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Magnetic states of the ionosphere of Venus observed by Venus Express

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Abstract

A dense ionosphere is created by solar ultraviolet radiation ionizing the upper atmosphere of Venus. Since the planet does not possess an intrinsic magnetic field, the ionospheric plasma can directly interact with the solar wind. This interaction leads to the formation of a pseudo-magnetosphere which deflects the solar wind flow around Venus. Therefore its plasma environment is highly variable, depending on solar EUV intensity, solar wind dynamic pressure, the amplitude of the interplanetary magnetic field and several other factors. Currently, the solar activity is still rather low and therefore the Venus Express spacecraft allows for the first in-situ investigation of the Venus plasma environment near solar minimum. Previous in-situ measurements by the Pioneer Venus Orbiter (PVO) took place at high solar activity and at different planetary latitudes. Using data from the magnetometer (MAG) and the electron sensor (ELS, part of the plasma package ASPERA-4) on board Venus Express, the locations of the photoelectron boundary (PEB), the induced magnetopause and the bow shock were determined (see Figure 1). Subsequently, the penetration of magnetic fields into the ionosphere was investigated. It is of particular interest to explore the different magnetic states of the ionosphere, since these influence the local plasma conductivity, currents and probably the escape of electrons and ions. The penetration of magnetic fields into the ionosphere depends on external conditions as well as on ionospheric properties. By analyzing a large number of orbits, using a combination of two different methods, we defined criteria to distinguish between the so-called magnetized and unmagnetized ionospheric states. Furthermore, we confirmed that the average magnetic field inside the ionosphere shows a linear dependence on the magnetic field in the region directly above the PEB, and we investigated several other interrelations between plasma parameters and magnetic fields. In order to confirm the identification of the PEB as well as its agreement with the ionopause position on the dayside, the Venus Express measurements will be compared to ionospheric density profiles resulting from model calculations.

1. Introduction

Figure 1 shows the plasma boundaries which were determined from ELS and MAG data. Green dots represent the bow shock locations, black dots stand for the magnetopause (or upper boundary of the magnetic barrier) and the ionopause/PEB locations are shown in red. Regions below the dashed line were not accessible to in-situ measurements due to the orbit configuration of Venus Express. The blue curve corresponds to part of one single orbit of Venus Express, on which the data shown in the lower panels were recorded. The uppermost of these three panels contains the ionospheric photoelectrons which are generally found in a very distinct energy range between about 18 and 25 eV. The second panel, on the other hand, shows the ELS electron spectrum within the range 5 - 100 eV (logarithmic scale), and one can clearly see the strong electron band on which the panel above focuses. The lowest panel shows the amplitude and direction (horizontal and radial with respect to the planet's surface) of the magnetic field, ranging from -5 to 25 nT in this case, where the dotted line is located at 0.
Since the magnetic field remains very low throughout the time when a strong photoelectron band is seen, i.e. Venus Express crosses the ionosphere, this is a clear example of an unmagnetized case. The single peak in magnetic field strength, accompanied by a decrease in electron count rates, is most likely a flux rope, a tube-like twisted magnetic structure which is well-known to occur in the ionosphere when no strong magnetic field prevails.

2. Figures

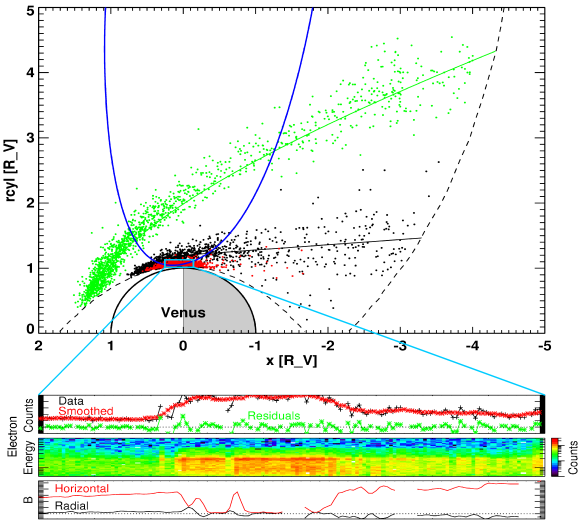

Figure 1: The plasma boundaries which were determined from ELS and MAG data, and an overview of the data for one single orbit. In the upper panel, cylindrical symmetry is assumed. The x axis points towards the Sun, whereas the y axis indicates the distance from the Venus-Sun line.

References

[1] Angsmann, A., Fränz, M., Dubinin, E., Woch, J., Barabash, S., Zhang, T.L. and Motschmann, U.: Magnetic States of the Ionosphere of Venus observed by Venus Express, Planetary and Space Science 59, pp. 327-337, 2011.