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Understanding the space environment: simulations, statistics and space weather (Julius Bartels Medal Lecture)

Tuija Pulkkinen
Department of Electronics and Nanoengineering, Aalto University, Espoo, Finland

Three disruptive transformations have taken place since the 1990's that have reshaped space research in a major way: Increased computational capacity and improved numerical methods have transformed numerical simulations from rough description of the large-scale dynamics to detailed models capable of describing magnetospheric processes to the accuracy that they compare well with in-situ observations. Coordinated satellite programs and multi-satellite missions have increased the coverage of the near-Earth space from single-satellite observations to statistical databases that allow analysis of the environment changes under varying conditions. The increased use of space assets in non-space-related applications has increased the need for accurate space weather monitoring and forecasts that set new requirements for the accuracy and processing times for as well observations and models. In this presentation, we focus on plasma and energy transfer across the bow shock from the solar wind into the magnetosheath, transport through the magnetosheath, and entry into the magnetosphere across the magnetopause. To that end, we use the GUMICS global magnetohydrodynamic simulation and the Themis 5-spacecraft mission plasma and magnetic field measurements. We show that the transport processes are not uniform, but are different during southward and northward IMF, and during strong and weak driving. We conclude by assessing how these results relate to our capabilities of producing valuable space weather services.