Multipoint Monitoring of the Plasmasphere Dynamics at low-Earth Orbit

Balázs Heilig(1), Hermann Lühr(2), Claudia Stolle(2,3), Jan Rauberg(2) , Guram Kervalishvili(2)
(1) Mining and Geological Survey of Hungary, Budapest, e-mail: heilig.balazs@mbfsz.gov.hu
(2) German Research Centre for Geosciences GFZ, Potsdam, Germany
(3) University of Potsdam, Potsdam, Germany

The plasmapause (PP), the outer boundary of the plasmasphere – as the plasmasphere itself – is dynamically linked to the ionosphere. Magnetospheric convection electric field is mapped down to the ionosphere by geomagnetic field lines of close to infinite conductivity. The night side sub-auroral ionosphere also has a key role in forming the new PP. Poleward of the plasmapause footprint the ionospheric conductivity is enhanced by the particle precipitation from the magnetosphere. In the sub-auroral ionosphere, the conductivity is lower. To maintain current continuity through this lower conductivity zone, the electric field increases. This increased electric field contributes to plasmasphere erosion. Plasmasphere dynamics cannot be fully understood without understanding the simultaneous processes in the underlying ionosphere.

We are developing a series of tools based on observations made at low-Earth-orbit (LEO) by the three Swarm satellites of ESA to monitor ionospheric phenomena dynamically linked to the plasmasphere boundary. The maybe most well-known phenomenon of these is the mid-latitude ionospheric trough (MIT). The MIT is a depletion of the plasma density in the topside ionosphere. Its location depends on the level of geomagnetic activity, as well as magnetic local time. MIT moves equatorward with increasing Kp and withdraws poleward during quiet periods. The trough minimum coincides with a peak in the electron temperature, both found poleward of the footprint of the plasmapause. Monitoring the location of the MIT, we improve our knowledge on the dynamic processes taking place at the PP, and we can also follow the motions of the plasmapause. Making use of the electron density and temperature data of the Langmuir probes, as well as GPS TEC onboard the Swarm satellites, we not only detect the MIT trough location, but also extract the main morphological features of the MIT, such as depth, width, gradients at the MIT walls, etc.

Recently, a close relationship was found between the equatorward boundary of the small-scale field aligned currents (SSFAC) and the ionospheric footprint of the PP. The two boundaries are not only closely collocated in the near-midnight MLT sector but the correlation between their simultaneous variation is also high [1, 2]. The plasmasphere is shielded from the electric field that drives the SSFAC outside the PP. This is likely one of the reasons the PP appears as a boundary of SSFACs. Diffuse precipitation of particles outside the PP may also contribute to the small-scale FAC fluctuations generally observed in the sub-auroral region. The SSFAC boundary is typically observed somewhat poleward of the PP.

LEO satellites have an orbital period around 90 minutes, so they cross the PP every 22.5 minutes on average. This means about 64 possible PP observations per satellite per day. Of course, none of the boundaries can be clearly identified at all crossings. Both MIT and the SSFAC boundary are easier to detect on the night side, and during geomagnetically active periods. The efficiency of detection also has a seasonal and longitudinal dependence. Based on our experiences, the success rate of detection is around 20% for both the MIT and the SSFAC boundary. It means that the method is already suitable for monitoring the PP dynamics at a timescale of hours. The higher the geomagnetic activity, the better the detection rate becomes. Since the typical timescale of PP dynamics is also of the order of hours, we are able to fully cover the main features of PP variation.

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References

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