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Multiscale simulation of the solar wind interaction with the dayside magnetosphere: comparison with MMS observations

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Ongoing exploration of the magnetosphere by the spacecraft of NASA's Magnetospheric Multiscale Mission (MMS) is revealing a very complex dynamic of the kinetic processes occurring at the dayside's plasma boundaries. One of the main obstacles to fully comprehending these observations is the need to follow both the evolution of the large-scale interaction of the solar wind with the dayside magnetosphere and the details of the kinetic processes that enable transport of energy and mass in localized regions such as at the bow shock and the magnetopause. To address this multiscale problem, we have carried out 3D regional particle-in-cell (PIC) simulations of the dayside magnetosphere for southward interplanetary magnetic field conditions. The model uses the results of global magnetohydrodynamic (MHD) simulations to set the initial state and the evolving boundary conditions of fully kinetic implicit iPic3D simulations. This approach allows us to cover large domains both in space and energy by including both magnetopause and bow shock in the kinetic domain and encompassing a vast range of particle energies from a few eV in the solar wind to keV in the magnetospheric boundary layer. We assess the results of the iPic3D simulations by producing wave spectra and particle velocity distribution functions, as well as measuring particle acceleration, anisotropy and agyrotropy observed in the different regions of the simulation domain and comparing them with local observations by the MMS spacecraft. We conclude by discussing the relevance of our results for the design and planning of future heliospheric missions aimed to study turbulent energy dissipation and particle energization in the solar wind and the bow shock/magnetosheath, such as the proposed THOR mission.