From the Photosphere to the CCMC: Coupled Focus Transport and MHD

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Outline

- Working with the CCMC in preparation for delivering LWS Strategic Capabilities
- Development on three fronts
- EPREM overview
- Coupling commonalities
- Code modes and output examples
- Conclusions

Working with the CCMC in preparation for delivering LWS Strategic Capabilities

It is good.

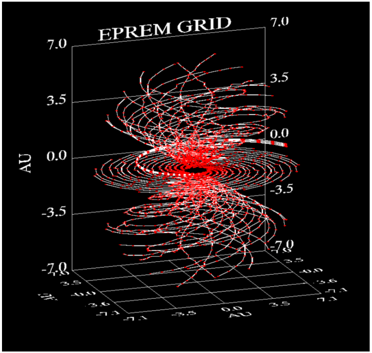
Three-pronged attack

The intersection of Magnetohydrodynamic (MHD) simulations of coronal mass ejections (CMEs) and energetic particle solvers is evolving into a fruitful set of tools for predicting particle fluxes and understanding acceleration. Development continues on the following projects:

- CMEs initiated low in the corona and simulated by Predictive Science Inc's Magnetohydrodynamics Around a Sphere (MAS) MHD code coupled to the Energetic Particle Radiation Environment Module (EPREM)
- CMEs initiated at 0.1 AU, simulated by Enlil, coupled to EPREM
- Stand-alone shock solver tool

Energetic Particle Radiation Environment Module

The Energetic Particle Radiation Environment Module (EPREM) solves the focused transport equation in the moving solar wind frame, along streamlines according to the formalism introduced by Kota, et al. in 2005. The streamlines are the connected history of nodes spawned at the same footpoint on the inner domain. Along each stream EPREM solves for particle transport, adiabatic focusing, adiabatic cooling and heating, convection, pitch angle scattering, perpendicular diffusion and particle drift.



Coupling Commonalities

EPREM can advance the field values at each node based on input from external MHD simulations. The same process is followed when coupling to both MAS and Enlil. The first external MHD output step is treated as an equilibrium and repeated until the nodes have reached a spatial equilibrium. After the initial propagation of nodes a seed population is injected on the inner boundary. The first coupled time-step is then run until the particles have reach an equilibrium, at which point the coupling is allowed to begin stepping forward in time.

The seed population is derived from Dayeh, et al., ApJ 693, 2009 and represents the spectra for quiet-time suprathermal ions at 1AU. We then scale the spectrum up to higher energies and radially back to the inner boundary.

Example: MAS + EPREM

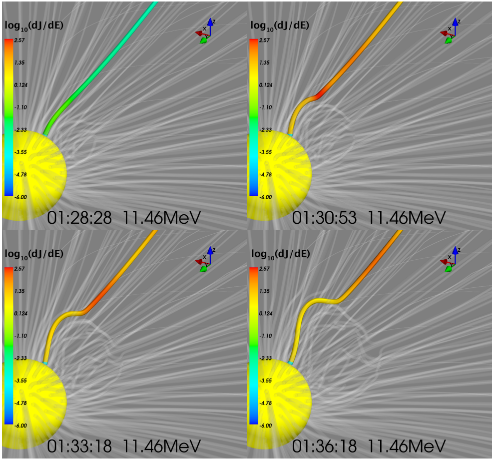


Figure: Streamline colored by log_{10} of the differential energy flux at 11.46 MeV at four snapshots during the eruption.

Example: MAS + EPREM

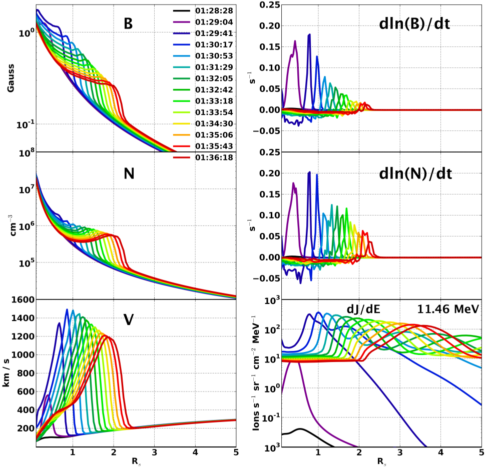


Figure: The colored lines are simulation time steps (HR:MIN:SEC) and all x-axes are in distance along the stream in solar radii. *(left panel)* B magnetic field magnitude, N number density, V bulk flow speed; *(right panel)* $dln(B)/dt$ change in the natural log of magnetic field magnitude w/ time, $dln(N)/dt$ change in the natural log of density w/ time, dJ/dE differential energy at 11.46 MeV.

Example: MAS + EPREM

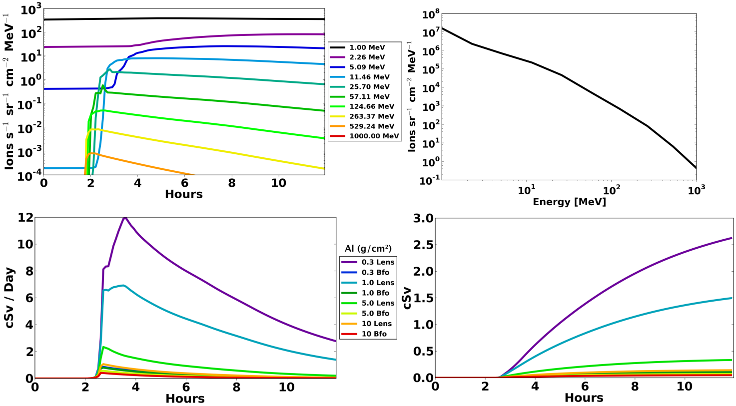
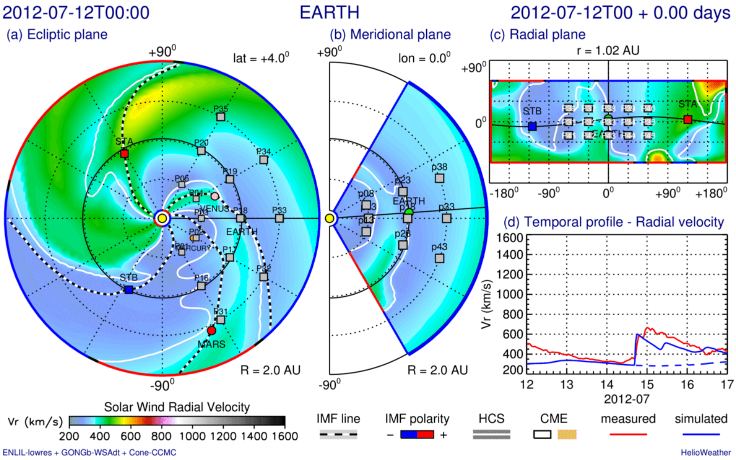


Figure: *(top left)* Flux at 1AU; *(top right)* Fluence at 1AU; *(bottom left)* Equivalent dose at 1AU for lens and blood forming organs behind various levels of aluminum shielding; *(bottom right)* Integrated equivalent dose at 1AU.

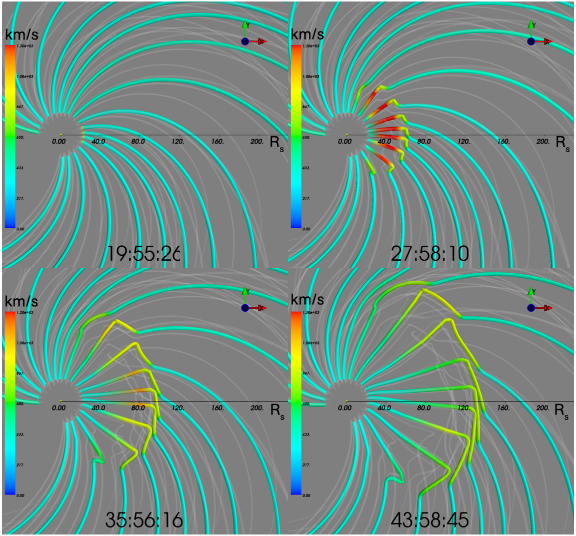
Example: Enlil + EPREM

Position hypothetical satellites throughout ENLIL domain

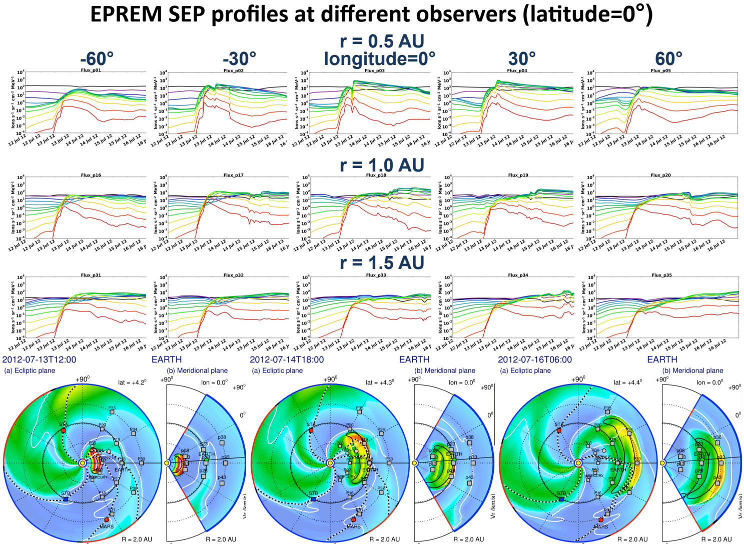


12 July 2012 CME WSA-ENLIL+Cone velocity contour plot

Example: Enlil + EPREM



Example: Enlil + EPREM



Stand-Alone Shock Tool

The run was initiated with a constant solar wind solution of 400 km/s and allowed to come to equilibrium. The shock profile to the right then propagated out from the inner boundary at 1800 km/s. The discontinuity is assumed to be a shock and the shock solver was applied everywhere $\nabla \cdot V$ was negative.

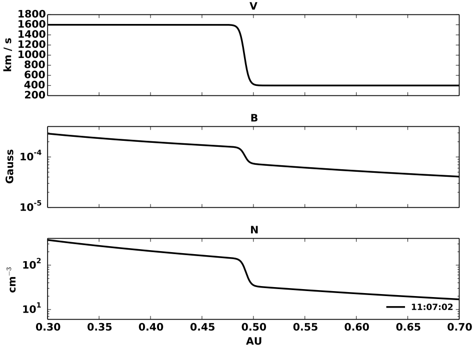
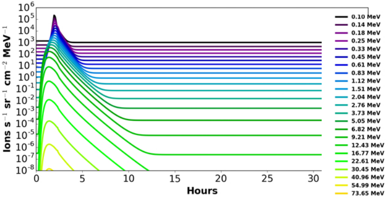
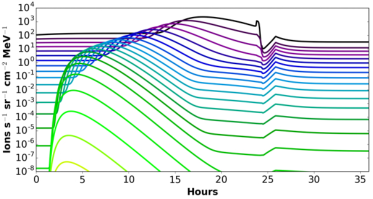
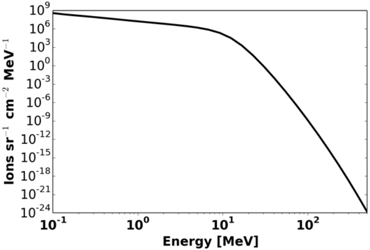


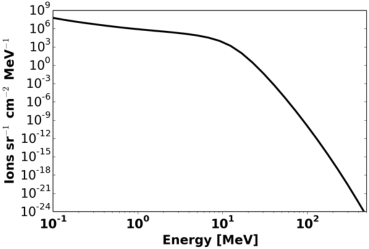
Figure: Solar wind speed, magnetic field strength, and density profile for the shock as it passes by 0.5AU

Stand-Alone Shock Tool









Conclusions

- Documentation and web front end for coupled codes
- Documentation and tidy package for stand-alone tool
- Thank you Leila and everyone at the CCMC!

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