Project Details

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Topic: A global model of the magnetosphere

Project Title:
Magnetosphere Aurora Reconnection Boundary Layer Emulator (MARBLE): Magnetosphere-Ionosphere Coupling on Multiple Scales

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Summary:
Understanding the connection between magnetospheric dynamics and the aurora has remained one of the most challenging problems in magnetospheric physics for the last fifty years. One of the more exciting developments in the last two decades was the discovery that dispersive Alfv n waves (DAW) play a significant role (comparable to quasi-static potentials) in accelerating magnetospheric electrons to energies capable of generating auroral arcs during periods of high auroral activity. DAW have also been invoked to directly connect collisionless reconnection physics to the aurora, with important implications for the relative timing between magnetotail reconnection onset and auroral substorm onset. Unfortunately, there does not exist a global magnetosphere code capable of modeling the physics of reconnection generated DAW and their coupling to the ionosphere. We propose to address this significant gap in our modeling capability by developing a new "collisionless Hall MHD" model in which frozen-in perpendicular ExB electron motion is self-consistently coupled to non-local electron and ion transport parallel to the magnetic field. The new computational model, MARBLE (Magnetosphere Aurora Reconnection Boundary Layer Emulator), will be designed to couple to an existing global Hall MHD code for the magnetosphere as well as a Fokker-Planck model for electron precipitation into the ionosphere. The new model will be capable of addressing the following science questions:

Q1. How does three-dimensional collisionless magnetic reconnection project to Earth's ionosphere?
Q2. How do reconnection generated field-aligned currents propagate to the ionosphere?
Q3. How is reconnection generated energy flux transported to the ionosphere?

MARBLE will be designed to run on clusters of Graphics Processing Units (GPUs) to enable reasonable simulation times for large magnetospheres with 5-10 cells per ion inertial length. Most of the development will occur on a dedicated 8 NVIDIA A100 cluster at NASA-GSFC. The same development environment will be available through an AWS cloud based interface provided by the Community Coordinated Modeling Center (CCMC) at NASA-GSFC. Our long term strategy will be to scale MARBLE up to larger clusters with thousands of GPUs.

Our proposed program will support two full time postdoctoral researchers with expertise in computational methods and machine learning to focus on: 1) the development of efficient numerical approaches for solving the electron and ion drift kinetic equations, 2) the use of deep learning to develop surrogate models for the propagation of input parameter uncertainties to quantities of interest.

MARBLE will be released under the NASA Open Source Agreement v1.3 and distributed in a NASA public github repository. In parallel, we will work with the CCMC to make MARBLE available to users through their Runs on Request web based interface. We will coordinate with the CCMC to ensure that we are meeting computational, storage, I/O, visualization and post-processing requirements at all stages in MARBLE's development. We will also work closely with the CCMC to establish a community driven model validation approach using both standard computational benchmarks as well as spacecraft and ground observations. This validation plan will promote an open science approach, with collaboration, transparency and reproducibility as core values. Several MARBLE community workshops will be organized during the course of the program.

Publication References:

no references