ENLIL at the CCMC

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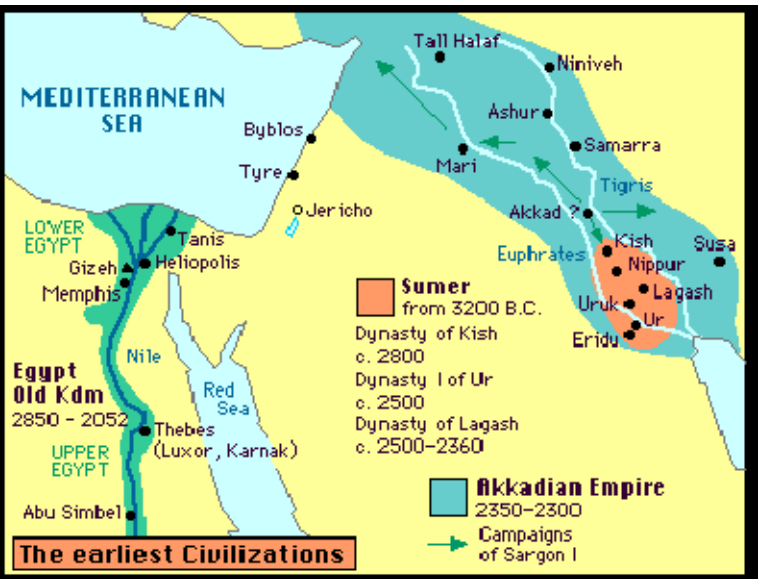
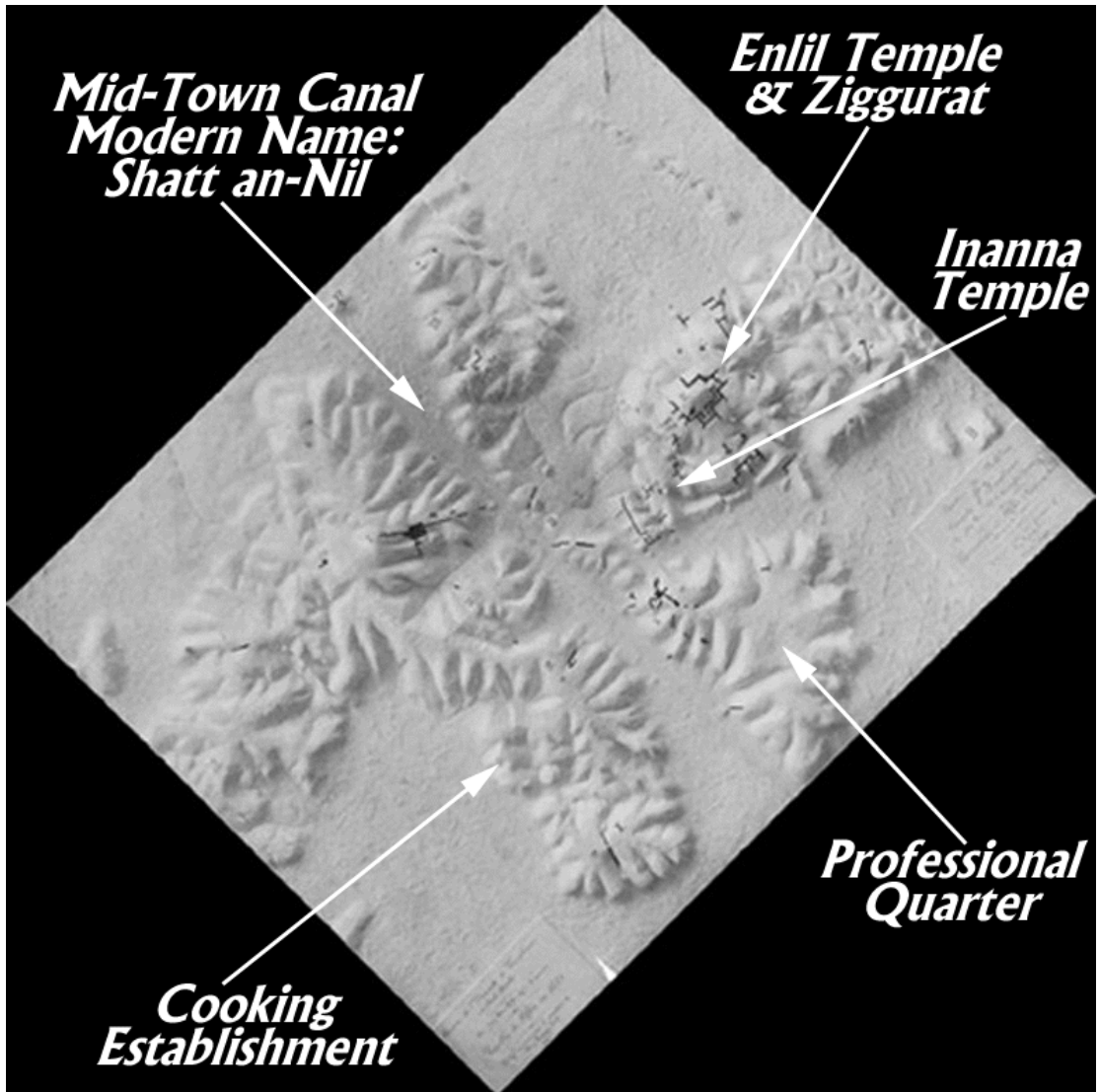
CCMC Workshop, Arecibo, Puerto Rico, November 5-8, 2007

ENLIL – Sumerian God of the Wind

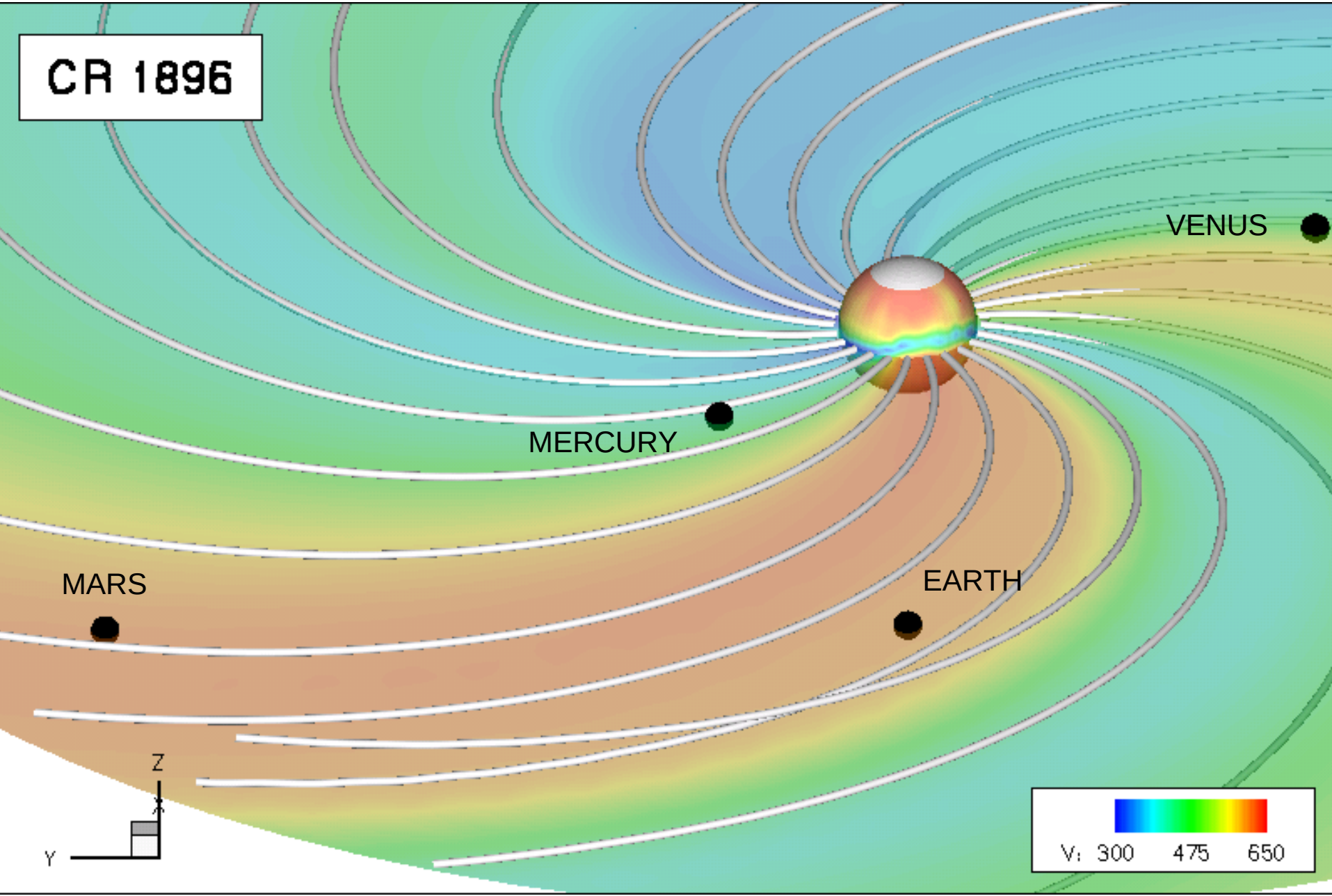




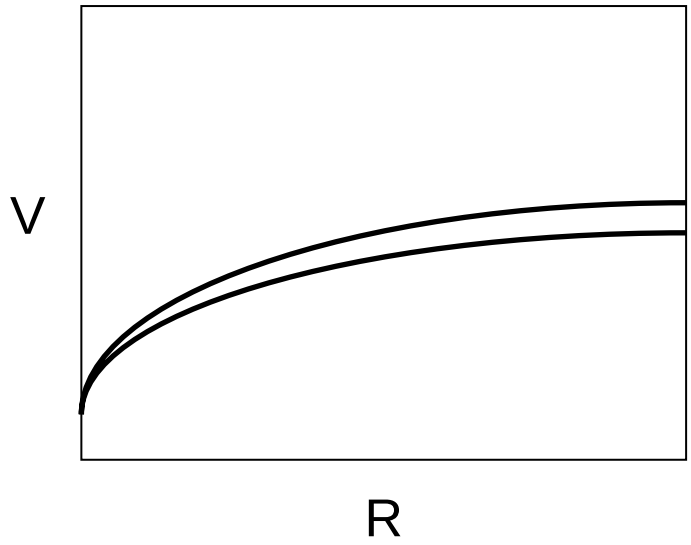
Versions at CCMC

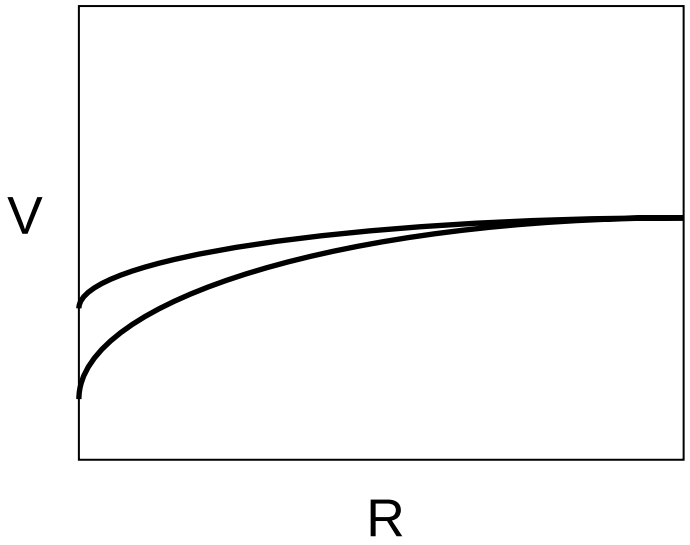
1.0	+ WSA
(2.0)	+ MAS, quick plots
2.3a	+ Cone model, additional metadata
(2.4)	+ IMF for SEP, updated file structure
(2.5)	+ IPS/SMEI, updated quick plots, STEREO support

Near Solar Minimum



Calibration of Input Data for ENLIL Runs

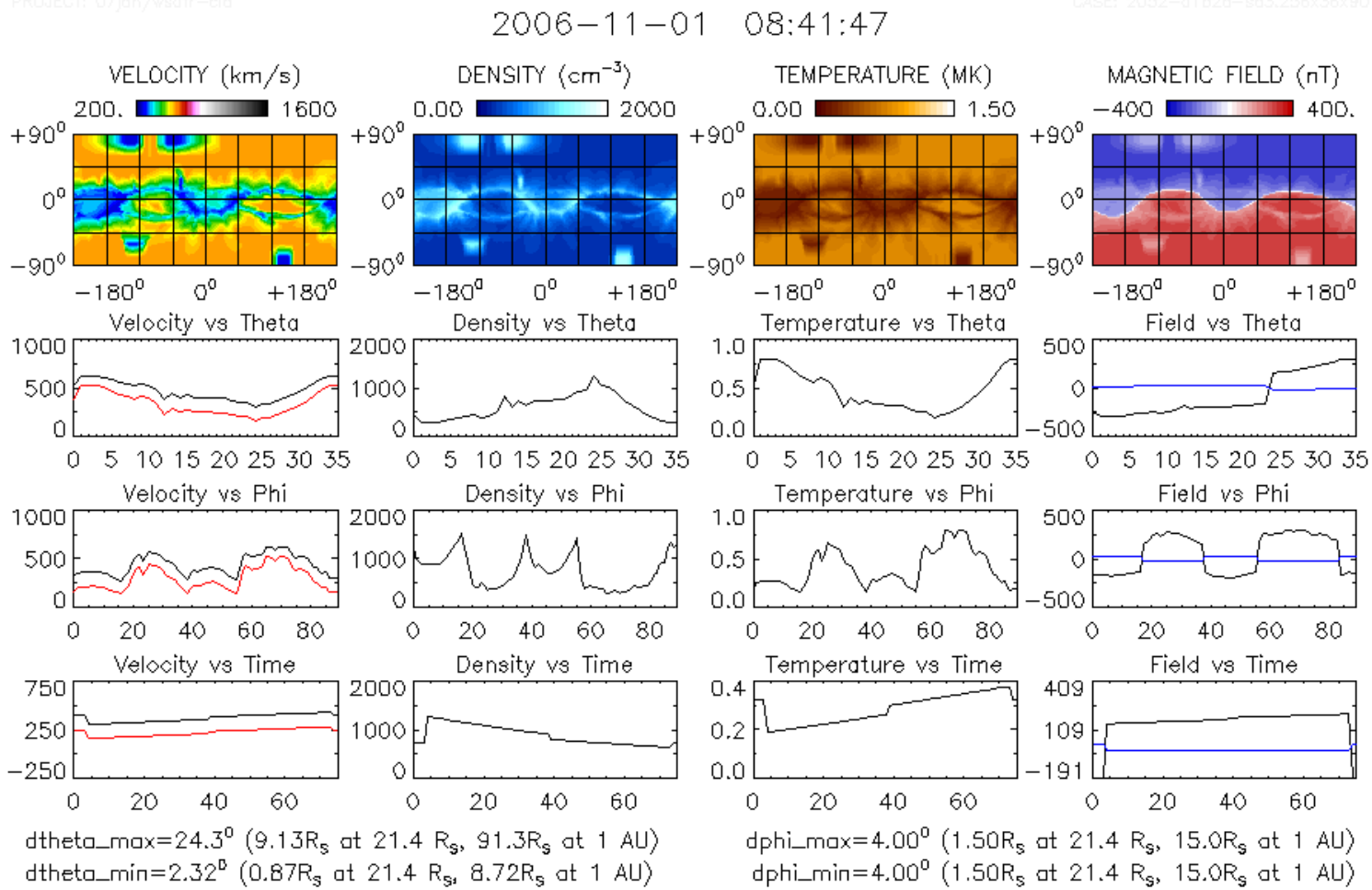




Solar wind expands: parameters at Earth depends on the coronal temperature, ratio of specific heats, and on initial speed.

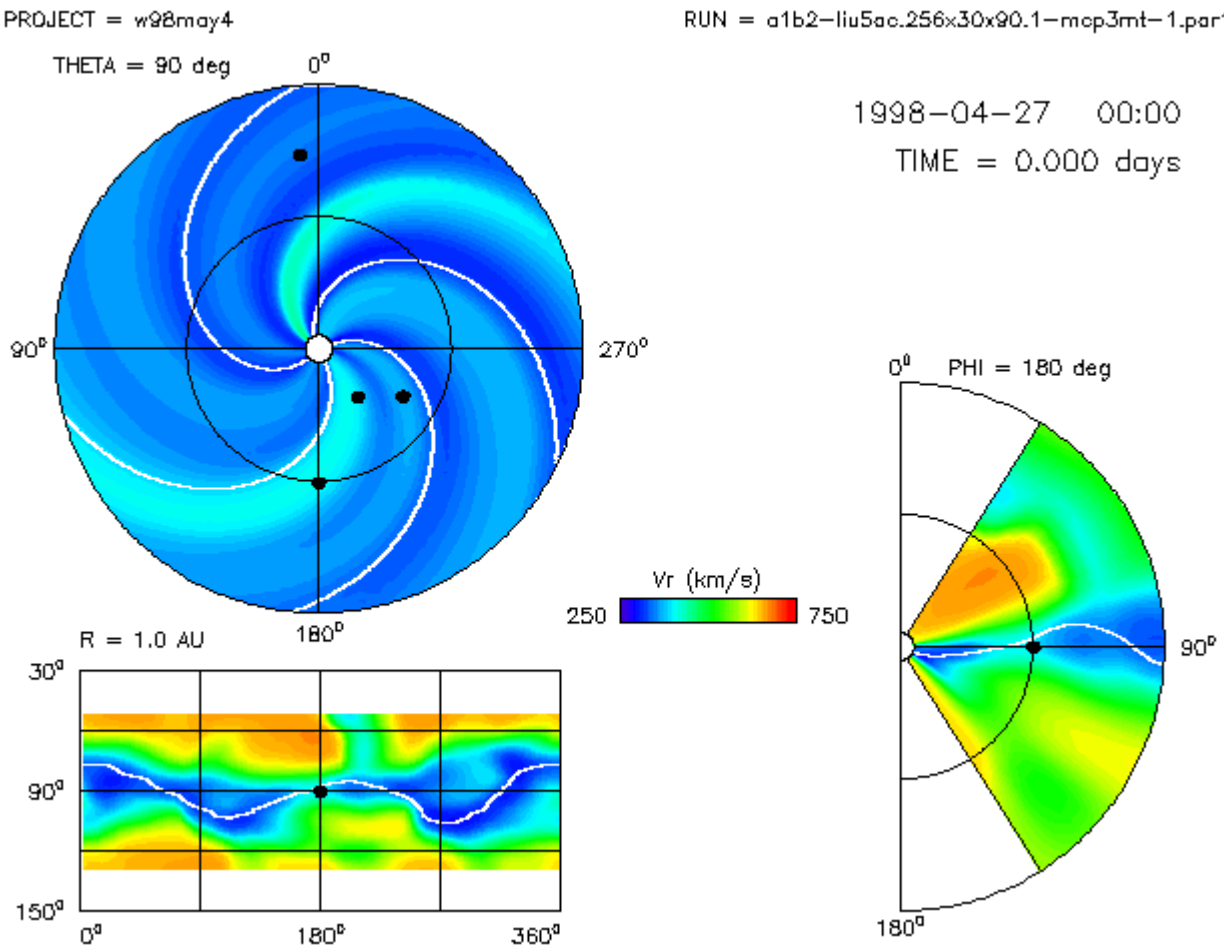
- Fast-stream solar wind proton number density (D_{fast} = 300 cm^{-3})
- Fast-stream solar wind mean temperature (T_{fast} = 1 MK)
- Ratio of specific heats ($\gamma = 1.5$)
- Ratio of alpha particles (α = 0)
- Momentum flux balance: NV^x (x = 2)
- Pressure balance (P_{the} = const)

Boundary Conditions – bnd.nc



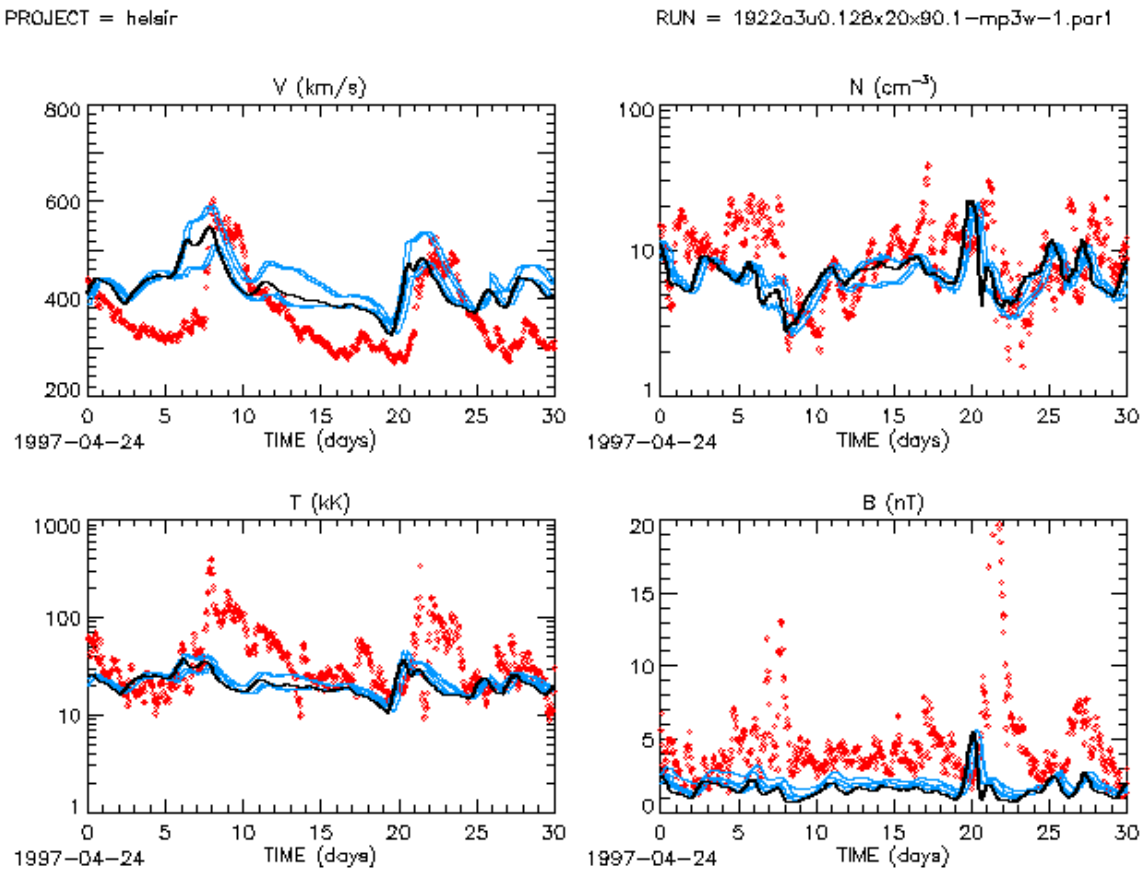
- Primary variables are shown at the inner boundary, latitudinal and longitudinal cuts intersecting the central meridian, and temporal evolution.
- Characteristic speed (red line) must be lower than the outflow speed.
- Grid spacing info is included at bottom.

3-D Values at Time Level – tim.****.nc



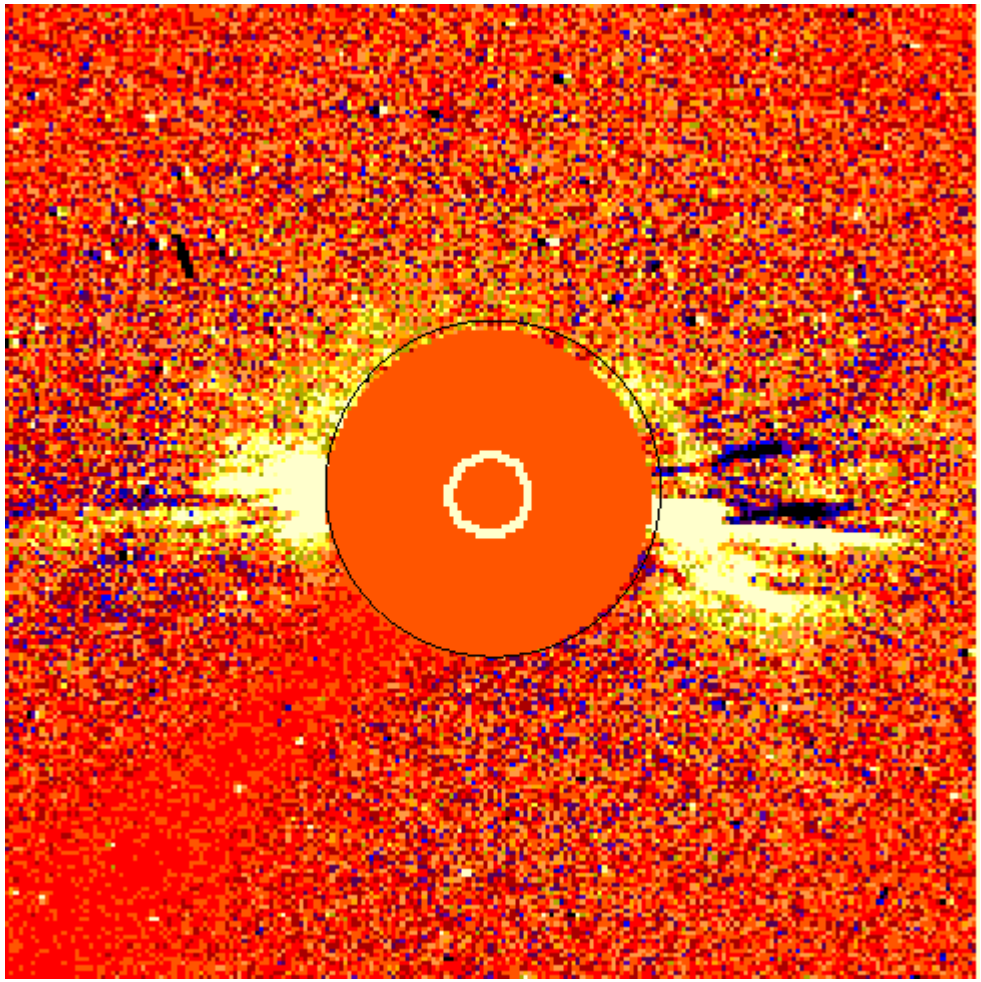
- Values are shown on various slices passing through Earth.
- Current sheet is shown by white line.
- Planet positions are shown by black spheres.
- Calendar data and physical time correspond to file record number (****).

Evolution at Geospace Positions – evg.nc



- Values are stored at Earth position (thick black line) and nearby grid points (light blue lines).
- Observations from NASA-OMNIweb are shown by red dots.
- Viewing evolution at nearby points can reveal effect of numerical resolution and can provide inclination of structures for geospace models

May 12, 1997 Halo CME

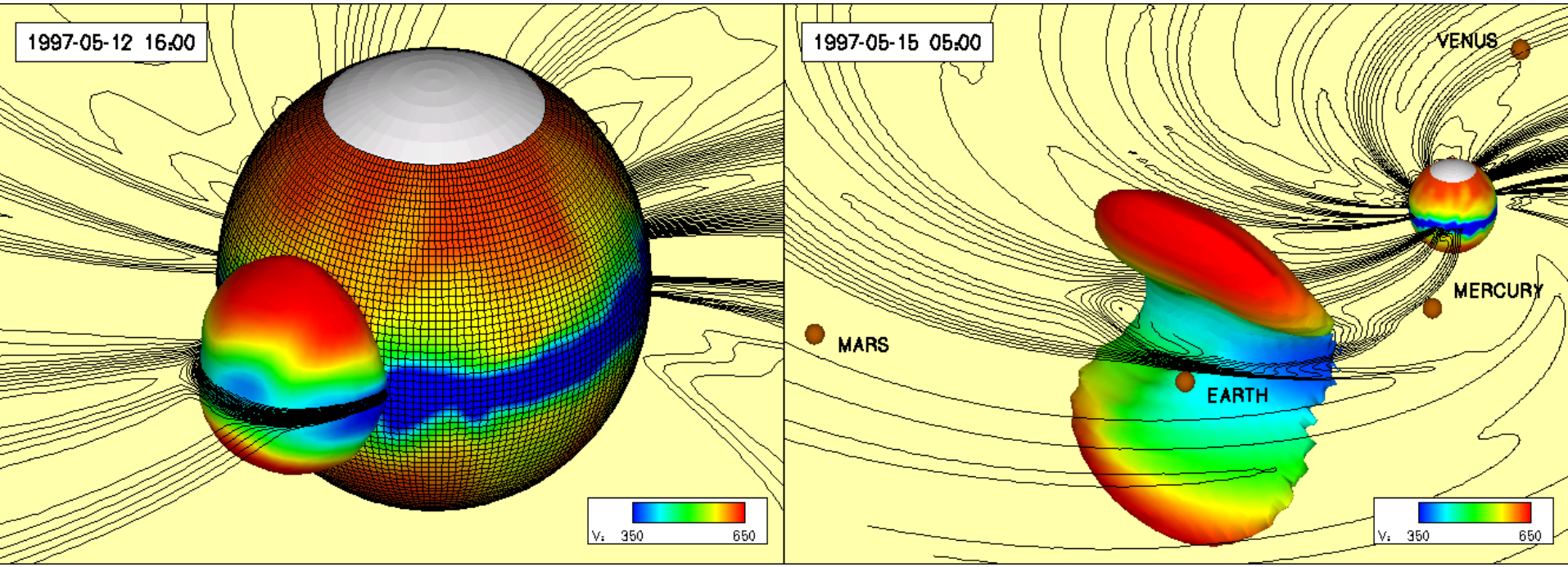


Running difference images fitted by the cone model

Verification of Cone Models

Launching of ICME

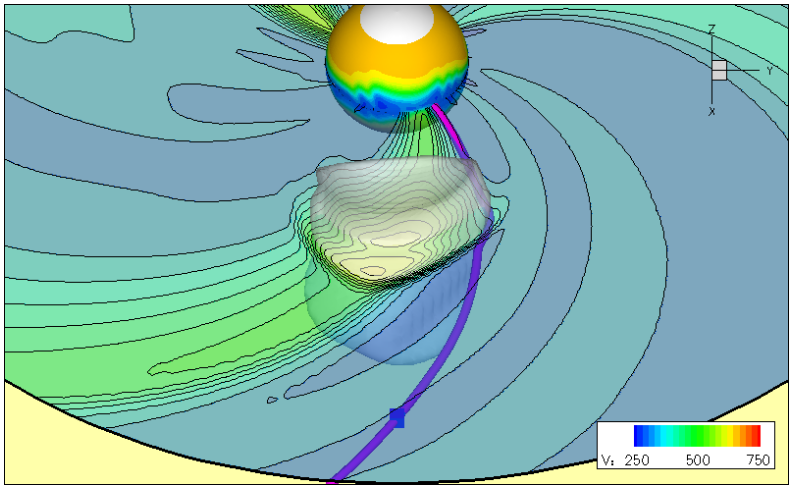
In-Situ Detection



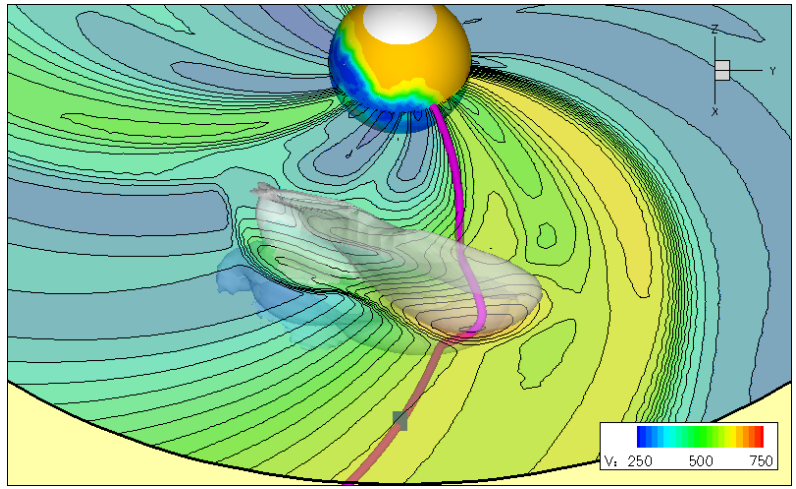
- Halo ICMEs with circular or elliptical cross-section would have similar parameters at Earth
- Multi-point observations are needed
- Suggested future STEREO observations

Application of the CME Cone Model

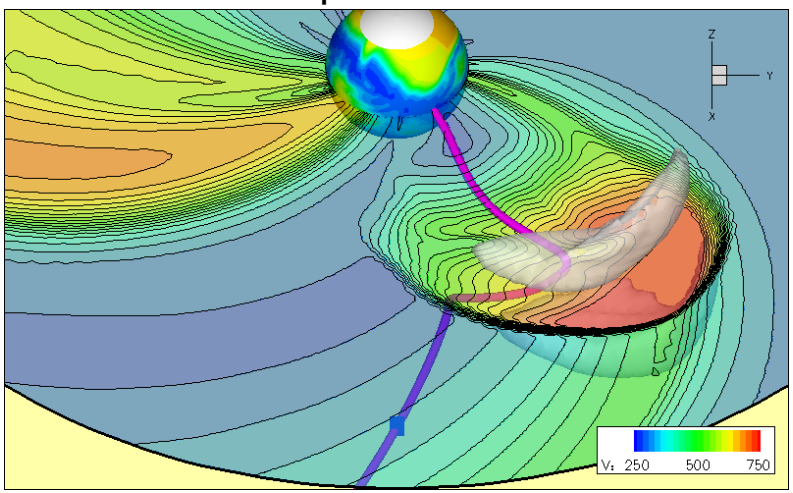
12 May 1997



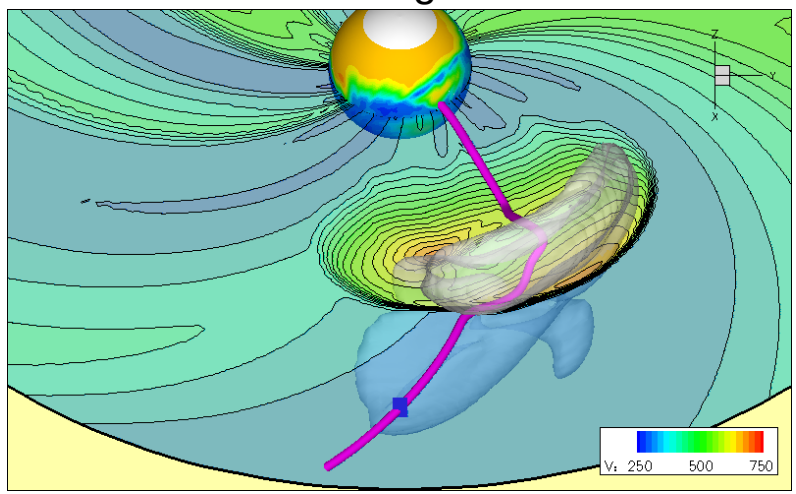
1 May 1998



21 April 2002



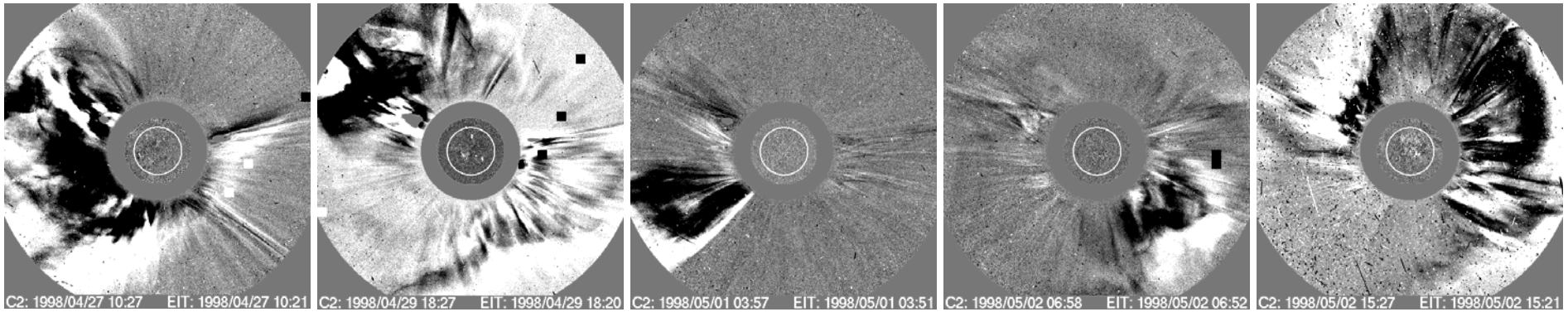
24 August 2002

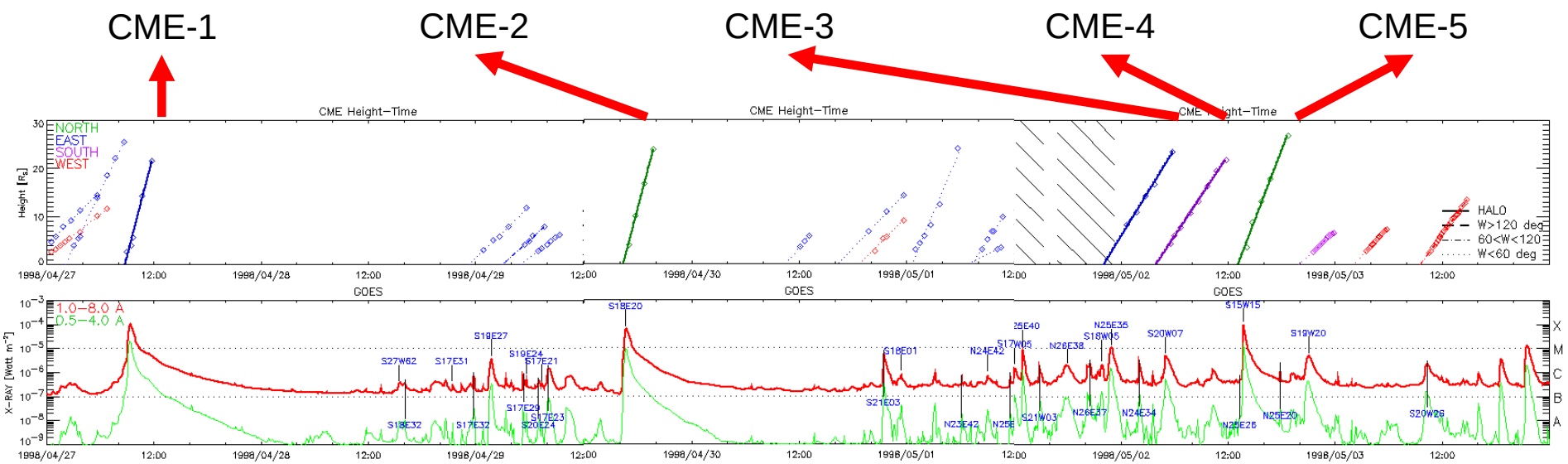


The heliospheric simulations may provide a global context of transient disturbances within a co-rotating, structured solar wind and they can serve as an intermediate solution until more sophisticated CME models become available.

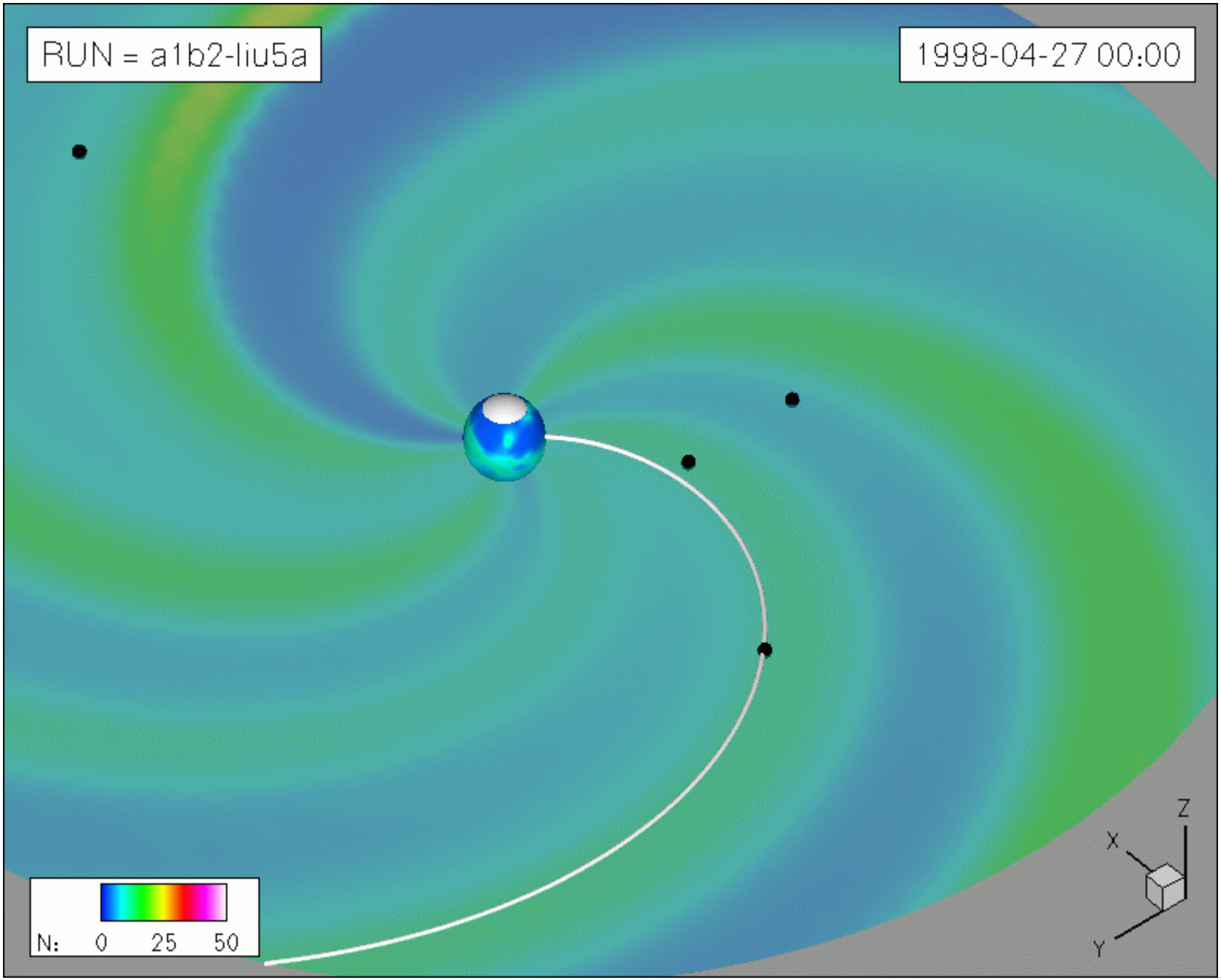
Multiple Events Challenge

http://cdaw.gsfc.nasa.gov/CME_list/

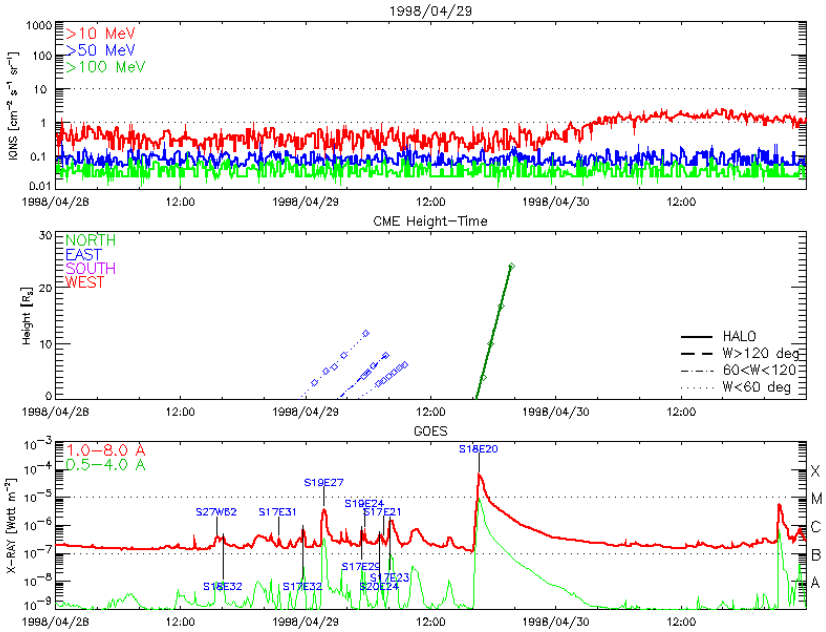


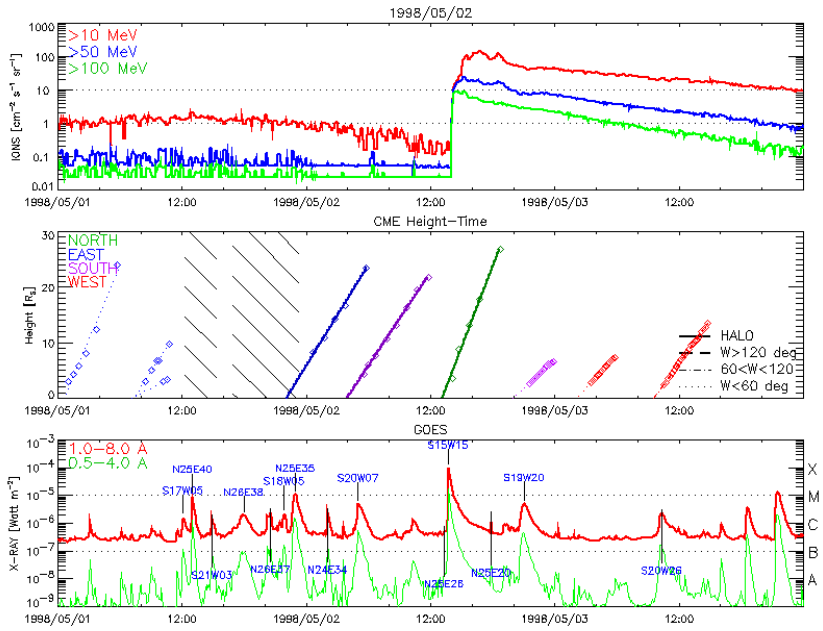


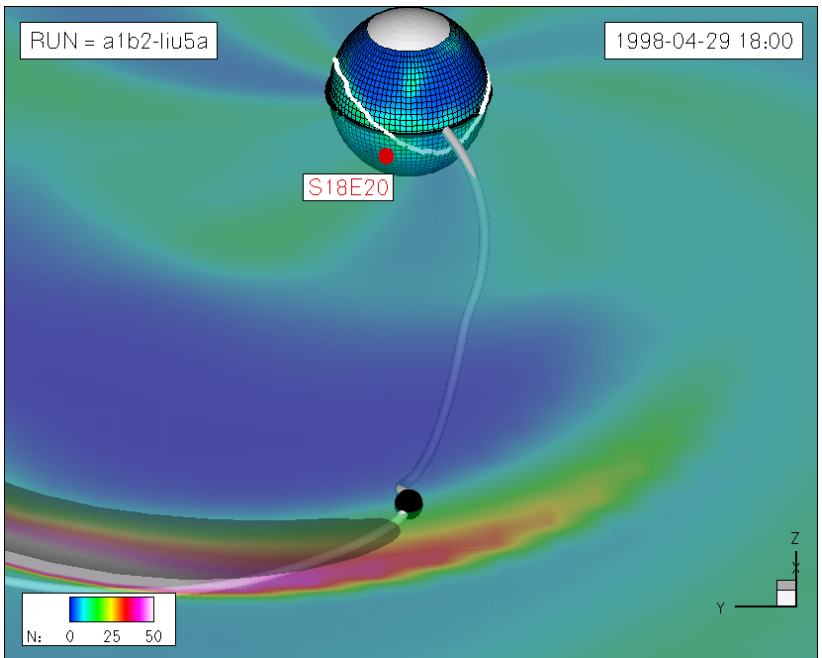
- 5 halo CMEs between April 27 and May 2, 1998
- 18 CMEs between April 27 and May 2, 1998

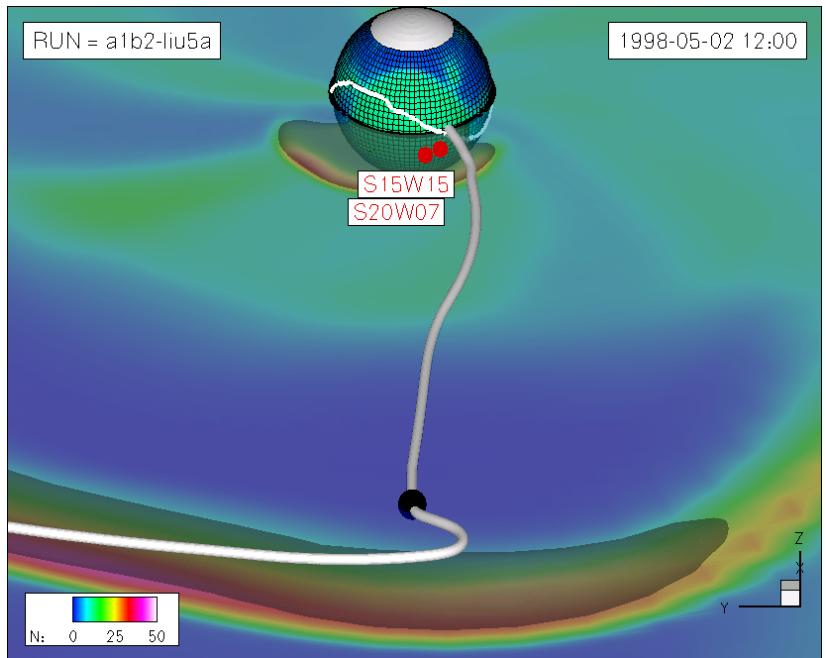

RUN = a1b2-liu5a
1998-04-27 00:00
N: 0 25 50
Z
X
Y

Connectivity of Magnetic Field Line

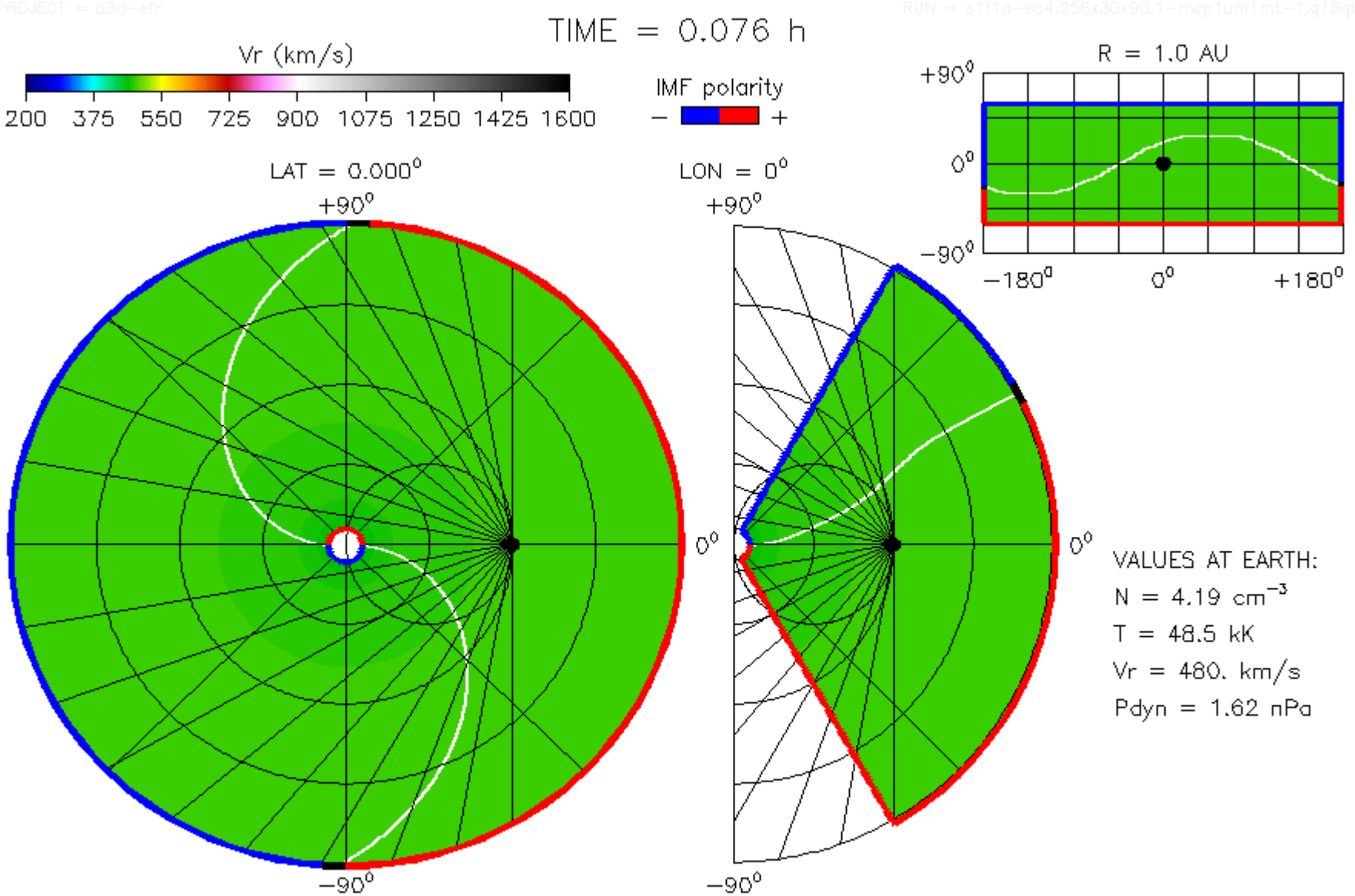






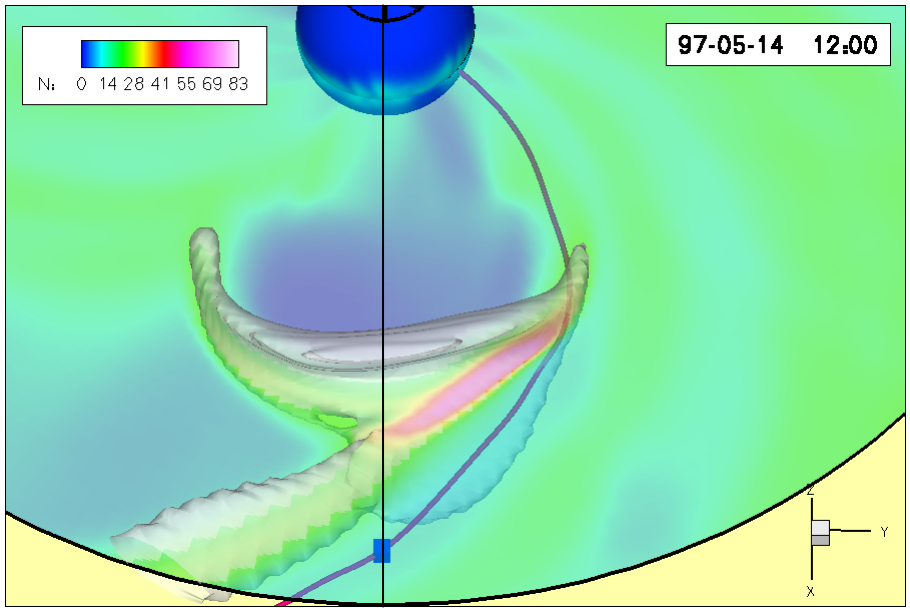


Plasma Cloud with Flux-Rope Geometry

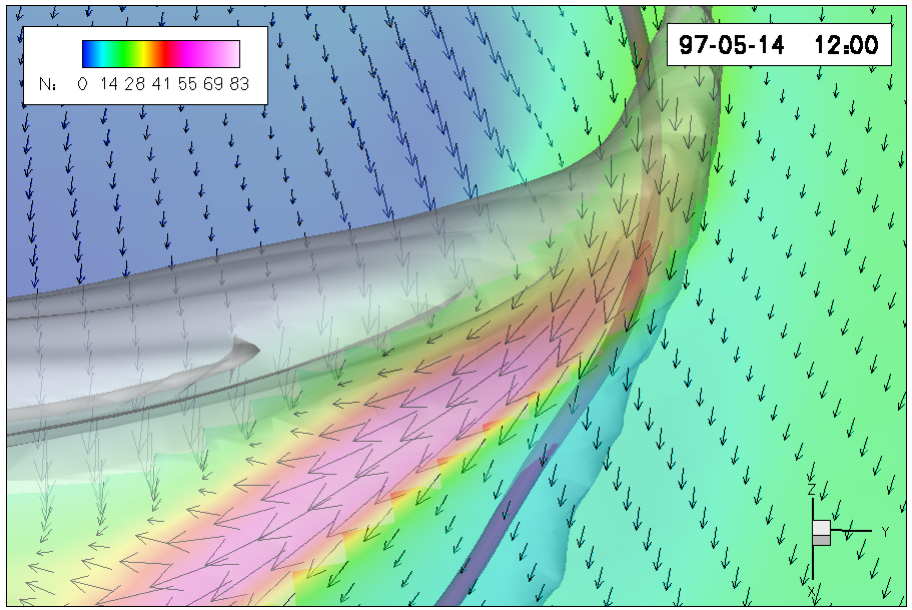


Energetic Particles & Radio Emission

Global view



Detailed view

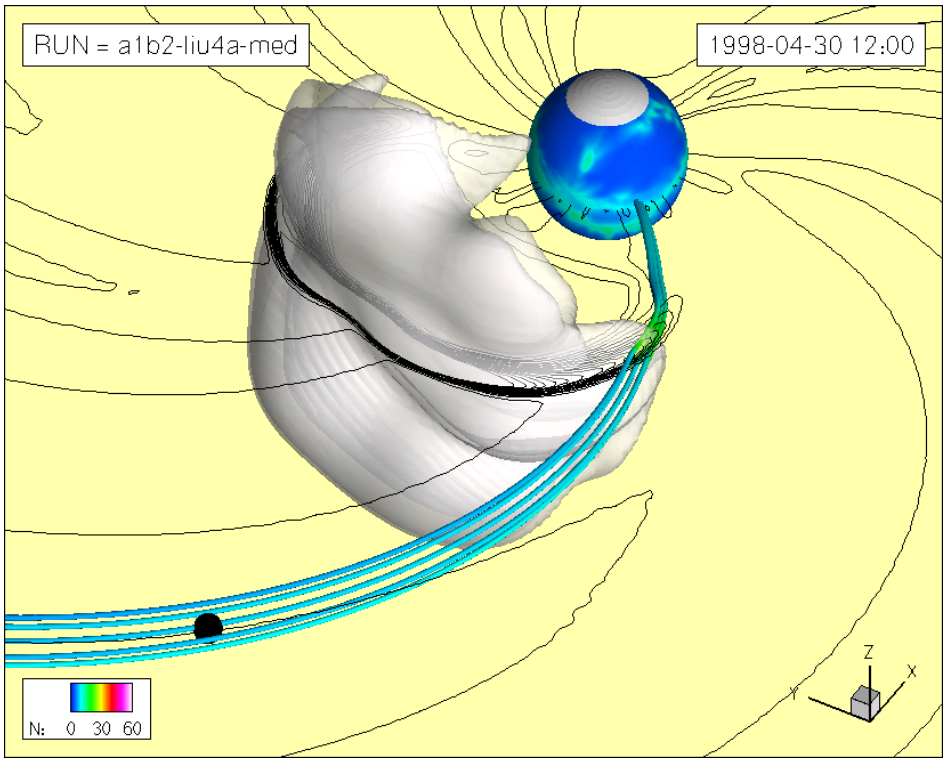


Important effect occurs away from the Sun-Earth line

Enhanced shock interaction together with quasi-perpendicular propagation relative to IMF lines favors particle acceleration and generation of radio emission

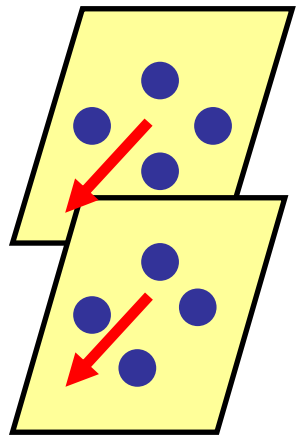
Shock Detection Challenge

Tracing Nearby IMF Lines



Four additional four IMF lines are traced from geospace, offset +/- 2^0 in latitude and longitude from the Earth location

Using 3-D Data



Shock front at $t=t_1$

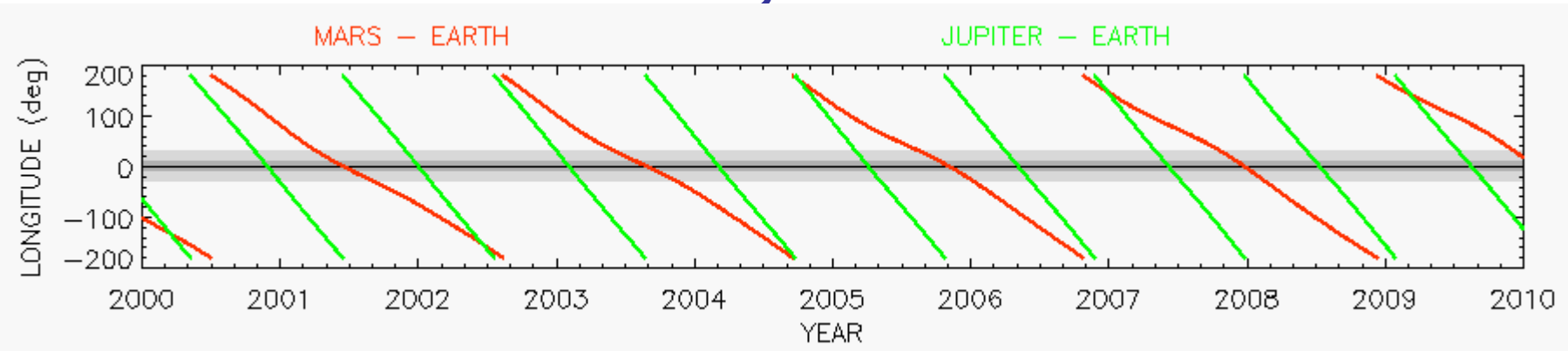
Shock front at $t=t_2$

Geometrically fitted parameters:

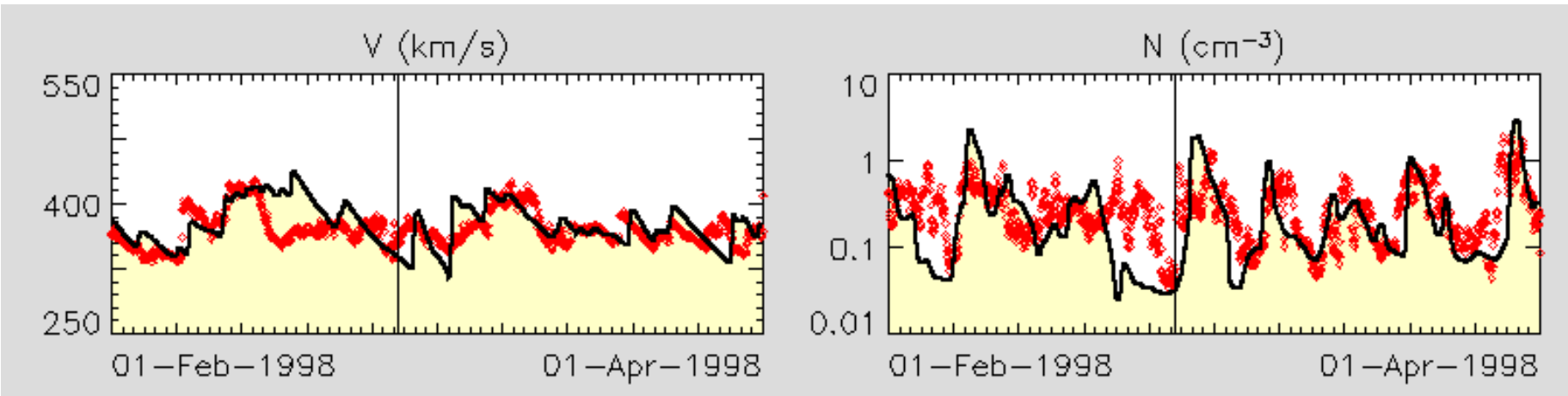
- shock inclination
- shock speed

Together with the pre-shock solar wind parameters, these enable application of the Rankine-Hugoniot formulae to determine shock jump conditions

Predictions Driven by In-Situ Observations



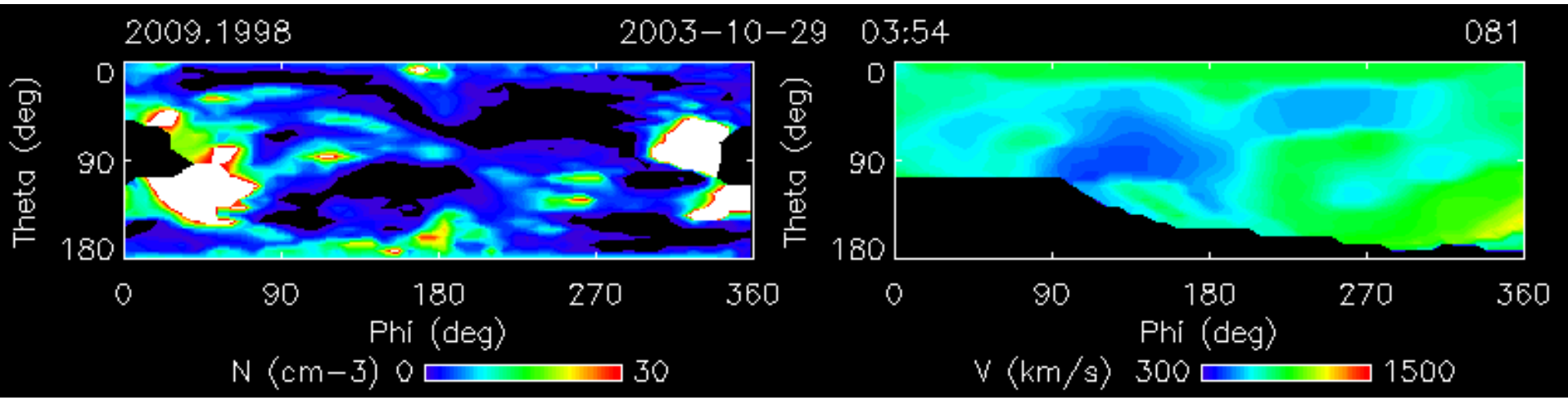
- Heliospheric computations can be driven by accurate in-situ observations of solar wind parameters
- This approach can be strictly applied only during times of radial alignment, and potentially important 3-D interactions are not accounted for



Prediction of the solar wind flow velocity (left) and proton number density (right) at Ulysses. Red dots show observations by Ulysses and a solid line shows results from 1-D MHD simulations driven by values observed at Earth.

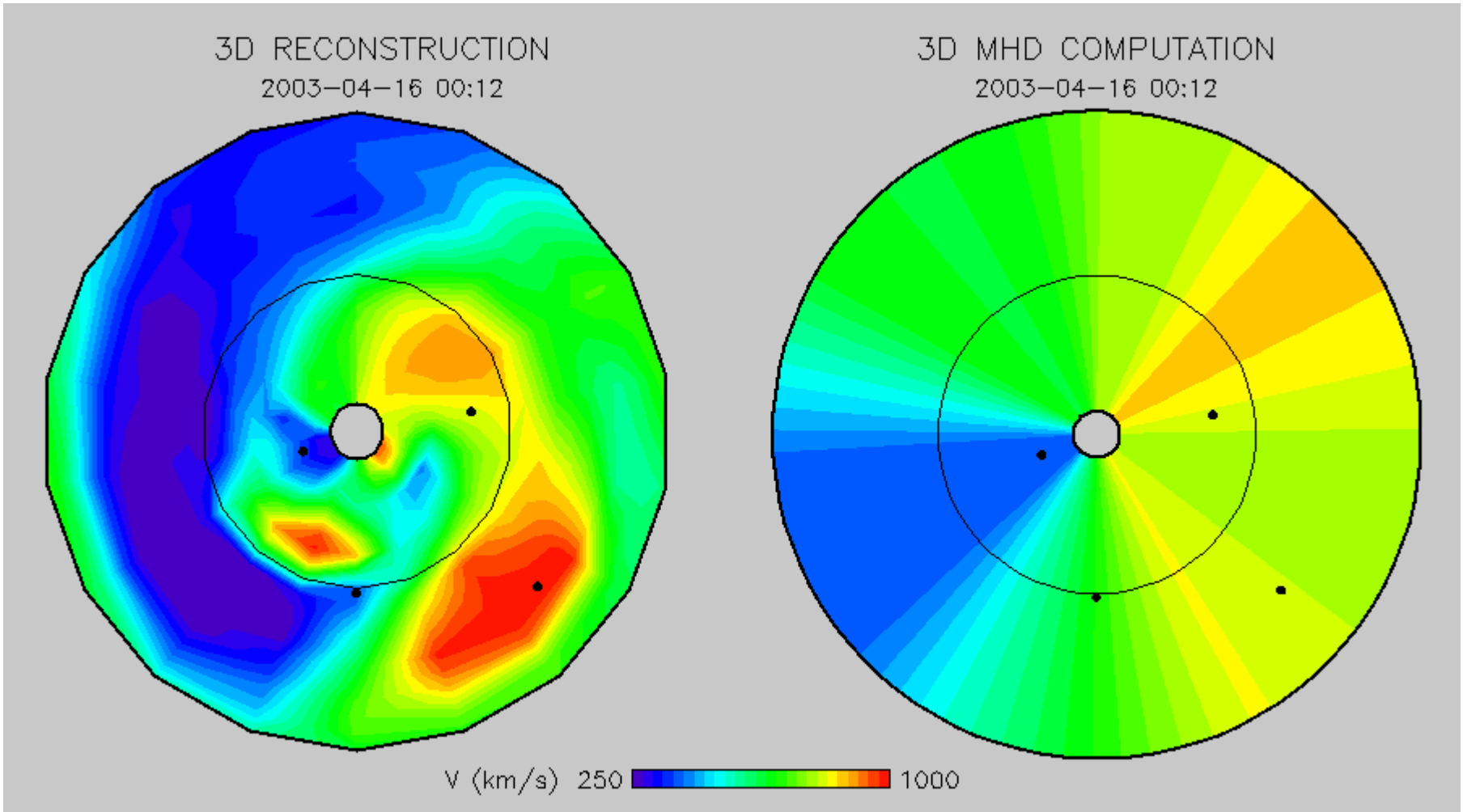
Utilization of IPS and SMEI Observations

Numerical 3-D MHD model requires reconstruction of the density and velocity across the whole inner boundary and specification of the temperature and magnetic field



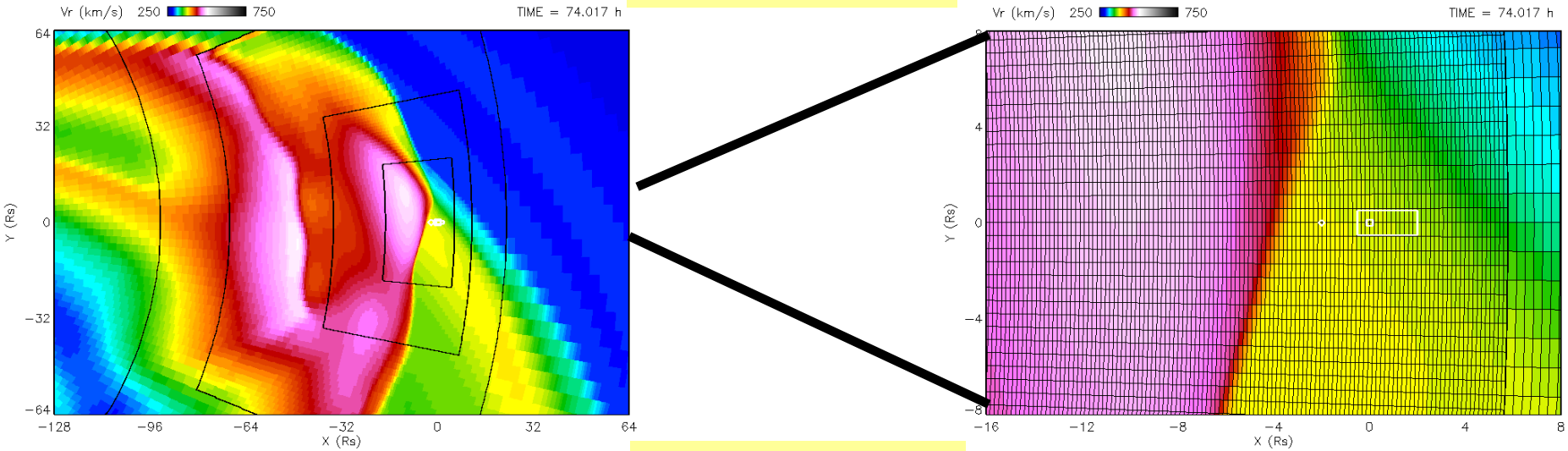
- Distribution of solar wind density (left) and velocity (right) at 35 Rs as extracted from the heliospheric tomography model.
- Black areas show missing values and white areas show values out of range

UCSD/IPS-Kinematic & UCSD/IPS-ENLIL

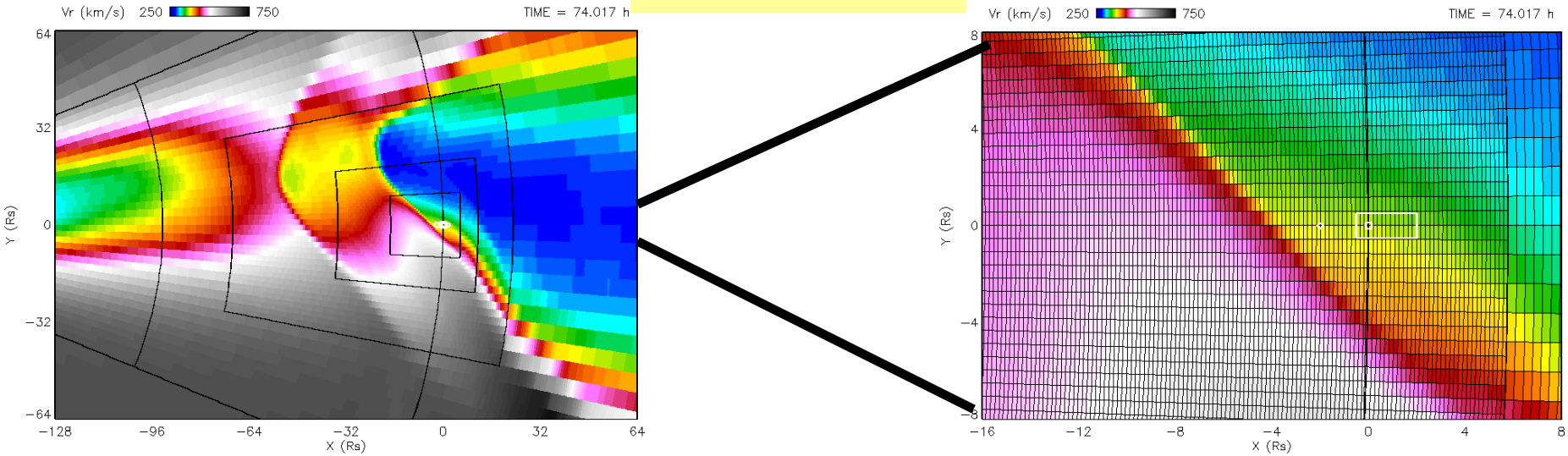


Fine Resolution of Interplanetary Shocks at Geospace by Nested Grids

Equatorial Plane

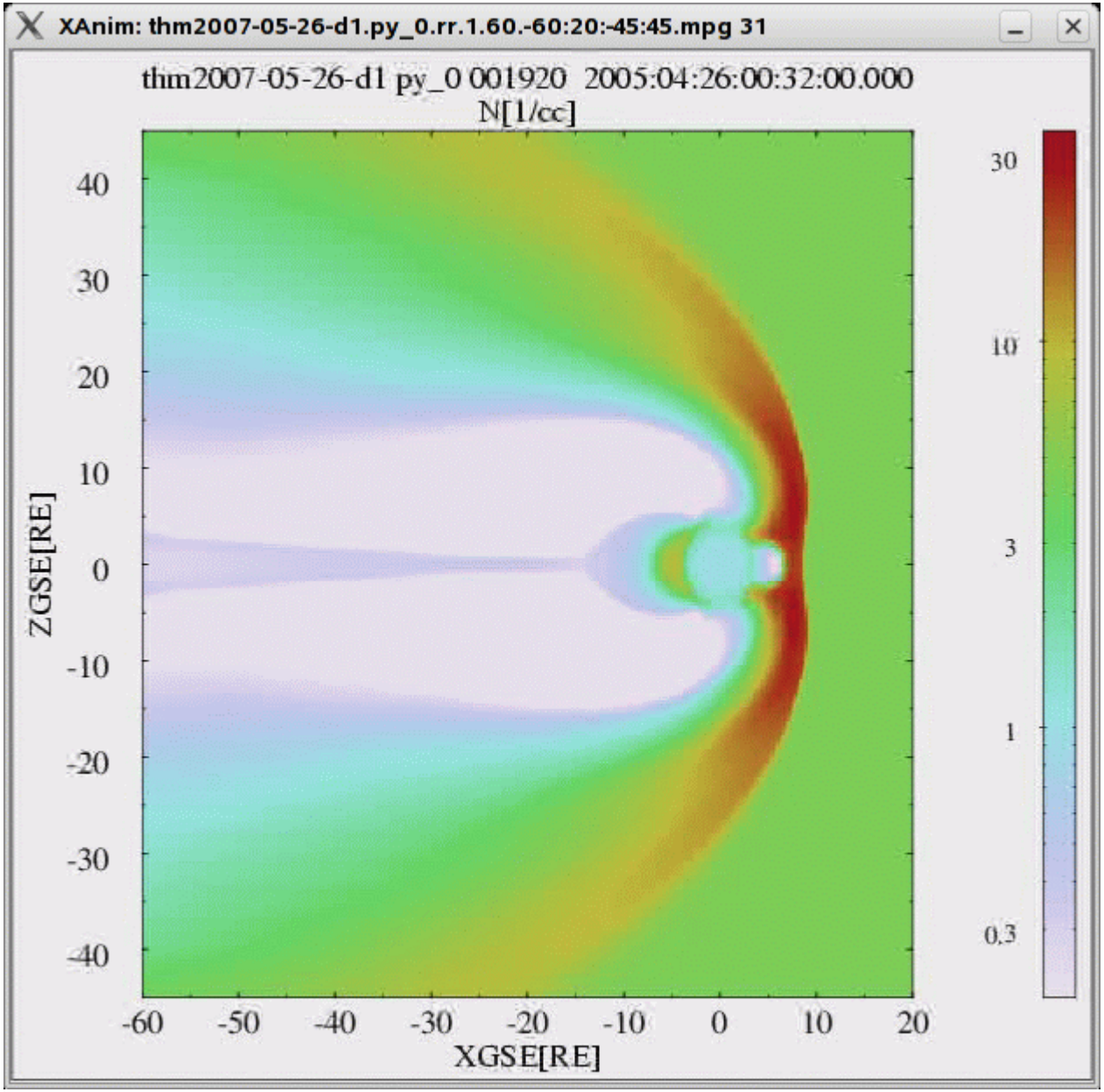


Meridional Plane



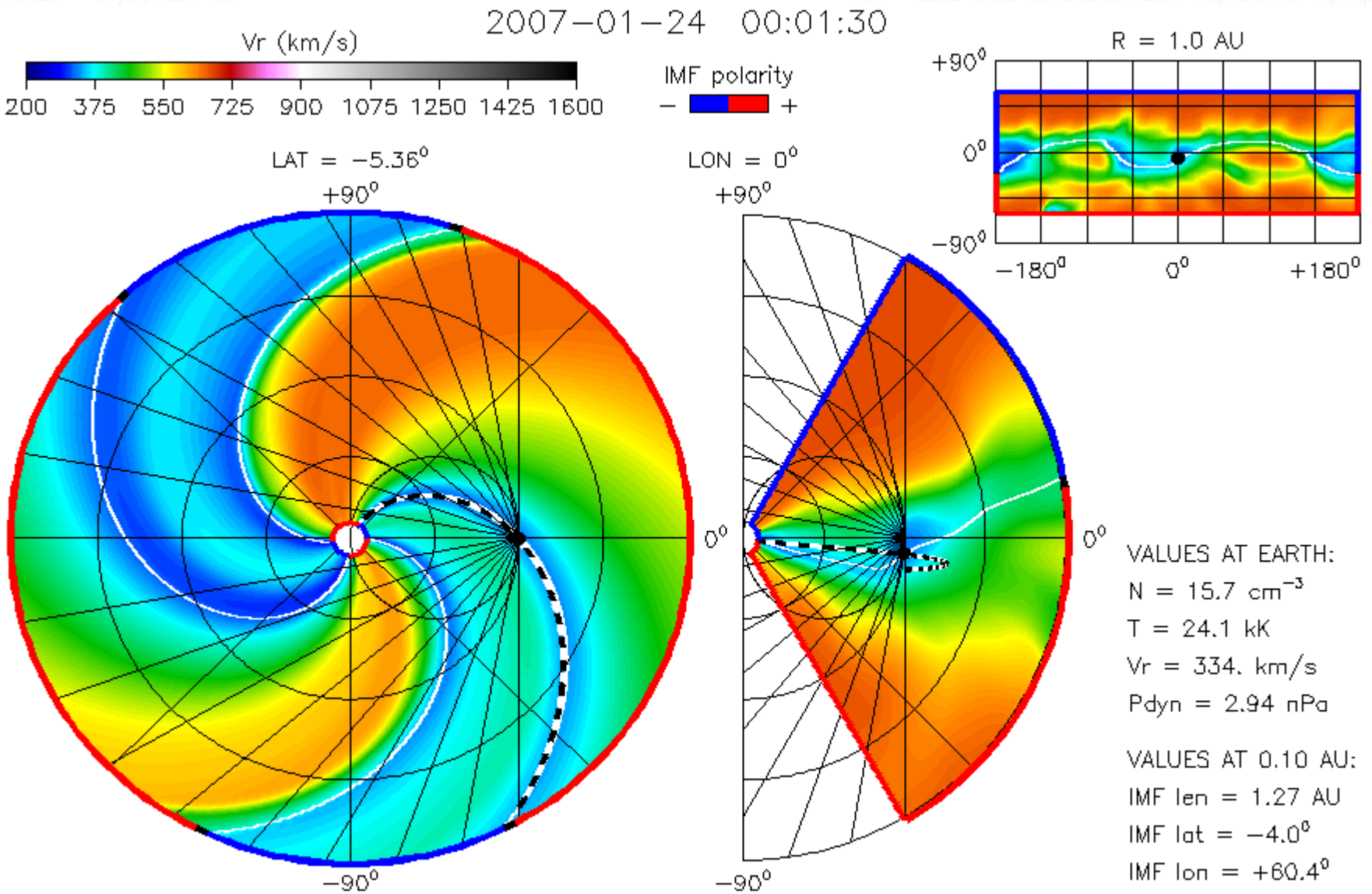
Shock Interaction with Magnetosphere

Driving OpenGGCM (Raeder and Kaghashvili) by ENLIL with nested grids

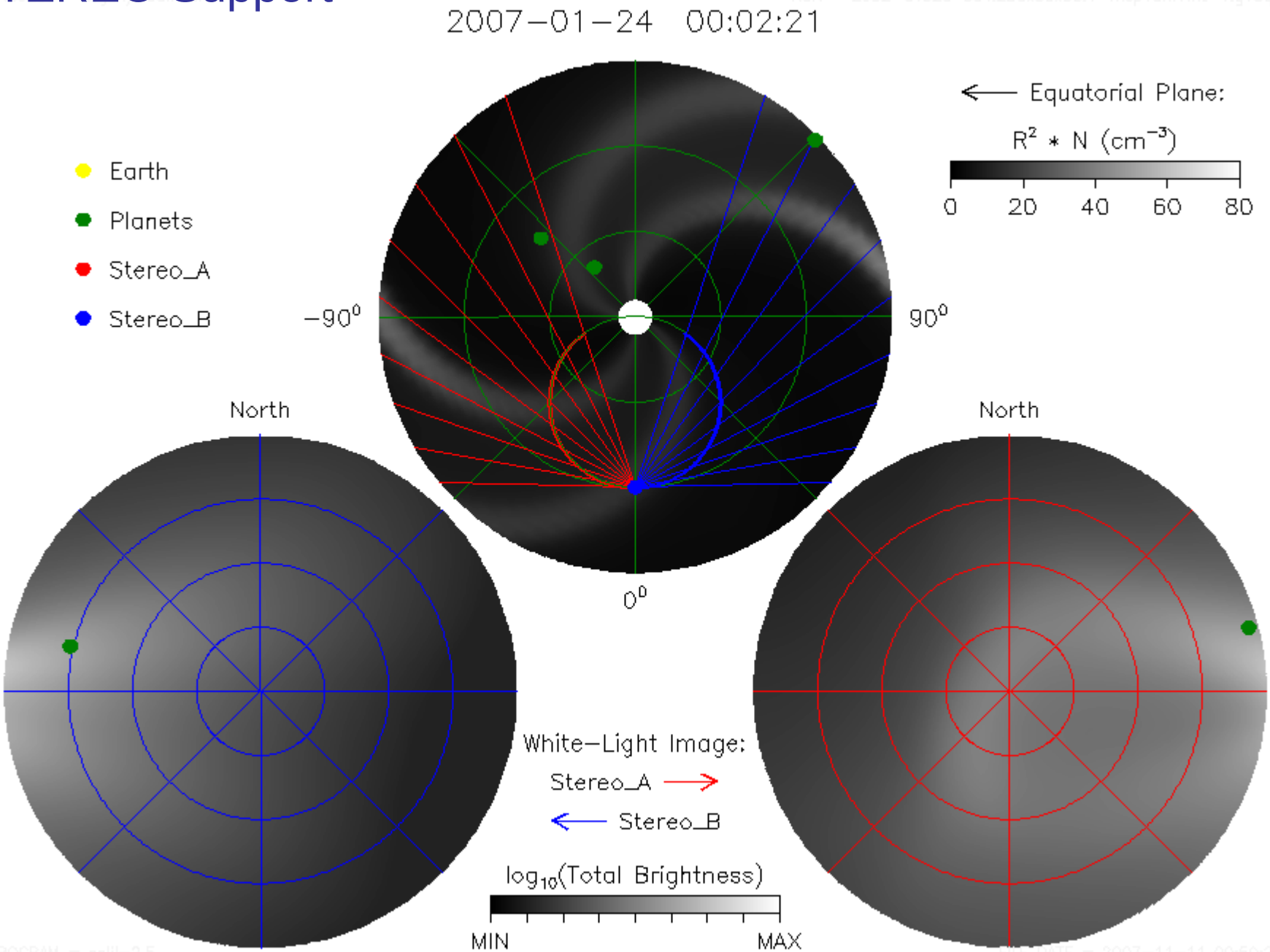


CME-1: 2005-01-24T18:18, S05W90, Φ=100⁰, V=700 km/s

CME-2: 2005-01-25T08:42, S05W80, Φ=120⁰, V=1000 km/s



STEREO Support



Plans for the Future

- Improved web interface and documentations
- Example run with default parameters
- Compatible metadata; VxO?
- User-provided plug-ins?
- Improved STEREO support
- IPS/SMEI tomography data
- Coupling with SEP model
- Improved numerical resolution and robustness
- Coupling with improved MAS model
- Coupling with geospace models