Modeling the plasmasphere electron density: from local Van Allen Probe observations to the global plasmasphere dynamics

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Abstract:
The electron number density is a fundamental parameter of plasmas and is critical for radiation belt modeling and wave-particle interactions. In this seminar, we present recently developed tools and models for reconstructing the plasmasphere dynamics. We first describe the approach we developed to determine plasma density from local Van Allen Probes electric field measurements. Here, we designed a neural network to infer the upper hybrid resonance frequency from the dynamic spectrograms obtained with Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS) instrumentation suite, which was then used to calculate the electron number density. The developed neural network was applied to 6 years of the EMFISIS data, and the obtained electron density data set was then used to develop a new global model of plasma density by employing neural network-based modeling approach. The model takes the time history of geomagnetic indices and location as inputs, and produces the distribution of plasma density in L and MLT as an output. Due to the limited availability of training data for $Kp \geq 7$, the model can be reliably applied during the time periods when $Kp < 7$. In order to overcome this limitation and reconstruct the global density evolution during high geomagnetic activity times, we employ the physics-based modeling approach. Unlike neural networks that strongly depend on the availability of training data, physics-based models perform stably during high geomagnetic activity time periods when the training data for neural networks is lacking or absent, if initialized and configured correctly. We then discuss advantages and limitations of these approaches and show how neural network- and physics-based modeling can be combined in order to simultaneously utilize advantages of both approaches. Finally, we present examples of the global plasma density reconstruction for the events occurred in the past including Halloween storm in 2003. We validate the global density reconstructions by comparing them to the IMAGE EUV images of the He+ particles distribution in the Earth’s plasmasphere for the same time periods.