Planetary space weather effects on the bow shock, the magnetic barrier and the ion composition boundary at Venus

Vech D.[1,2], K. Szegő[2], A. Opitz[3], P. Kajdic[4], M. Fraenz[5], E. Kallio[6] and M. Alho[6]

1) Luleå University of Technology, Kiruna, Sweden, vech.daniel@wigner.mta.hu, 2) Wigner Research Centre for Physics Budapest, Hungary 3) ESA/ESTEC, Noordwijk, The Netherlands, 4) National Autonomous University of Mexico, Mexico City, Mexico 5) Max Planck Institution for Solar System Research, Göttingen, Germany, 6) University of Aalto, Espoo, Finland

1) Overview

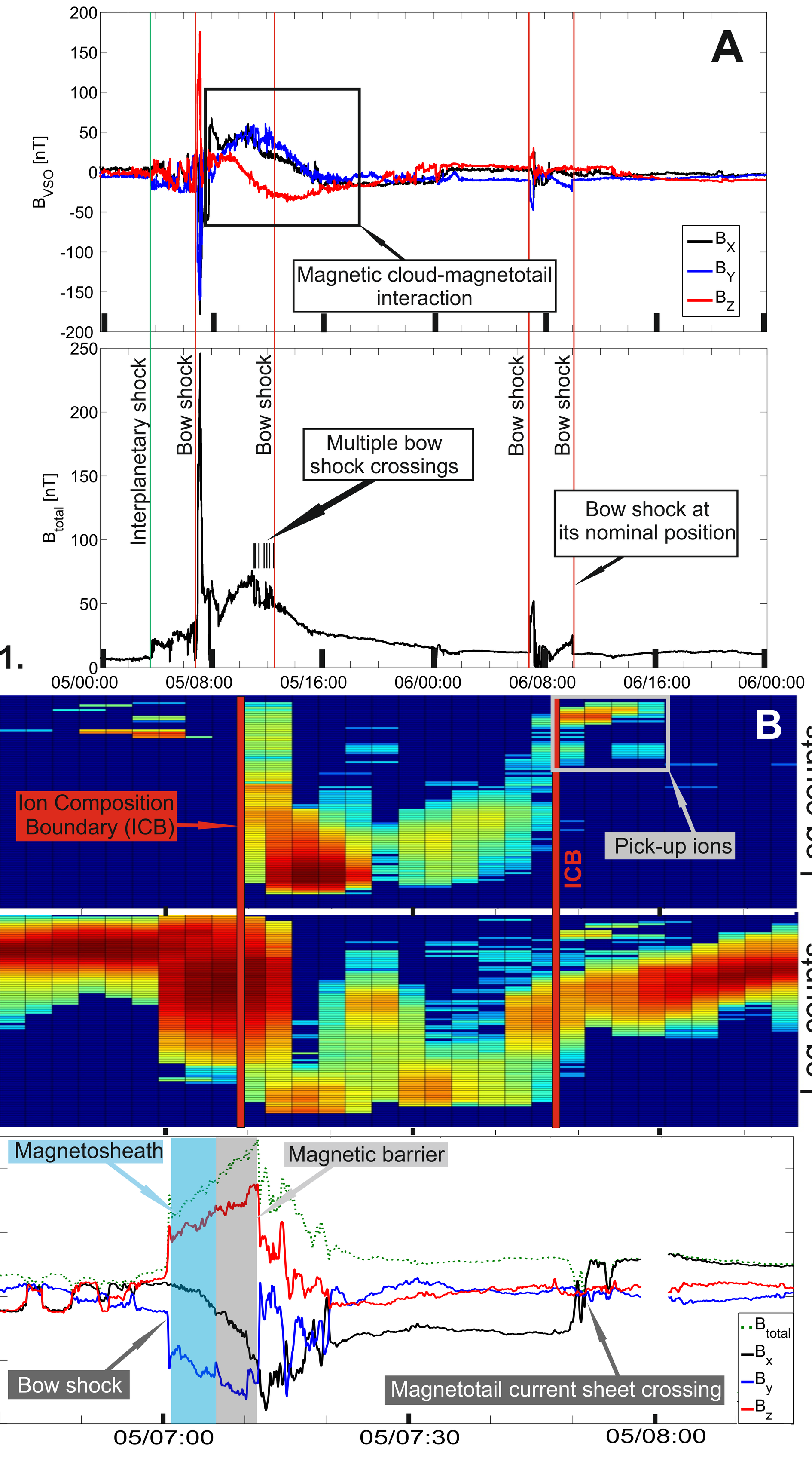
The purpose of this study is to investigate the interaction between the plasma environment of Venus and Interplanetary Coronal Mass Ejections (ICMEs) when the magnetic field magnitude of the Venusian magnetic barrier is anomalously large. We analyze the ICMEs that cause these unusually high magnetic field intensities in the induced magnetosphere and we discuss the plasma properties of the magnetic barrier, the position of the bow shock and the ion composition boundary during these events.

2) Event selection

For the event selection the entire Venus Express dataset was used from April 2006 to November 2014. The peak magnetic field of the magnetic barrier was obtained for each orbit. The magnetic barrier was identified in the dayside magnetosheath as the region with the highest magnetic field. Nearly 2600 orbits were investigated and it was found that the average of the peak values is approximately 42 nT. We were interested in the cases when the peak of the magnetic field was significantly higher than this value and we selected the events with >65 nT peak value, resulting in the identification of 152 events of interest. Further investigation was required to confirm that the anomalous magnetic field intensities are due to ICMEs and to distinguish them from other space weather phenomena. Based on the STEREO and SOHO coronagraph images it was possible to confirm that the in-situ observations are related to ICME passages and out of the 152 events with high peak field 42 could be clearly related to ICME passages. In this study we analyzed these 42 events.

3) A case study

One of the 42 investigated cases is shown in details in **Figure 1**. This event was observed on 5 November 2011. Panel A shows the magnetic field measurements on the day when the ICME arrived and during the following one. Panel B shows the heavy ion spectrogram, proton spectrogram and the magnetic field measurements on 5 November on smaller timescale. The interaction between the magnetic cloud and the induced magnetosphere was observed (panel A). The pattern of the magnetic field is very special and similar magnetic structures were observed in only six out of 42 events.



4) Solar wind conditions during ICME passages

In **Figure 2** 20-minutes averages of the solar wind parameters are presented which were obtained before inbound bow shock crossing in the analyzed 42 cases. Ten day periods are presented which are centered on the day when the ICME arrived at Venus (day 0). The data points on each day are marked with blue circles while the median and average value of each bin (each day) are in green and red, respectively. Panel A,B,C show that the solar wind velocity, density and temperature increased during the ICME. The radial and tangential components of the Interplanetary Magnetic Field (IMF) are investigated separately: panel D and E show that the tangential component (panel D) of the IMF increased significantly on day 0 and remained unusually large on day 1 as well. The radial component (panel E) was above average in only a few cases on day 0. We also note that 83% of the ICMEs drove interplanetary shocks.

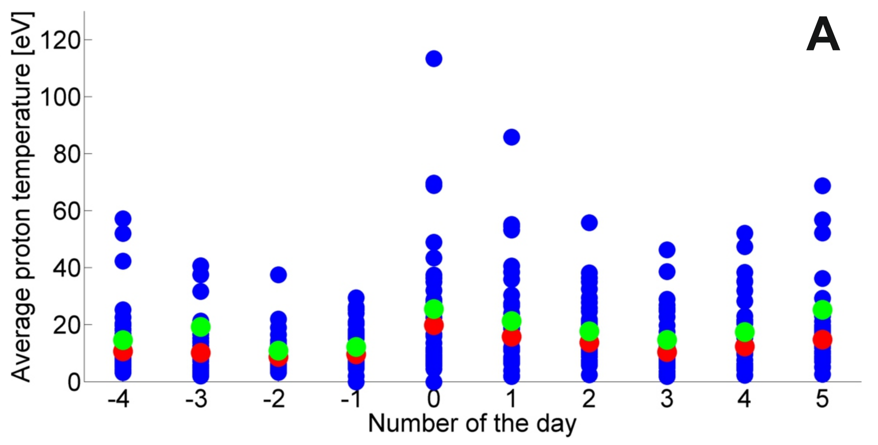
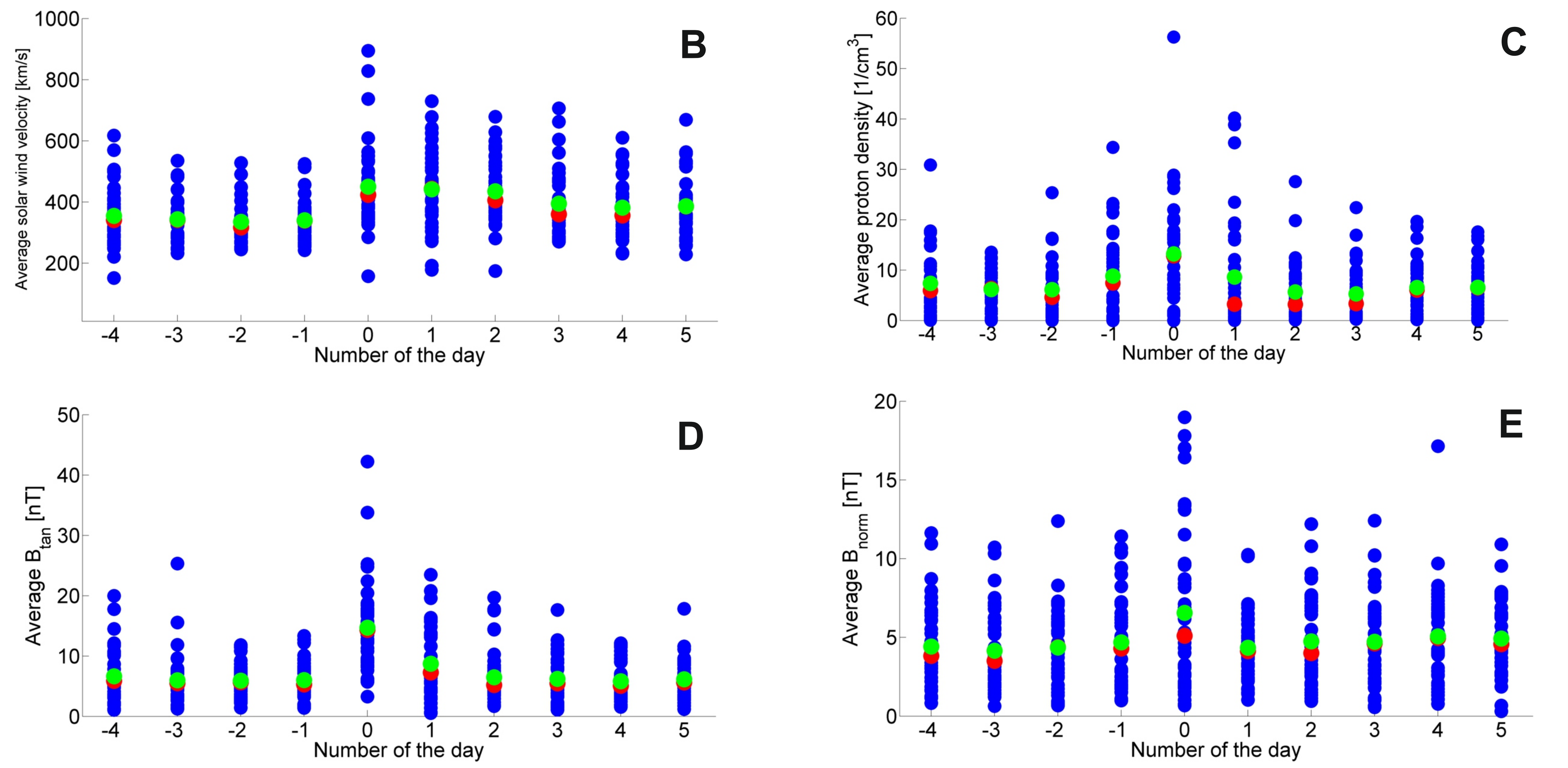


Figure 2.



5) Position of the bow shock

The bow shock crossings for the 42 cases are presented in **Figure 3**. The green marks show the bow shock crossings (including the multiple bow shock crossings as well) on the day when the ICME arrived at Venus, the red dots represent the bow shock location during the following day, the rest of the days are marked with blue dots. We have sorted the events into two groups by differentiating cases where there was no magnetic cloud (left panel) observed by VEX (36 cases) and cases where there was a clear signature of a magnetic cloud passage at Venus (right panel). During the 36 ICME sheath cases the bow shock remained unchanged, while in the 6 magnetic cloud events we observed a largely expanded bow shock even at distances above 10 Venus radii.

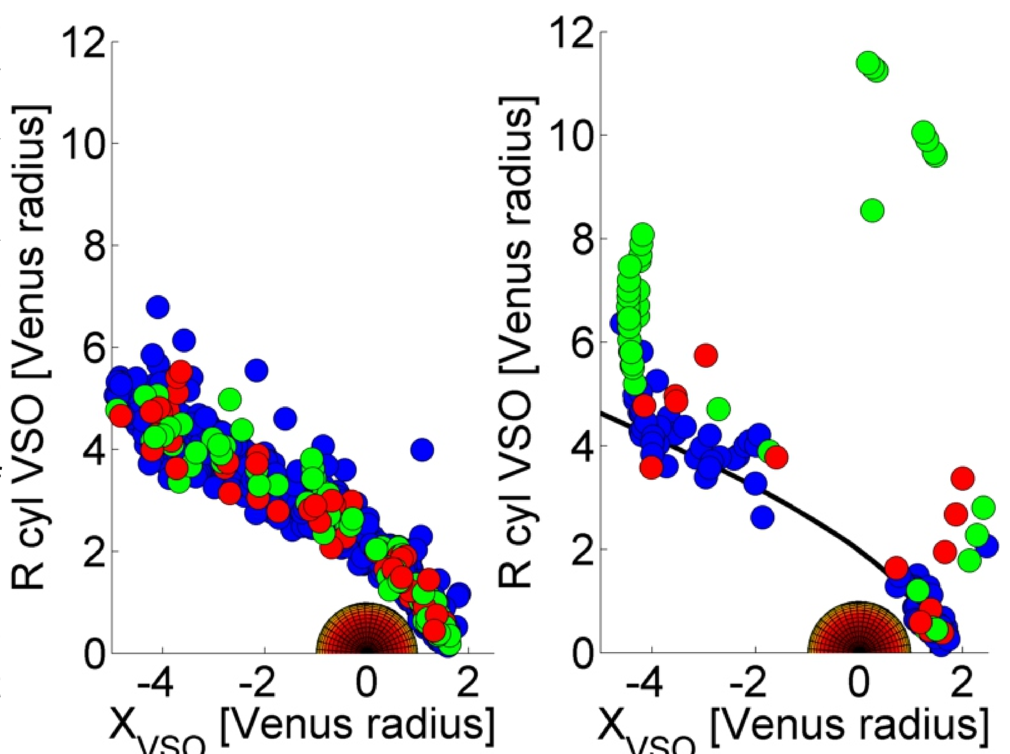


Figure 3.

6) Plasma parameters of the magnetic barrier

The average proton density and proton temperature of the magnetic barrier are presented in **Figure 4**. This figure has the same format as Figure 2. The average values are based on the measurements made between the upper boundary of the magnetic barrier and the ion composition boundary. The upper boundary is defined as the altitude where the solar wind dynamic pressure and the magnetic pressure in the induced magnetosphere are equal [*Zhang et al.*, 2008]. It can be seen that the proton density was increased while the proton temperature was close to its average during the ICME passages (day 0). The altitude of the upper boundary of the magnetic barrier is shown in **Figure 5**. The green marks show the position of the upper boundary during ICME passages while the blue dots show the rest of the days. It can be seen that the altitude of the upper boundary did not correlate with the ICMEs.

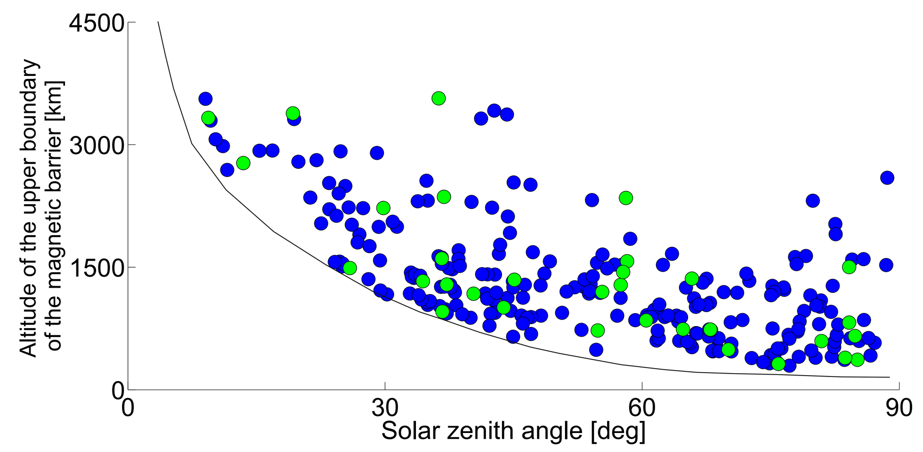


Figure 5.

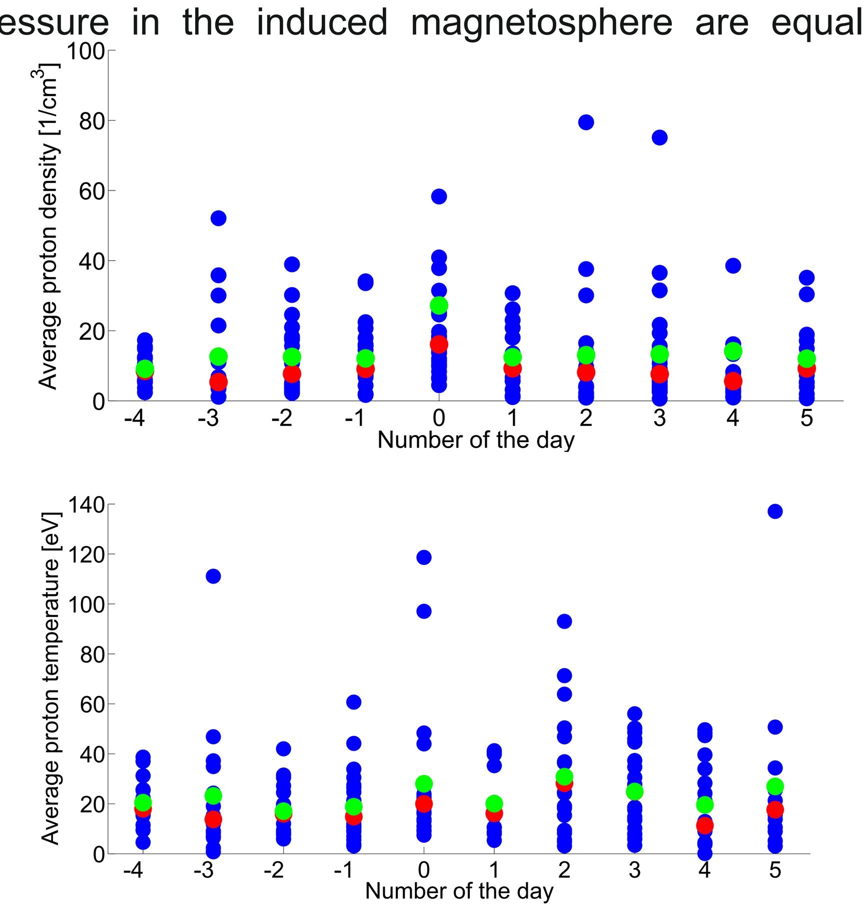


Figure 4.

7) Position of the Ion Composition Boundary (ICB)

The position of the ICB is investigated in **Figure 6**. Three examples are presented, during these events the solar wind dynamic pressure was the highest among all the observed cases. The red and blue dots show the position of the in and outbound ICB crossings in the 10 day intervals. The position of the ICB during the ICME is marked with „0.". It can be seen that on the nightside the altitude of the ICB decreased while on dayside it remained unchanged.

A statistical study was prepared on the elapsed time between in and outbound ICB crossing in **Figure 7**. It has the same format as Figure 2. In order to make the different orbits easily comparable, the elapsed time was normalized to the time measured during the ICME passages. In this way it can be seen that VEX spent nearly 50% less time in the ionosphere during ICME passages compared to the average days.

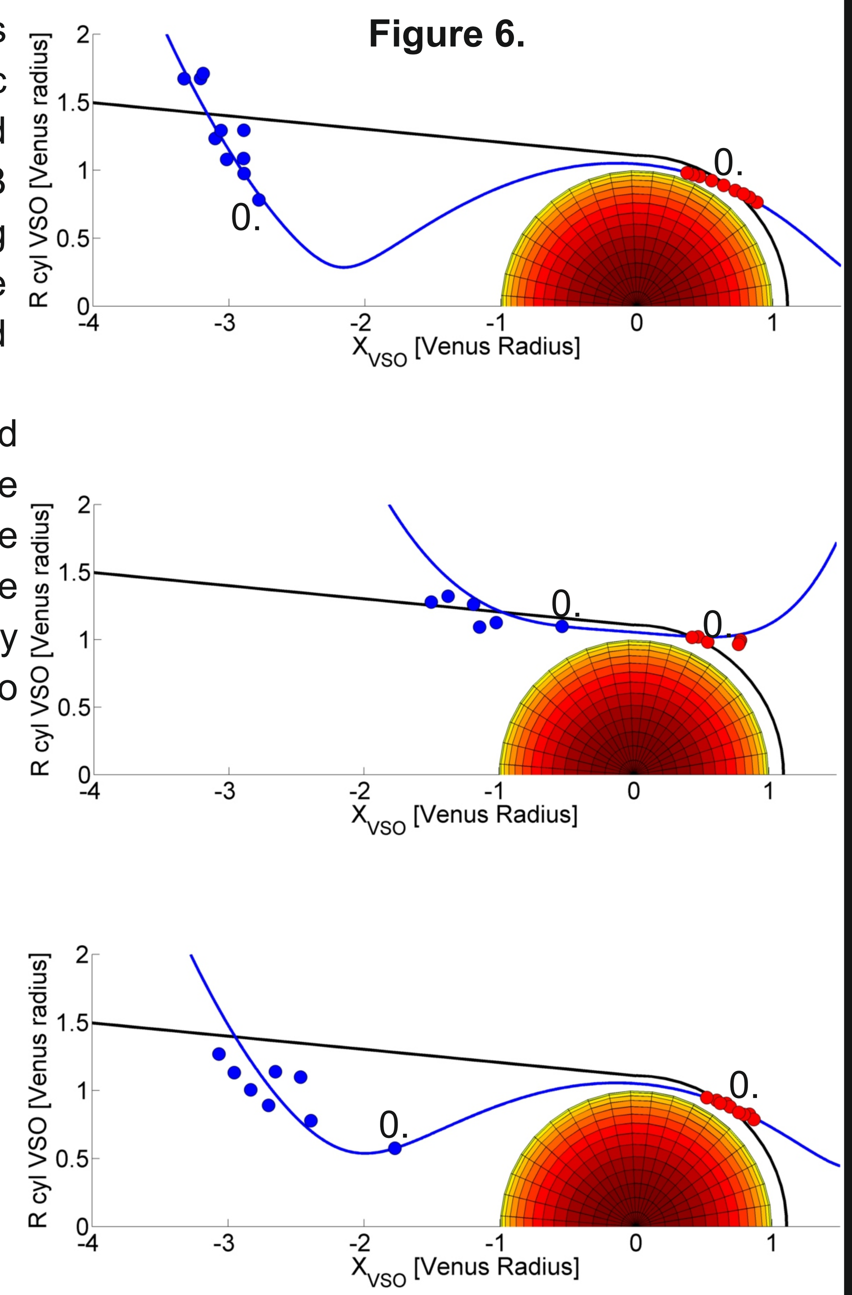
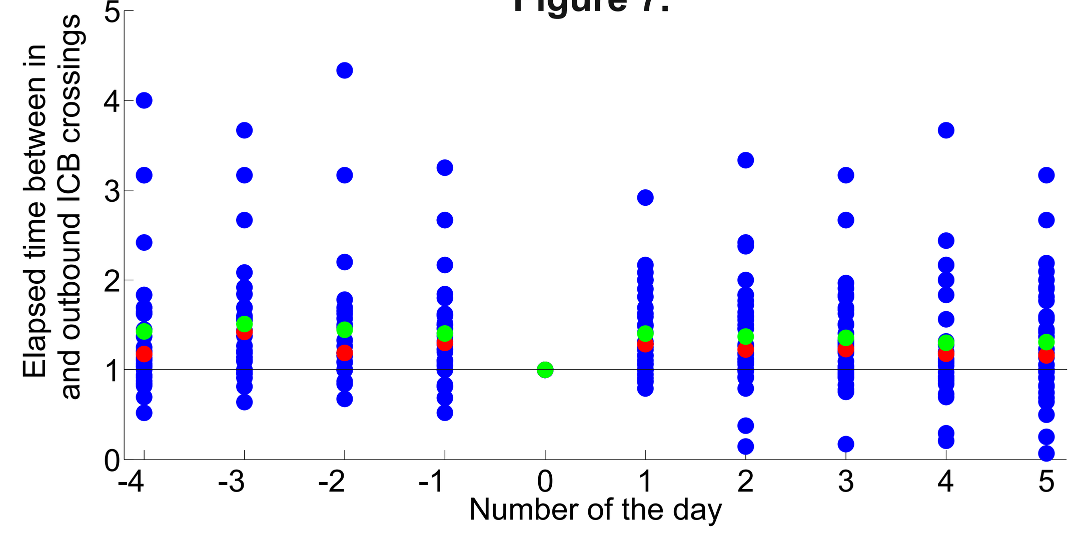


Figure 6.

Figure 7.



8) Summary

ICMEs with interplanetary shocks and large tangential magnetic fields tend to cause anomalously large magnetic fields in the magnetic barrier.

The effect of the ICME sheath region and the magnetic cloud on the bow shock were distinguished from each other. Anomalously distant bow shock crossings occurred only during magnetic cloud passages. This is explained by the decreased magnetosonic Mach number during those periods. During the ICME sheath region passage the position of the bow shock remained unchanged.

The size of the magnetic barrier was not affected by the ICME. Its upper and inner boundaries (the dayside ion composition boundary) were not affected by the ICME. We conclude that the anomalously large magnetic field intensities are not related to the shrinking of the altitude of the magnetic barrier. We suggest that the anomalously strong magnetic field is rather the result of the very intense magnetic field in the ICME sheath region which suddenly piles up in front of the obstacle.

The altitude of the nightside ion composition boundary decreased which is attributed to the increased solar wind dynamic pressure.

References:
Vech, D. et al., 2015, Space weather effects on the bow shock, magnetic barrier and ion composition boundary at Venus, submitted to JGR
Zhang, L. T., et al., 2008, Initial Venus Express magnetic field observations of the magnetic barrier at solar minimum, Planetary and Space Science, 56, 790-795

Acknowledgements

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