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Time-Varying Solar Wind Interaction with Earth: Global, Realistic, 3D Hybrid-Kinetic Simulations

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We present the first global three-dimensional (3D) kinetic interaction between the solar wind and Earth using its true scales (no scaling is applied) obtained from a hybrid-kinetic model of plasma (particle ions, fluid electrons). Achieving this level of accuracy in kinetic modeling of the solar wind plasma interaction with Earth has been a long-standing challenge. We use *Amitis*, a high-performance hybrid-kinetic plasma model that is three-dimensional (3D) in both configuration and velocity spaces and runs in parallel on Graphics Processing Units (GPUs). Our simulations incorporate typical solar wind plasma conditions near Earth, exploring a spectrum of time-varying Interplanetary Magnetic Field (IMF) orientations and solar wind dynamic pressure variations. The spatial and temporal scales of the magnetosphere are physically represented in our model, and no scaling has been applied in our simulations. We investigate the dynamic response of the foreshock, bow shock, and magnetopause to varying IMF orientations and solar wind variations, covering physical time scales exceeding an hour. We also investigate the flux of precipitating ions into the upper ionosphere and its time-variabilities. Significantly, our study underscores substantial disparities between the outcomes derived from our hybrid-kinetic model and those obtained from Magnetohydrodynamics (MHD) simulations.