Semi-relativistic MHD and Implicit Schemes in Space Weather Modeling

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Space weather describes the effects of Solar activity on Earth. One of the challanges in the numerical modeling of space weather is that the propagation speed, in particular the Alfvén speed, can approach the speed of light in the magnetosphere near the Earth. This poses a severe problem, since the time steps of an explicit time integration scheme are limited by the Courant-Friedrichs-Lewy (CFL) numerical stability condition: the waves must not propagate more than one cell size in one time step. In a well resolved simulation, the cell size may be as small as several 100 km-s, which limits the time step to be less than 0.01 or even 0.001 seconds. On the other hand, typical time scales of the magnetosphere are on the order of minutes.

I will discuss two ways of circumventing the time step limitation: (i) replacing the classical MHD equations with the semi-relativistic MHD equations with an artificially lowered speed of light; (ii) implicit time integration techniques.