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Multi-physics large-scale simulations of the terrestrial magnetosphere and geomagnetic storm studies

Simulations à grande échelle de la magnétosphère terrestre et des orages géomagnétiques

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Geospace is a highly complex dynamical system and often exhibits nonlinear responses to driving from the solar wind. Its evolution involves an enormous number of coupled physical processes operating on spatial scales from meters to tens of thousands of kilometers and temporal scales from seconds to months, throughout the terrestrial magnetosphere-ionosphere system. The system has the capability to efficiently accelerate charged particles up to very high energies over relatively short times and distances. This efficient acceleration of charged particles and their subsequent injection into the near Earth space leads to a large magnetic field depression due to the intensification of the near-Earth currents. The dynamics of these currents, and in particular of the ring current, involve plasma transport, losses, strong coupling between residing plasma and large scale electric and magnetic fields as well as wave-particle interactions. Modeling such an environment is a complex task and requires a framework approach rather than studying each of its components in isolation. The system behavior is mainly encompassed in the coupling of the system elements rather than the components that make up the system, so describing its complexity requires self-consistent coupling between the elements.

Developed at University of Michigan, the Space Weather Modeling Framework (SWMF) is a high-performance, flexible and robust computational framework designed for simulating the global space environment. SWMF integrates numerical models from numerous physics domains that can be customized to self-consistently simulate physical processes and coupled domains from the solar surface to the upper atmosphere of the Earth. This allows studying these complex, multi-scale space plasmas and their interactions on a system level, promoting a global understanding of the processes driving space weather, and advancing us toward physics-based prediction of the near-Earth environment. This presentation will illustrate recent advancements made within the SWMF, allowing for enhanced modeling and predictive capabilities, thanks to a suite of self-consistently coupled, first-principle models describing these interconnected and collocated plasma environments.