Numerical Simulation of Heliospheric Disturbances

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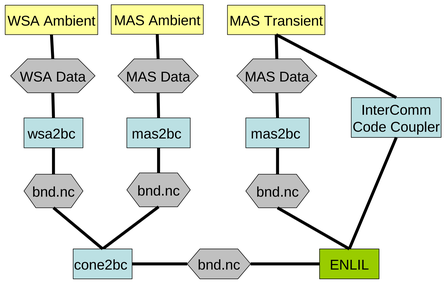
Overview

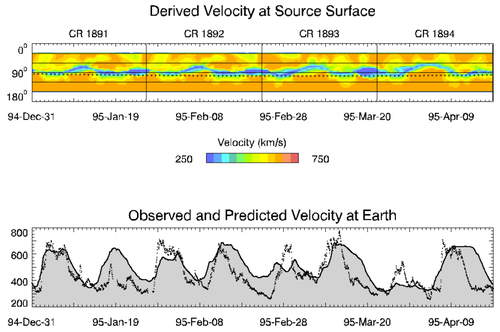
- Domain: Inner and mid heliosphere (between 0.1 and 2 or 5 AU)
- Model: 3D magnetohydrodynamic (additional tracing equations)
- Numerical scheme: explicit finite-volume TVD-MUSCL-HLL
- Parallelization: Domain decomposition and MPI procedures
- Initialization:
  - magnetic field at solar photosphere (WSA and MAS models)
  - mass ejections in solar corona (geometrical+kinematical fitting)
- Application: Space weather research and forecasting
- Deliverables:
  - NASA/Community Coordinated Modeling Center (CCMC)
  - NOAA/Space Environment Center (SEC)
- Acknowledgements: AFOSR/MURI, NASA/LWS, NSF/CISM

Driving of Heliospheric Computations



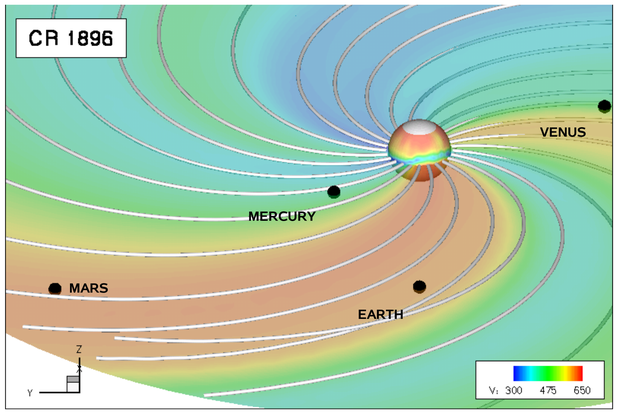
Various models of the solar corona can be used to drive the heliospheric computations. Computational system shares data sets (grey) and uses couplers (blue) between various models.

Ambient Solar Wind



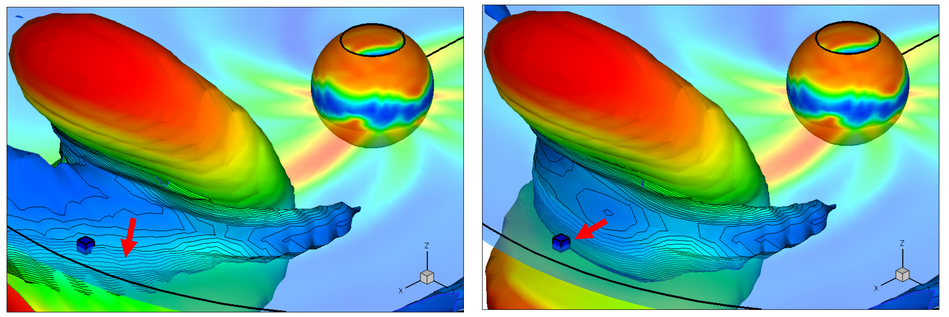
Distribution of the outflow velocity at 21.5 Rs (top) is used to simulate solar wind in the heliosphere. Predicted values at Earth (solid line) are compared with the Wind spacecraft observations (bottom).

Ambient Solar Wind



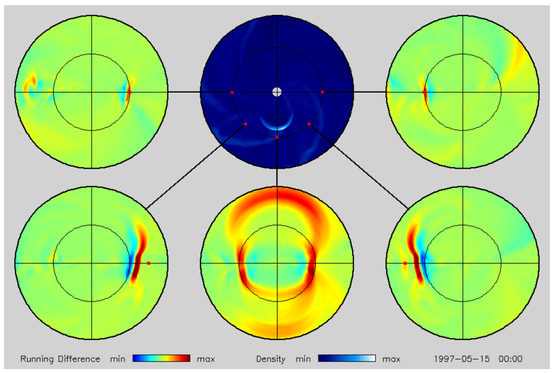
Flow velocity in the equatorial plane (color) and interplanetary magnetic field lines (white lines) during minimum solar activity (driven by WSA model) shows co-rotating structured solar wind.

Interaction of ICMEs with Ambient Wind



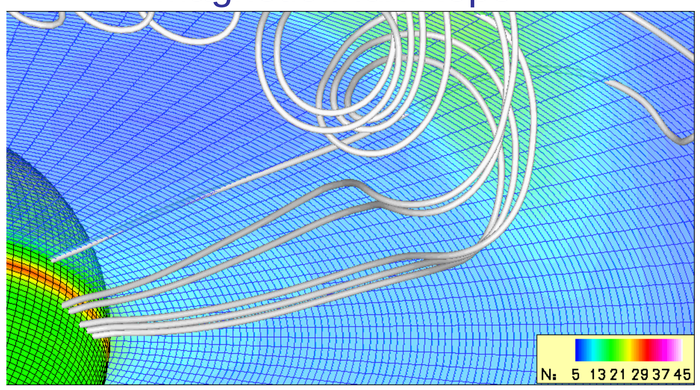
Visualization of an interplanetary disturbance on May 13 12:00 UT. The flow velocity is shown on the inner boundary and on the equatorial plane using a translucent color scale. The injected cloud is shown as an iso-surface at 25% of maximum value of its density and it is colored according to the corresponding flow velocity. The contours ahead of the cloud show an iso-surface for the total density at 20 cm^{-3}.

Synthetic Heliospheric Imaging



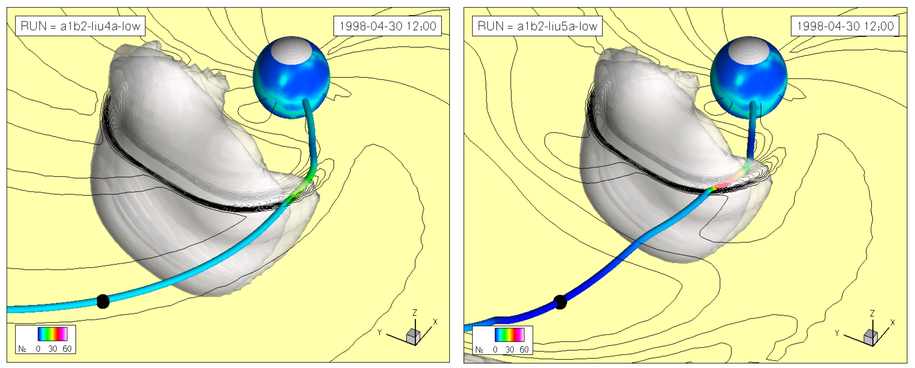
Simulated multi-perspective remote observations of a transient disturbance from different positions in the equatorial plane at 1 AU. The running difference imaging can be compared with STEREO spacecraft observations.

Magnetic Flux Rope



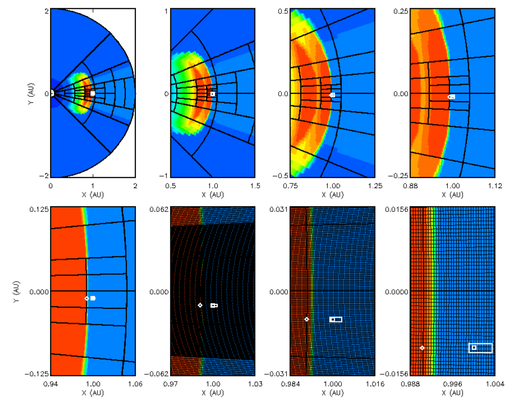
Selected magnetic field lines (white lines) show an interplanetary magnetic flux generated by hypothetic coronal magnetic eruption (MAS model) and launched into the heliosphere within the slower and denser heliospheric streamer belt.

ICMEs and IMF Connectivity



Interplanetary coronal mass ejections (ICMEs, white shaded structure), interplanetary magnetic field (IMF) lines (colored by normalized density). during the April/May 1998 events. Geospace is magnetically connected to weak or strong shock front depending on rarefaction caused by preceding ICME.

Higher Resolution of Shocks



Nested grids with progressively finer resolution can be used to achieve higher resolution of interplanetary shocks when hitting the geospace. This is possible due to large driver size and shock self-steepening.