to correctly reproduce the thermal profile, aerosols cooling and heating terms are added. We describe how aerosols number density profiles can be calculated to have a good match of the thermal profiles.

1. Introduction

SOIR is an infrared spectrometer that probes the Venus terminator region since 2006. The measurements are taken on the morning and evening sides of the terminator, covering all latitudes from the North Pole to the South Pole. The covered wavelength range - 2.2 to 4.3 µm - allows a detailed chemical inventory of the Venus atmosphere [1-6]; vertical profiles of CO_2, CO, H_2O, HCl, HF, SO_2 and aerosols are regularly inferred. CO_2 is detected from 70 km up to 165 km, CO from 70 km to 140 km, and the minor species typically below 110 km down to 70 km. Number density profiles of these species are computed from the measured spectra. N_2 and O are also considered in the model, but are not measured by SOIR. For N_2, we assume 3.5% of the total density, while O is taken as in [7].The mean profiles are presented in Figure 1.

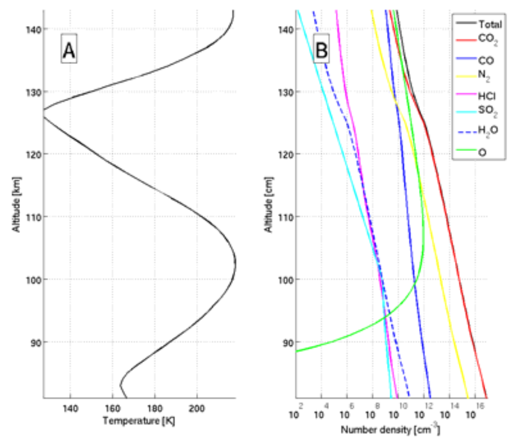

Figure 1: Panel A, mean SOIR temperature profile; Panel B: mean number SOIR number density profiles

Temperature profiles are obtained while computing the spectral inversion of the CO_2 spectra combined with the hydrostatic law [8], see Figure 1. The time variability of the CO_2 density profiles spans over two orders of magnitude, and a clear trend is seen with latitude. The temperature variations are also important, of the order of 35 K for a given pressure level, but the latitude variation are small.

2. The radiative model

A 1D radiative transfer model has been developed to reproduce the SOIR terminator profiles, derived from the Mars thermosphere code presented in [9]. This model has been expanded to better account for the CO_2, CO, and O non-LTE radiative heating and cooling processes which have to be considered in the dense atmosphere of Venus. Radiative cooling by minor species detected by SOIR (e.g. HCl, SO_2, and H_2O) are found to be small in comparison to the

15 µm CO_2 cooling. Aerosol cooling in the 60-90 km altitude range may be important to reach the thermal balance. The radiative terms are plotted in Figure 2.

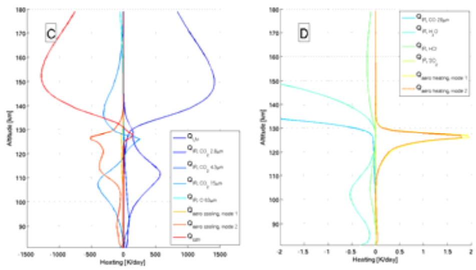

Figure 2: Radiative terms at steady state for which the model temperature best matches the SOIR mean profile. The profiles are separated in two panels as a function of their magnitude.

There is a good agreement between the 1D model temperature profile and the mean SOIR temperature profile. Further we can suggest parameters that can be adjusted to improve the agreement between model and measurements. The remaining differences can be attributed to the atmosphere dynamics at the terminator.

3. Summary and Conclusions

We developed a 1D radiative transfer model to study the thermal profiles at the Venus terminator. We considered the main species present in the Venus mesosphere and thermosphere, together with the aerosols. Aerosols need to be added to cool the mesosphere and to correctly fit the SOIR mean temperature profile.

Acknowledgements

Venus Express is a planetary mission from the European Space Agency (ESA). This research program was supported by the Belgian Federal Science Policy Office and the European Space Agency (ESA PRODEX program). The authors also recognize the support from the FP7 EuroVenus project (G.A. 606798). This work was partially funded with a Court séjour grant of the Belgian Fonds National de la Recherche Scientifique and by the Lunar and Planetary Laboratory of the University of Arizona. The author would like to thank the FNRS for the Chargé de Recherche position.

References

[1] Bertaux, J.L., et al., *A warm layer in Venus' cryosphere and high altitude measurements of HF, HCl, H_2O and HDO.* Nature, 2007. **450**(29 November): p. 646-649, doi:10.1038/nature05974.

[2] Vandaele, A.C., et al., *Carbon monoxide short term variability observed on Venus with SOIR/VEX.* Planet. Space Sci., 2014. **In press**.

[3] Mahieux, A., et al., *Hydrogen halides measurements in the Venus upper atmosphere retrieved from SOIR on board Venus Express.* Planet. Space Sci., 2014. **In press**.

[4] Mahieux, A., et al., *Venus mesospheric sulfur dioxide measurement retrieved from SOIR on board Venus Express.* Planet. Space Sci., 2014. **In press**.

[5] Mahieux, A., et al., *Update of the Venus density and temperature profiles at high altitude measured by SOIR on board Venus Express.* Planet. Space Sci., 2014. **In press**.

[6] Fedorova, A., et al., *HDO and H_2O vertical distributions and isotopic ratio in the Venus mesosphere by Solar Occultation at Infrared spectrometer onboard Venus Express.* J. Geophys. Res., 2008. **113**(E00B22).

[7] Bougher, S.W., D.M. Hunten, and R.J. Phillips, *Venus II: Geology, Geophysics, Atmosphere, and Solar Wind Environment.* The University of Arizona Press, 1997.

[8] Mahieux, A., et al., *Densities and temperatures in the Venus mesosphere and lower thermosphere retrieved from SOIR on board Venus Express: Carbon dioxide measurements at the Venus terminator.* J. Geophys. Res., 2012. **117**(E07001): p. doi:10.1029/2012JE004058.

[9] Yelle, R., et al., *Perturbation of the Mars Atmosphere by the Near-Collision with Comet C/2013 A1 (Siding Spring).* Icarus, 2014. **237**: p. 202-210.