Title: Turbulent Energy Transfer across Boundary Layers in the Earth’s Magnetosphere

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Abstract:
In this project, based on PRACE Tier-0 resources, a series of large-scale fully kinetic plasma simulations are performed to understand realistic energy transfer physics in collisionless space plasmas. Space such as between planets, stars and even galaxies is almost commonly filled with plasma with its density small enough to neglect particle collisions. In such a collisionless system, the boundary layer between regions with different plasma properties plays a central role in transferring energy and controlling the dynamics of the system itself. In a representative collisionless system, the Earth’s magnetosphere, the energy input from the solar wind is transferred and changes its properties through different physical processes at various boundary layers, which eventually leads to the global dynamics of the magnetosphere and various energetic space weather phenomena such as auroral substorm. Although a number of theoretical, numerical and experimental studies have been performed to understand the boundary layer physics and related energy transfer processes in the magnetosphere, quantitative aspects of the transfer processes are still poorly understood. This is mainly because the realistic transfer processes basically involve a broad range of temporal and spatial scales from the electron kinetic to magneto-hydrodynamic (MHD) scales, which were difficult to be handled by previous research tools. Thus, the main goal of this project is to quantify the realistic energy transfer processes covering all necessary scales by effectively combining state-of-the-art fully kinetic simulations which cover a broad range of scales and high-resolution in-situ spacecraft observations which cover necessary scales to provide realistic parameters to the simulations. To this end, we systematically perform large-scale fully kinetic simulations using the high-performance VPIC code under realistic conditions obtained from the recently launched high-resolution MMS (Magnetospheric Multiscale) spacecraft. In this study, we particularly focused on the effects of background turbulence, which is believed to commonly exist in collisionless space plasmas and cause cross-scale energy cascades, on the energy transfer processes across the two representative boundary layers in the magnetosphere; magnetopause locating at the edge of the magnetosphere, and the magnetotail current sheet locating in the nightside magnetosphere. First, our new simulations of the magnetopause demonstrated that the pre-existing background turbulence enhances the velocity shear-driven turbulence at the magnetopause to the same level as observed by MMS. Next, another simulation of the magnetotail current sheet demonstrated that the background turbulence drives electron-scale turbulent disturbances within the magnetic shear-driven macro-scale turbulence, as very recently detected by MMS. These new findings indicate the importance of the background turbulence to quantitatively understand realistic energy transfer processes at the plasmas boundary layers in collisionless plasmas.