EPSC Abstracts
Vol. 6, EPSC-DPS2011-769, 2011
EPSC-DPS Joint Meeting 2011

Collapse of Venus' polar thermosphere density as detected by Venus Express.

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Abstract

The Venus Express (VEX) spacecraft offers the opportunity to probe *in-situ* the density of the polar atmosphere of Venus at altitude range between 165-185 km. Two methods have been used to derive the density at dedicated campaigns of the Venus Express Atmospheric Drag Experiment (VExADE). The first method uses the tracking data of the spacecraft to precisely compute the drag acceleration of its motion when passing through the thermosphere at the periapsis pass of its orbit [1]. The second method uses the inertial wheels on board the spacecraft to measure the torque generated by the atmospheric drag during the periapsis pass [2]. Both methods provide reliable and similar estimates of the density at the periapsis pass. The estimated density from the first three campaigns is about 2-3 times lower than the one predicted from available empirical models. It suggests either polar collapse of the thermospheric structure or colder thermospheric temperatures than predicted by the models.

1. Introduction

During the first three dedicated VExADE campaigns, the periapsis of the Venus Express (VEX) spacecraft has been lowered down to 175 km of altitude with respect to its nominal 250 km altitude. It has offered the opportunity to measure the density of the polar thermosphere of Venus for the first time *in-situ*. These new measurements have been performed at polar latitudes and under solar minimum conditions, thus allowing us to test the predictions of available empirical models like the VTS3-Hedin model [3] and the VenusGram (modelVenus-GRAM 2005 Rel. Oct 2009), which have been constructed with *in-situ* measurements peformed at equatorial latitudes and under solar maximum conditions.
Hereafter, the methods used to infer the density are briefly presented, and the results obtained with the first three VExADE campaigns are presented and discussed.

2. Methods of density measurements

The first method consists in performing Precise Orbit Determination (POD) of the spacecraft, using the tracking data acquired during the periapsis as well as in the higher altitude part of the orbit. This method permits to estimate a scale factor of the drag acceleration experienced by the spacecraft during the periapsis pass. This scale factor is then applied to the density predicted by available models in order to infer the density at the periapsis pass. This method is fully described in [1]. The second method consists in orienting the solar panels of the spacecraft to provoke a torque on the spacecraft during the periapsis pass. The attitude of the spacecraft is, however, maintained by varying the rotation rate of the inertial wheels on board the spacecraft. The recorded rotation rate is then used to infer the density along the periapsis pass [2].

3. Results and interpretations

The first three VExADE campaigns have provided reliable measurements of the density of the polar thermosphere at ten periapsis passes for the 175-185 km altitude range. The VExADE densities are on average half and one-third the density predicted by the VTS3-Hedin and the VenusGram models, respectively (Fig. 1). Some torque measurements have also been performed providing similar density estimates (not shown on Fig. 1), providing independent validation of the two methods.
One way to explain these lower densities is to assume that the atmosphere below the altitude range probed

by VEX is colder than the temperature predicted by the VTS3 model. Between 100 and 180 km altitude the mean scale height is around 6 km, so the two altitudes are separated by around 13 scale heights. Our densities near 180 km are around a factor of 1.8 lower than those predicted by VTS3, which would imply the pressure level being around 0.6 scale height lower in altitude than predicted by VTS3. Integrated over the range from 100 to 180 km, this would (assuming the VTS3 mean molecular weight values) suggest the average temperature being around a factor of 0.6/13, or as much as 4.6% colder than assumed by VTS3. The VTS3 model predicts polar solar minimum temperatures of around 150-205 K in the 100-180 km altitude range, so our observations might suggest temperatures ranging from 143-195 K instead.

An alternative way to account for the VExADE lower densities is to assume that VTS3 does not take into account atmospheric processes, which would lower the pressure altitude levels. Our VExADE densities can be viewed as a lowering of pressure levels with respect to those of VTS3 by an amount of 0.6 scale height at the altitude range of 175-185 km. A polar collapse of the atmospheric structure has been detected for the first time at a lower altitude range of about 65 km from the images of the Venus Monitoring Camera (VMC) onboard VEX [4]. The cloud top layer altitude has also been measured at an altitude lower at the poles than at equator by an amount of 5 to 8 km [5], which is about 0.8 to 1.3 times the 6 km scale height at 65 km altitude. This pressure level lowering observed at the cloud top layer can easily account for the lower densities measured by VExADE at altitude near 180 km. In turn, it would suggest that the polar vortex structure would expand upward at higher altitude range than detected by the VMC images. Moreover, any such depletion at the base of the thermosphere would reduce any need for colder thermosphere temperatures. The Venus Thermosphere Global Circulation Model [6] assumes a flat lower boundary pressure level altitude near 90 km and to our knowledge has not produced the lower polar temperatures needed to explain our observations.

4. Summary and perspectives

The first three VExADE campaigns have provided reliable measurements of the density of Venus' polar thermosphere using two independent methods. A collapse of the density over the polar latitudes has been detected while not predicted by current models. More VExADE density measurements are, however, needed to carry out a more detailed comparison with the Venus' thermosphere model in order to better determine whether depletion at base of the thermosphere or generally a colder thermosphere is the more likely explanation for the detected polar density collapse. The fourth campaign (performed in October 2010) and the fifth campaign (May 23^{th}-June 3^{rd}) will probe the polar thermosphere at altitude as low as 165 km, using both methods, and will allow monitoring its density along the increasing phase of the solar cycle.

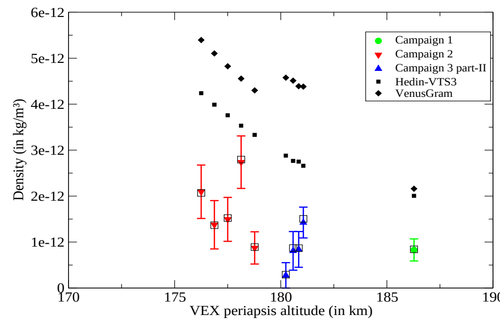

Figure 1: Density estimates from POD calculations vs altitude of the VExADE tracking passes compared with the Hedin-VTS3 and VenusGram predicted densities. Solid circle, triangle-down and triangle-up symbols are for VExADE campaign 1, 2 and 3, respectively, using VTS3 as initial density model. Open square symbols are VExADE density estimates obtained when using the VenusGram as initial model.

References

[1] Rosenblatt P. et al., submitted to Icarus, 2011.

[2] Svedhem H. et al., Abstract C31-0008-10, 38^{th} COSPAR Scientific Assembly, Bremen, Germany, July 18-25, 2010.

[3] Hedin A.E. et al., J. Geophys. Res. 88, pp. 73-83, 1983.

[4] Markiewicz W.J. et al., Nature, 450, 7170, pp. 633-636, 2007.

[5] Ignatiev N.I. et al., J. Geophys. Res., 114, 10 pp., 2009.

[6] Bougher S.W. et al., J. Geophys. Res. 104, pp. 16591-16611, 1999.