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A combined neural network- and physics-based approach for modeling the plasmasphere dynamics

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Plasmasphere is a torus of cold plasma surrounding the Earth and is a very dynamic region. Its dynamics is driven by space weather, and having an accurate model of the plasmasphere is very important for wave-particle interactions and radiation belt modeling. In the recent years, feedforward neural networks have been successfully applied to reconstruct the global plasmasphere dynamics in the equatorial plane [Bortnik et al., 2016, Zhelavskaya et al., 2017, Chu et al., 2017]. These neural network-based models have been able to capture the large-scale dynamics of the plasmasphere such as plume formation and erosion of the plasmasphere on the night side. However, neural networks (NNs) have one limitation. When data is abundant, NNs perform really well but when the data is limited or there is no data at all, which typically happens during extreme geomagnetic storms, NNs do not perform well since these data are underrepresented in the training set and NNs cannot learn from the limited number of examples. This limitation can be overcome by employing physics-based modeling during the periods of high geomagnetic activity. Physics-based models perform stably during high geomagnetic activity time periods if initialized and configured correctly. We present the combined approach to model the global plasmasphere dynamics that utilizes advantages of both neural network- and physics-based modeling and produces accurate global plasma density reconstruction. We show the examples of the global plasma density reconstruction for several events including the 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.