Project Details

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Project Title:
Integration of Extended MHD and Kinetic Effects in Global Magnetosphere Models

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Summary:
The primary science focus of the proposed Strategic Capability (SC) is the integration of extended magnetohydrodynamics (XMHD) and kinetic effects in global models. While our application is geared to the Earth s magnetosphere where, thanks to in situ observations, a rich database exists for the verification and validation of the predictions of such a SC, the core science module of the model has much broader applicability, and has potentially transformative implications for our ability to understand and predict a broad range of heliospheric space weather events that involve magnetic reconnection, instabilities of current sheets, and turbulence. Over the last 15 years, there has been significant progress in our theoretical understanding of these processes in collisionless systems. It has become clear from these studies and comparison with observations that it is essential (i) to study plasma dynamics in the high-Lundquist-number regime, and (ii) to go beyond the standard framework of the resistive MHD model to include multi-fluid physics (referred to here as XMHD), including a generalized Ohms law, enhanced equations of state (EOS) for electrons and ions that incorporate kinetic effects, and multiple charged particle species. The proposed SC will be in the form of a state-of-the- art version of OpenGGCM, a traditional version of which is presently used extensively in the community and the NASA-CCMC for space weather predictions.

Intrinsic Merit: The present SC will assimilate and represent nearly 15 years of remarkable advances in our understanding of extended MHD and kinetic effects within the framework of a global magnetosphere code. These advancements have been brought about for two principal reasons: (1) sophisticated computer simulation codes that are based upon novel algorithms and software, developed in partnership with applied mathematicians and computer scientists that exploit the power of advances in high- performance computing technologies, and (2) the availability of multi-satellite observations. The present multi-institutional team of investigators have played leading roles in several of these advancements, especially in the area of magnetic reconnection and associated plasma instabilities, and have in hand a suite of mature physics-based modules, based on high-Lundquist-number MHD, Hall MHD, hybrid, multi species, and fully kinetic particle-in-cell codes, as well as a global magnetosphere code, OpenGGCM. In this SC, we address foundational issues in multi-fluid science that impact our ability to predict accurately space weather events within the context of global magnetosphere simulations, and show a pathway to use this foundational science to improve significantly the accuracy of space weather predictions.

Relevance and Broader Impact: These enhanced capabilities will enable our global magnetosphere code to accurately model the kinetic scale processes (e.g., magnetic reconnection) responsible for extreme space weather events with direct impact on human society. While our application is geared to the Earth s magnetosphere, the core science module of the model has much broader applicability, and has potentially transformative implications for our ability to understand and predict a broad range of heliospheric space weather events that involve magnetic reconnection, instabilities of current sheets, and turbulence. The team, which is a partnership between academia and national laboratories, consists of several junior scientists, postdoctoral fellows, and graduate students who will be educated in this broadly interdisciplinary subject, involving theoretical as well as experimental space plasma physics, applied mathematics, and high-performance computing. The PI as well as other institutional PI s have a strong track record of mentoring postdoctoral fellows and graduate students (including women, one of whom is identified as a leader of this project).

Publication References:

no references