Topside Ionosphere and Plasma Sphere Modelling

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Abstract

Using a machine learning technique and over five million electron density records from the Japanese satellites Hinotori, Akebono, and Arase, we created a novel topside ionosphere and plasma sphere model. The topside ionosphere and plasma sphere model (TIP-model), which takes into account latitude, longitude, universal time, season, and solar and magnetic activity throughout time, can calculate electron concentrations at altitudes ranging from 500 km to 30,000 km. The model displays the plasma sphere's 3D structure over time as a result of solar and magnetic activity. Plasma pause, plasma tail/erosion of the plasma sphere, and plasma escape near the magnetic pole are all accurately modelled by the TIP-model that was created.

Keywords: Topside ionosphere; Plasma sphere, modelling, Artificial intelligence

Introduction

The magnetosphere of the Earth includes the plasma sphere. The ionosphere of the Earth generates cold, dense plasmas (a few eV). While ions are heavier than electrons and cannot go to the inner magnetosphere, electrons in the ionosphere flow along the lines of the Earth's magnetic field and those with energies greater than the escape energy can. As a result, an electric field appears in the space between the inner magnetosphere and the ionosphere. The created electric field causes the ionospheric ions to start rising. Together, the electrons and ions of the ionospheric migrate to the inner magnetosphere. Light ions like H+, He+, and O+ are able to quickly leave the ionosphere. Because of the geomagnetic activity, the region of the plasma sphere shifts in size, which results in a significant loss of plasm aspheric plasma and/or a refilling of the plasma sphere during the geomagnetic active periods. Lightning generates whistler radio waves that travel through the ionosphere, plasma sphere, and magnetosphere following the magnetic field lines of the planet. During the propagation process, the radio waves change frequencies. Carpenter noted a sharp decrease in frequency dispersion at the plasma pause. The Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) satellite recorded photos of the plasma sphere while observing the resonance scattering of sunlight by He$^+$ in the plasma sphere. The IMAGE satellite also noticed a tail on the plasma sphere, which was brought on by plasma spheric rotation and the electric fields produced by the interaction of the solar wind and magnetosphere. Intriguing phenomena like fingers, crenulations, channels, notches, shoulders, and shadows were also visible on the IMAGE satellite. Utilizing satellite and ground-based ULF wave data, the plasma density gradient in the radial direction at the equator was calculated. Using the power-law model, the plasma density gradient was calculated to be between 4-6. A plasma sphere model was created using a neural network. A plasma sphere model was created by Bortnik et al. using the SYM-H index and three Time History of Events and Macroscale Interactions During Substorms (THEMIS) probes to reconstruct the equatorial electron number density of the inner magnetosphere as a function of space and time. The topside ionosphere and plasma sphere contain a variety of structures, including the equatorial density anomaly, plasma trough, plasma heating/outflow in the polar region, plasma pause, plasma tail, plasma erosion, plasma refilling, and so on. These phenomena are highly influenced by geographic and geomagnetic latitude and longitude, local time and season, as well as solar and magnetic activity. Because it takes a few days to obtain the plasma density along a magnetic flux tube, the time history effects of the plasma

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sphere are crucial for developing a model of the plasma sphere. Five million electron density records from the three Japanese satellites are still not enough to build an empirical model of a time-dependent 3D ionosphere and plasma sphere since the three satellites do not cover the entire plasma sphere in time and space.

Conclusion

For the first time, a time-dependent 3D Topside Ionosphere and Plasma Sphere Model (TIP model) was created using a machine learning technique using over five million electron density values collected by the Hinotori, Akebono, and Arase satellites. The TIP-model predicts electron concentrations as a function of universal time starting on January 1, geographic latitude/longitude, and solar and magnetic activity with five-day histories at altitudes ranging from 500 km to 30,000 km. Plasma pause, plasma tail/erosion of the plasma sphere, and plasma escape towards the magnetic pole are all accurately modelled by the TIP-model.