Enabling Breakthrough Kinetic Simulations of the Magnetosphere Using Petascale Computing

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Currently global magnetospheric simulations are predominantly based on single-fluid magnetohydrodynamics (MHD). MHD simulations have proven useful in studies of the global dynamics of the magnetosphere with the goal of predicting eminent features of substorms and other global events. But it is well known that the magnetosphere is dominated by ion kinetic effects, which is ignored in MHD simulations, and many key aspects of the magnetosphere relating to transport and structure of boundaries await global kinetic simulations. We are using our recent innovations in hybrid (electron fluid, kinetic ions) simulations, as being developed in our Hybrid3D (H3D) code, and the power of massively parallel machines to make, breakthrough 3D global kinetic simulations of the magnetosphere. The innovations include (i) multi-zone (asynchronous) algorithm, (ii) dynamic load balancing, and (iii) code adaptation and optimization to large number of processors. In this talk, we will show results from our recent simulations that are the largest global hybrid simulations to date and used 98 K cores. In particular, we focus on what we believe to be the first demonstration of the formation of a flux rope in 3D global hybrid simulations. As in the MHD simulations, the resulting flux rope has a very complex structure, wrapping up field lines from different regions and appears to be connected on at least one end to Earth. Magnetic topology of the FTE is examined to reveal the existence of several separators (3D X-lines). The formation and growth of this structure will be discussed and spatial profile of the magnetic and plasma variables will be compared with those from MHD simulations. In the northward IMF case, we demonstrate the presence of reconnection tailward of the cusp.