Investigation of the Photoelectron Boundary using ASPERA-3 Electron Spectrometer Data

Firdevs Duru, Daniel Hughes, Rudy Frahm, Tom Gore, Ben Pierson

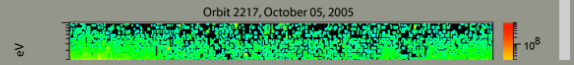
Coe College, Department of Physics, Cedar Rapids, USA; Southwest Research Inst, San Antonio, TX, USA; University of Notre Dame, IN, USA

Introduction

Boundaries between the Martian ionopshere and the solar wind are inportant to understand the past and future of the planet. One of these boundaries is the photoelectron boundary (PEB) defined as the end of the dayside photoelectron-dominated ionosphere. In this study, we investigate the PEB with data from the Electron Spectrometer (ELS) on the Analyzer of Space Plasmas and Energetic Atoms (ASPERA-3) instrument onboard Mars Express (MEX). In addition to digitizing the data, an algorithm to predict the location of the PEB is also used. The data obtained from both methods is combined to provide the final results.

Instruments and Data

The photoelectron peaks are observed as horizontal lines in the ELS data on the ASPERA-3 instrument. ASPERA-3 at energies between 21 and 24 eV and at 27 eV. Figure below provides an example for the electron spectrum for the orbit 2217 from October 5, 2005.



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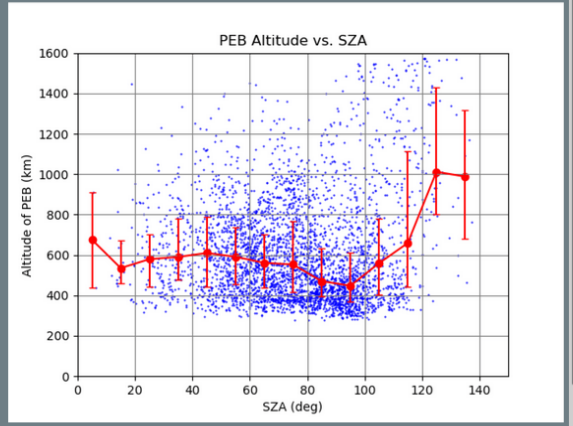
Algorithm and PEB Altitude

Due to the large volume of data, in addition to the manual analysis, an algorithm similar to the one created by Wang et al., 2022 has been used to identify PEB crossings. The two data sets are put together to obtain the final results.

In this algorithm, a dimensionless quantity is calculated to quantify the relative contributions of ionospheric photoelectrons and magnetosheath/ solar wind electrons.

The average altitude of the PEB as a function of the solar zenith angle (SZA) is provided by the figure below.



The average altitude is almost constant on the dayside with values around 600 km and increases substantially after the terminator

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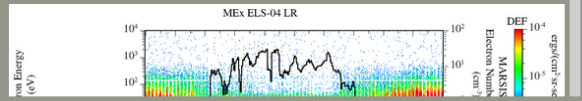
Comparison with Other Boundaries

The location of the PEB is compared to the ionopause defined as a sharp gradient in the local electron density obtained by the MARSIS radar on MEX. In 45 % of the cases, when the local electron density dats is available, the PEB coincides with the sharp density gradient. An example is shown below.



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Conclusions

Close to 2500 PEB crossings are obtained combining the manual data and the results from the algorithm. The data sets spans over 14 years.

According to the preliminary result:

The average altitude of the PEB is around 600 km on the dayside and much higher on the nightside.

The crossings above strong crustal field regions happen at higher altitudes.

The PEB altitude is observed to decrease with increasing solar wind pressure.

The PEB coincides with a sharp decrease in the local electron density in 45 % of the cases.

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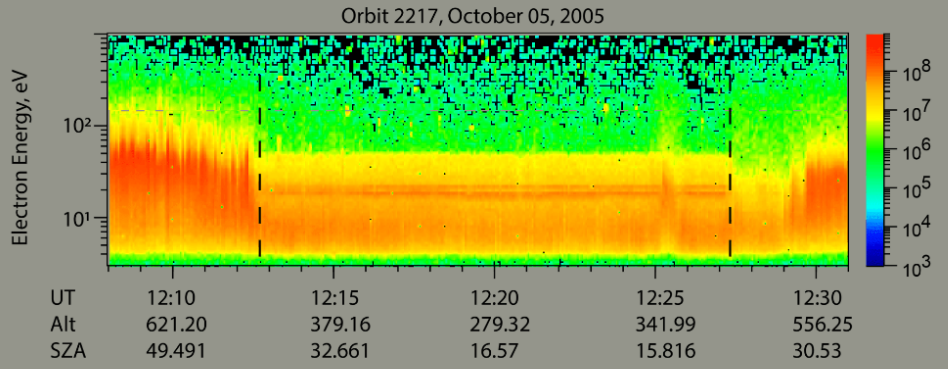


The data is shown for 23 minutes during which the spacecraft starts at higher altitudes, descends to the periapsis, and ascends back to about 600 km. The photoelectron peaks are seen as two distinct horizontal lines between energies 20 and 30 eV. The start and end of these lines are marked with dashed lines.

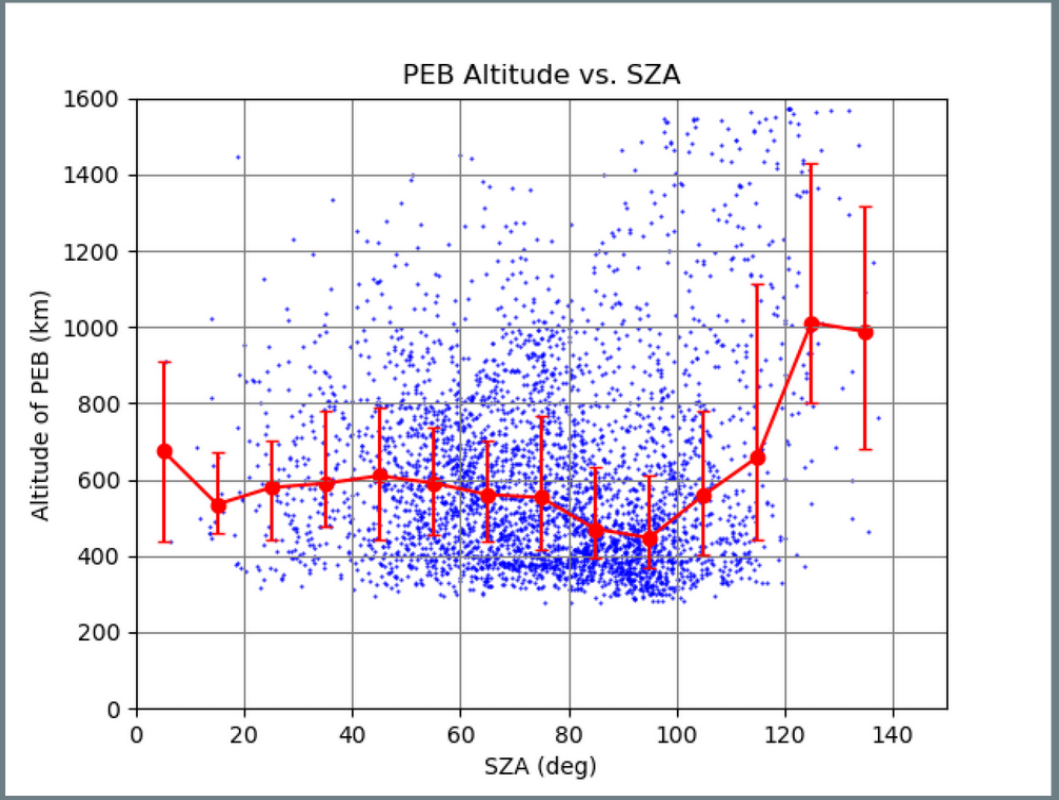
With this method we collected over 2000 PEB boundary crossings between July 2005 and September 2019.

Algorithm and PEB Altitude

Due to the large volume of data, in addition to the manual analysis, an algorithm similar to the one created by Wang et al., 2022 has been used to identify PEB crossings. The two data sets are put together to obtain the final results.

In this algorithm, a dimensionless quantity is calculated to quantify the relative contributions of ionospheric photoelectrons and magnetosheath/solar wind electrons.

The average altitude of the PEB as a function of the solar zenith angle (SZA) is provided by the figure below.

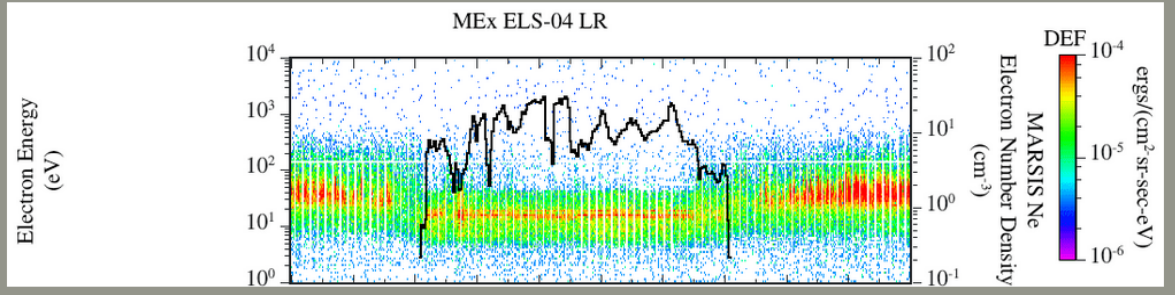


The average altitude is almost constant on the dayside with values around 600 km and increases substantially after the terminator.

The average altitudes also are substantially higher over the regions of strong crustal magnetic fields.

Comparison with Other Boundaries

The location of the PEB is compared to the ionopause defined as a sharp gradient in the local electron density obtained by the MARSIS radar on MEX. In 45 % of the cases, when the local electron density dats is available, the PEB coincides with the sharp density gradient. An example is shown below.



In the above orbit, the end of the photoelectrons are where the sharp density gradient is observed in both inbound and outbound leg.

In about 35% of the cases, there is a gap between the PEB and the magnetosheath. Especially, in the SZA range between 30 and 110, the average altitude of the magnetosheath is noticibly higher than the average PEB altitude. Difference goes up to 400 km around the terminator.

Conclusions

Close to 2500 PEB crossings are obtained combining the manual data and the results from the algorithm. The data sets spans over 14 years.

According to the preliminary result:

The average altitude of the PEB is around 600 km on the dayside and much higher on the nightside.

The crossings above strong crustal field regions happen at higher altitudes.

The PEB altitude is observed to decrease with increasing solar wind pressure.

The PEB coincides with a sharp decrease in the local electron density in 45 % of the cases.

A gap is observed between the magnetosheath boundary and the PEB in about 35 % of the cases.