

Modeling and Forecasting the Solar Wind

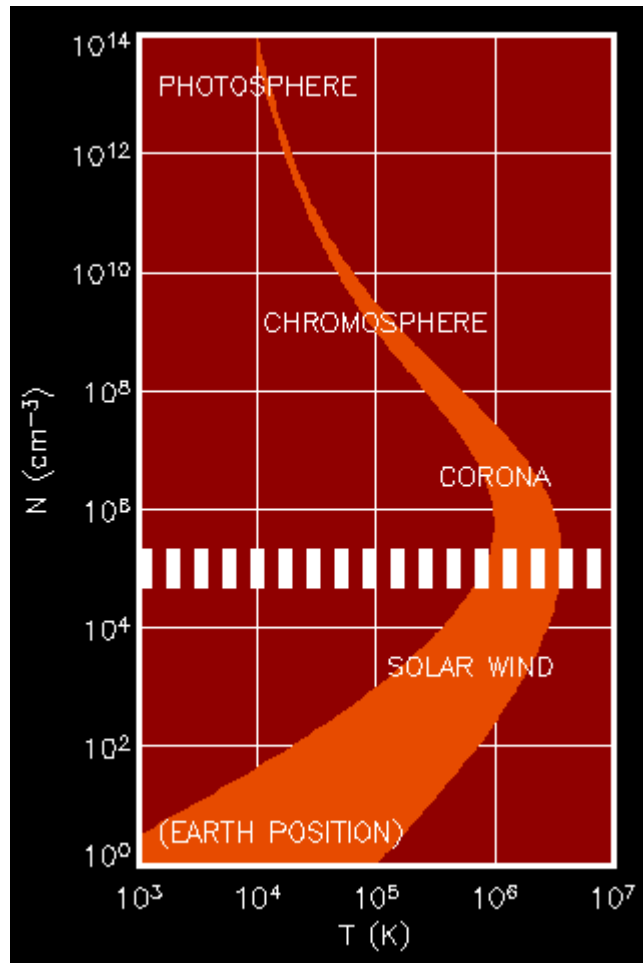
D. Odstrcil

University of Colorado & NOAA/Space Weather Prediction center

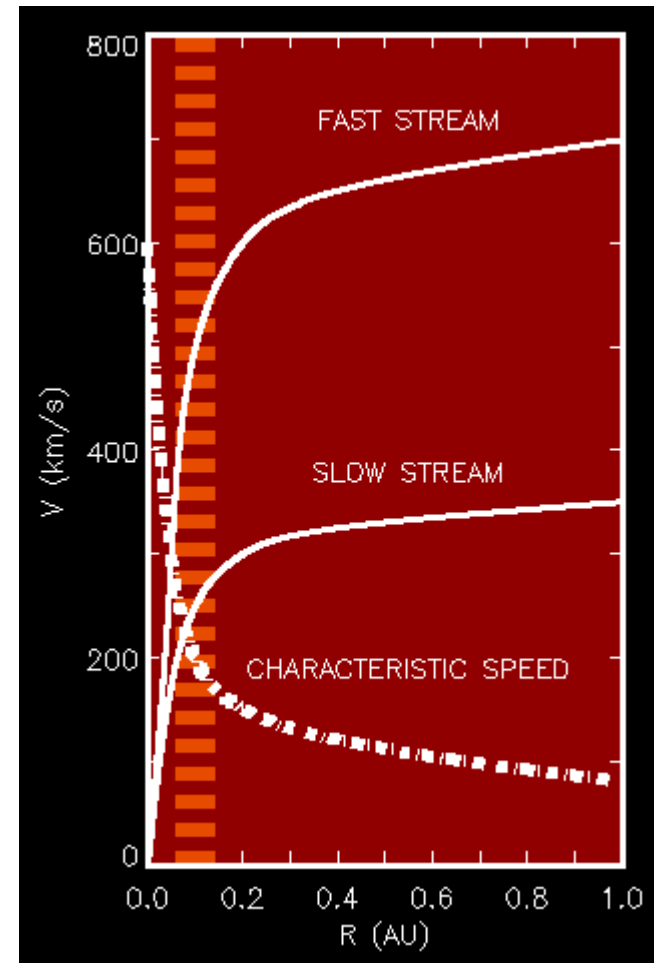


SVECSE 2008, Bozeman, MT, June 1-6, 2008

Solar Wind Plasma Parameters



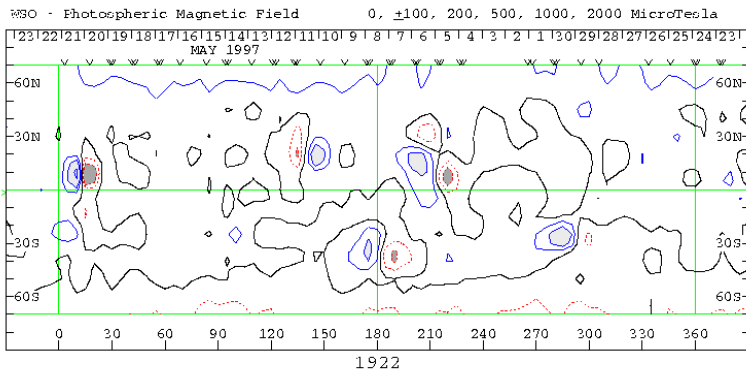
Large variations in plasma parameters between the Sun and Earth; different regions involve different processes and phenomena



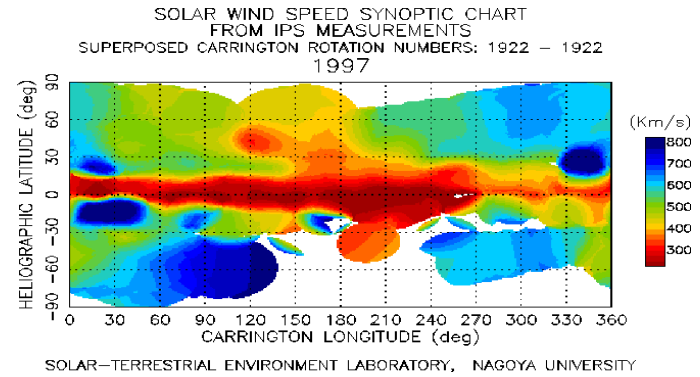
We distinguish between the coronal and heliospheric regions with an interface located in the super-critical flow region (usually 18-30 R_s)

Remote and In-Situ Observations

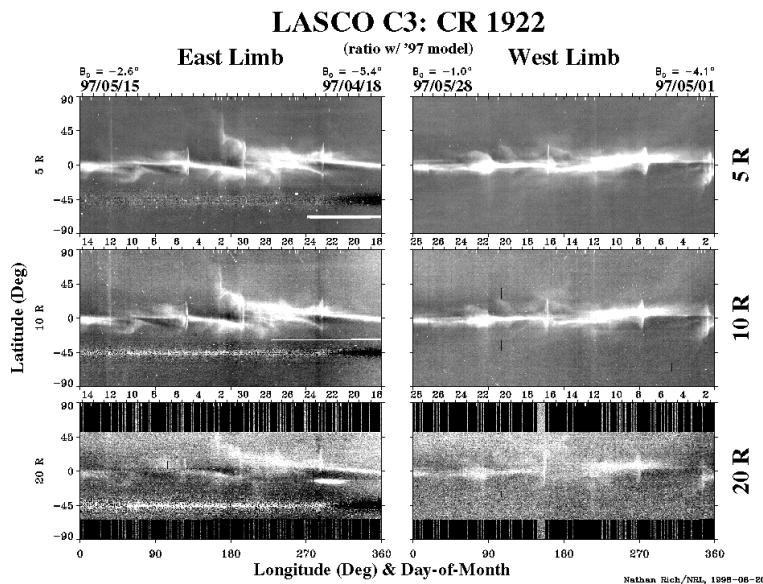
Photospheric magnetic field



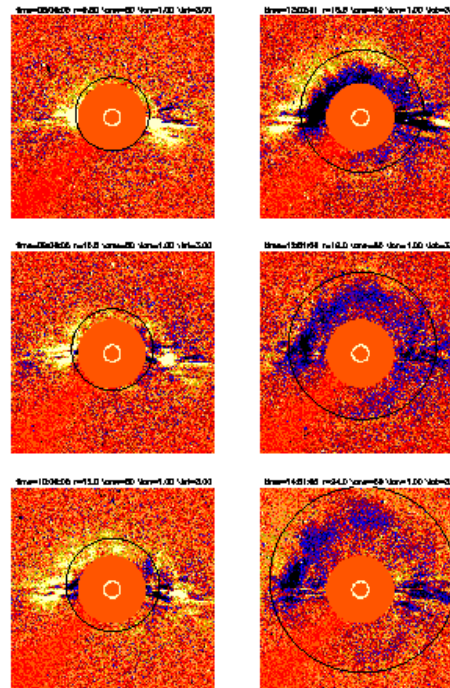
IPS Observations



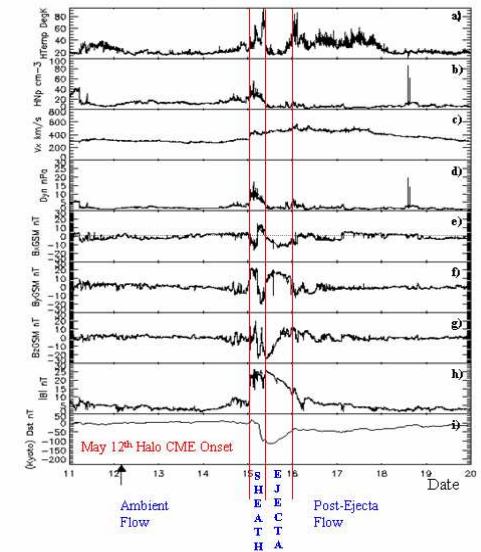
Coronal density at limbs



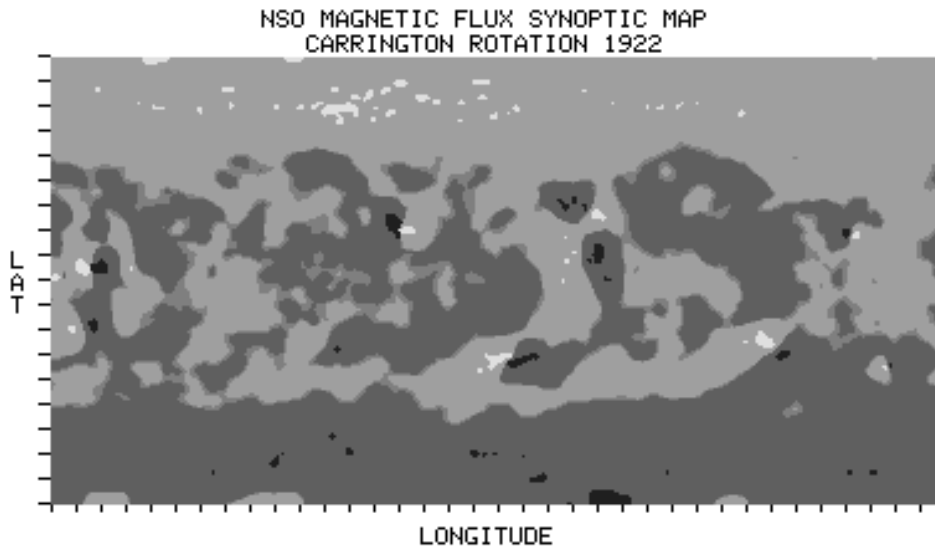
Halo-CME



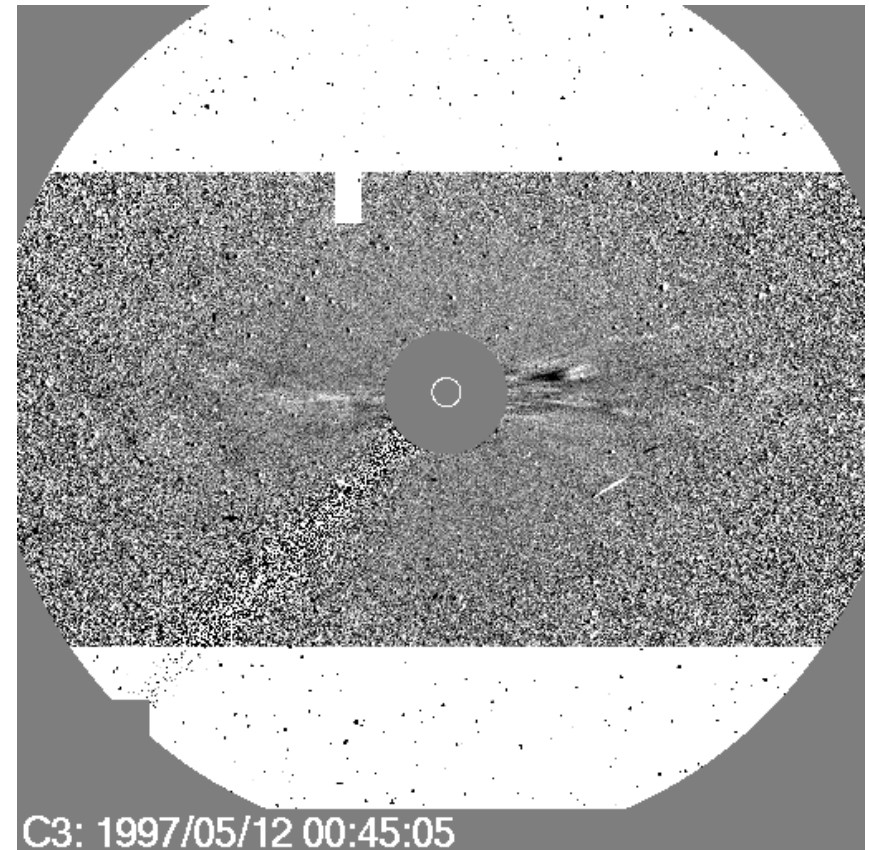
Parameters at Earth



Initialization of Numerical Models

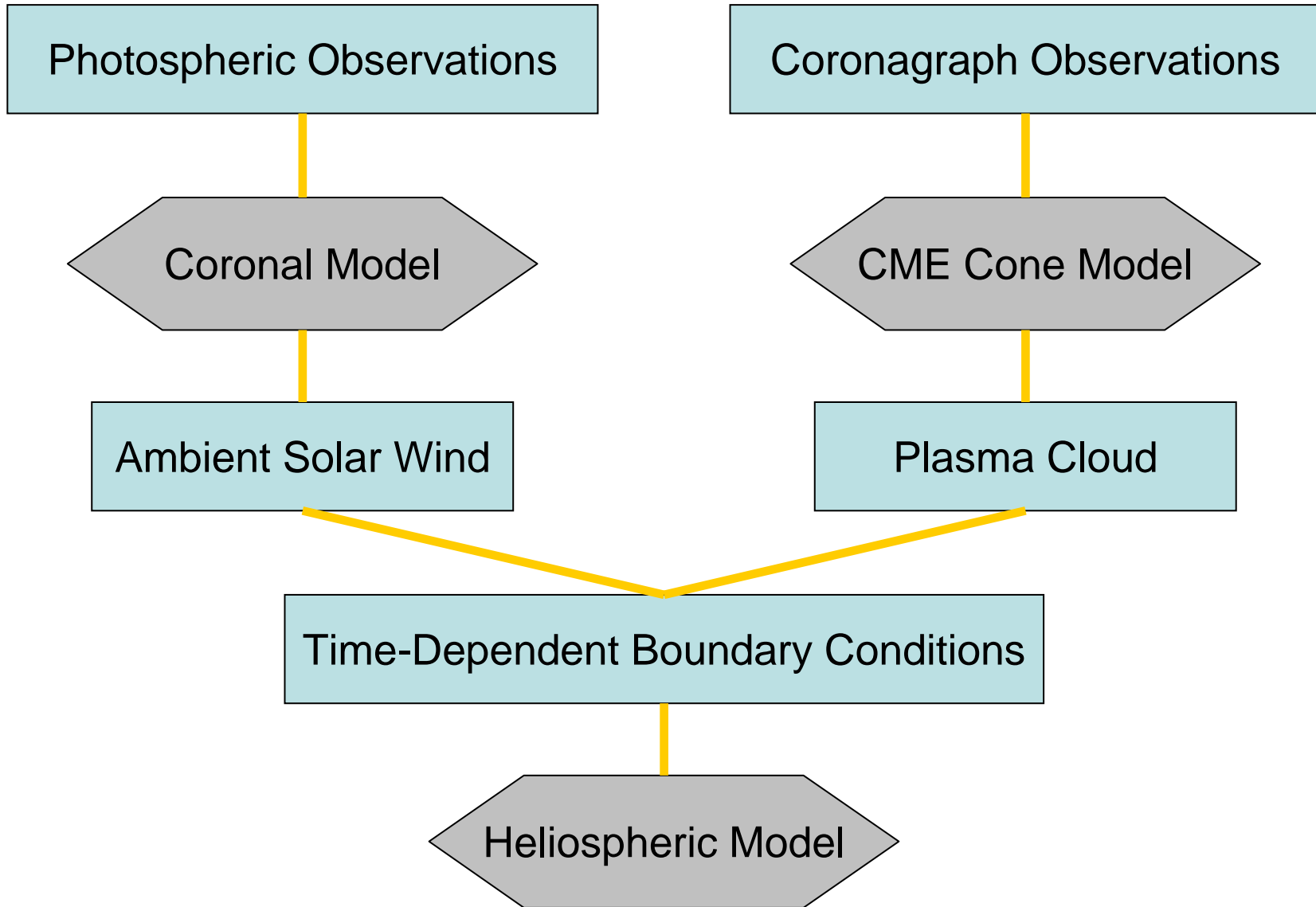


Remote solar observations of the photospheric magnetic field

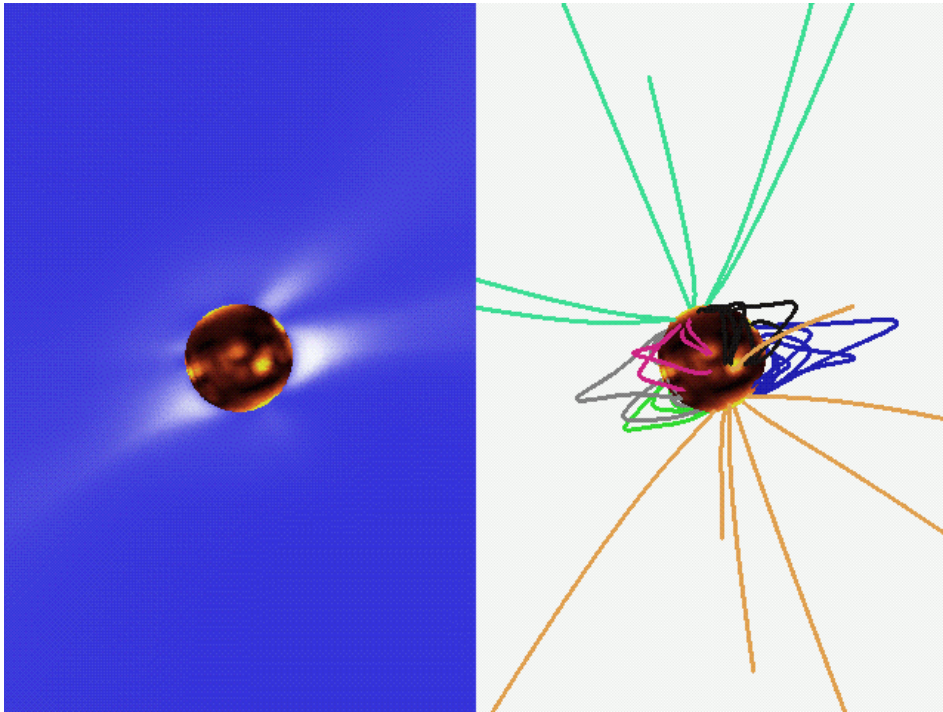


Remote coronal observations of the white-light scattered on density structures

Specifying the Boundary Conditions

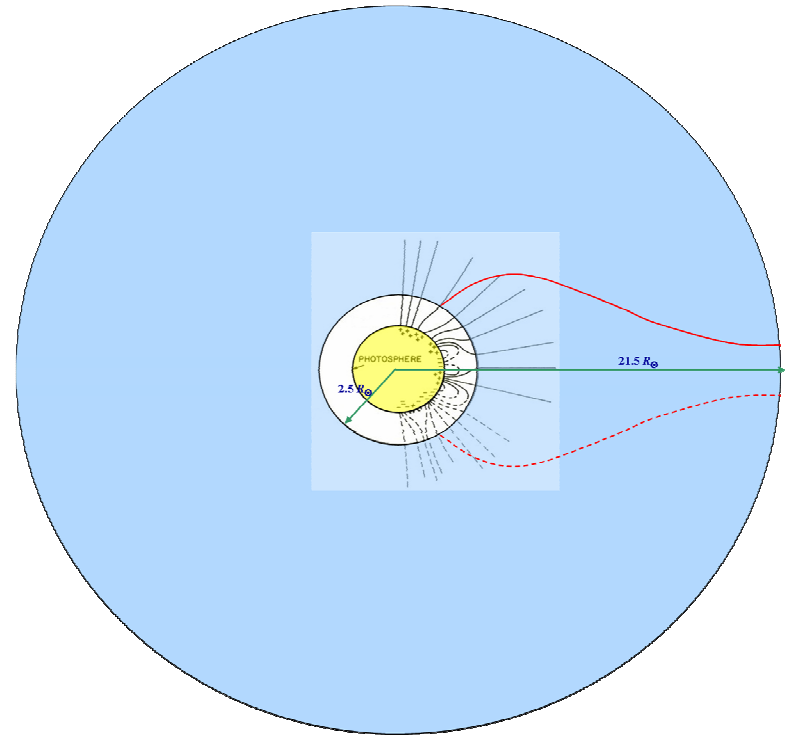


Ambient Solar Wind Models



SAIC 3-D MHD steady state coronal model based on photospheric field maps

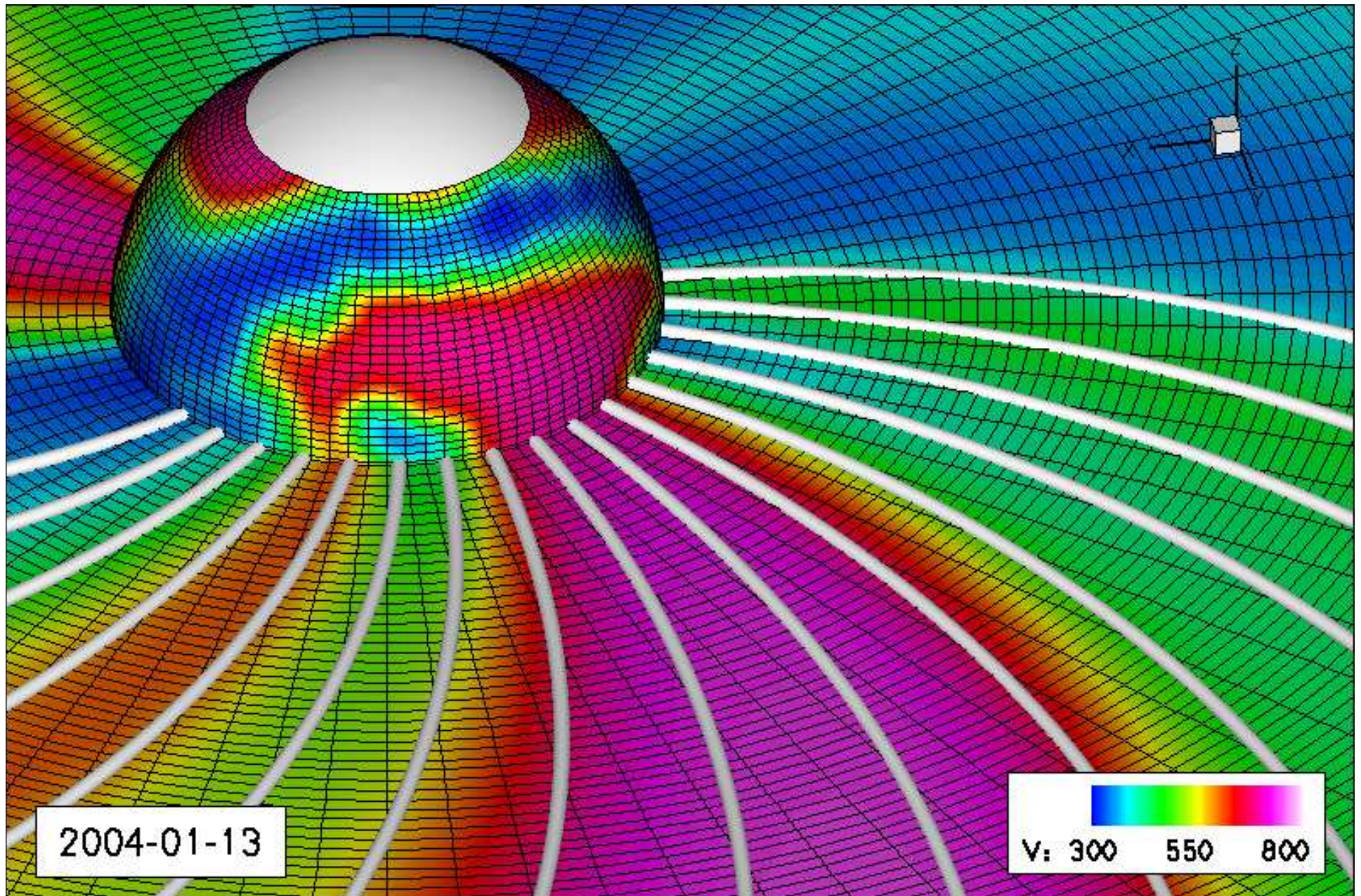
[SAIC maps – Pete Riley]



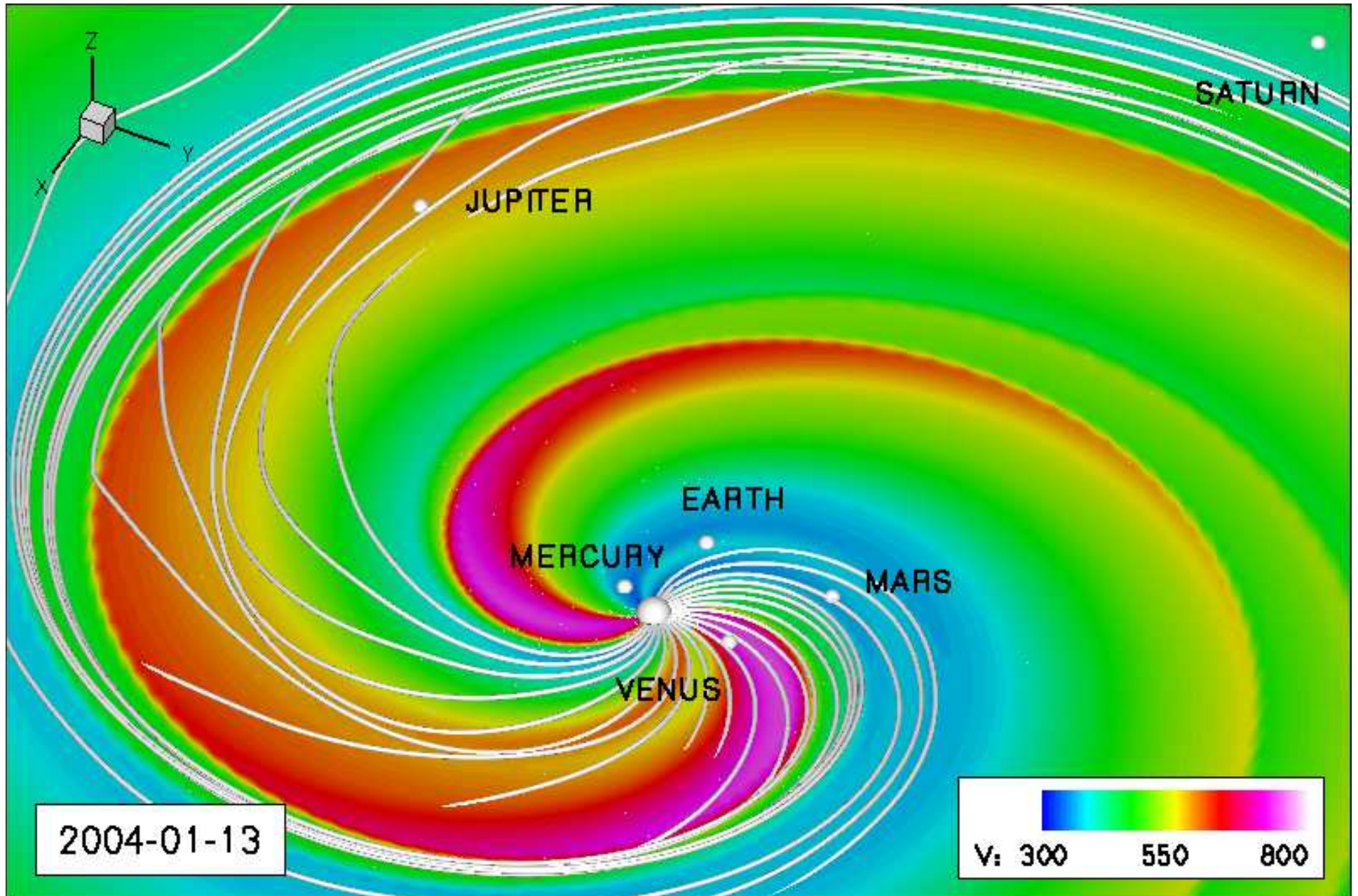
CU/CIRES-NOAA/SEC 3-D solar wind model based on potential and current-sheet source surface empirical models

[WSA maps – Nick Arge]

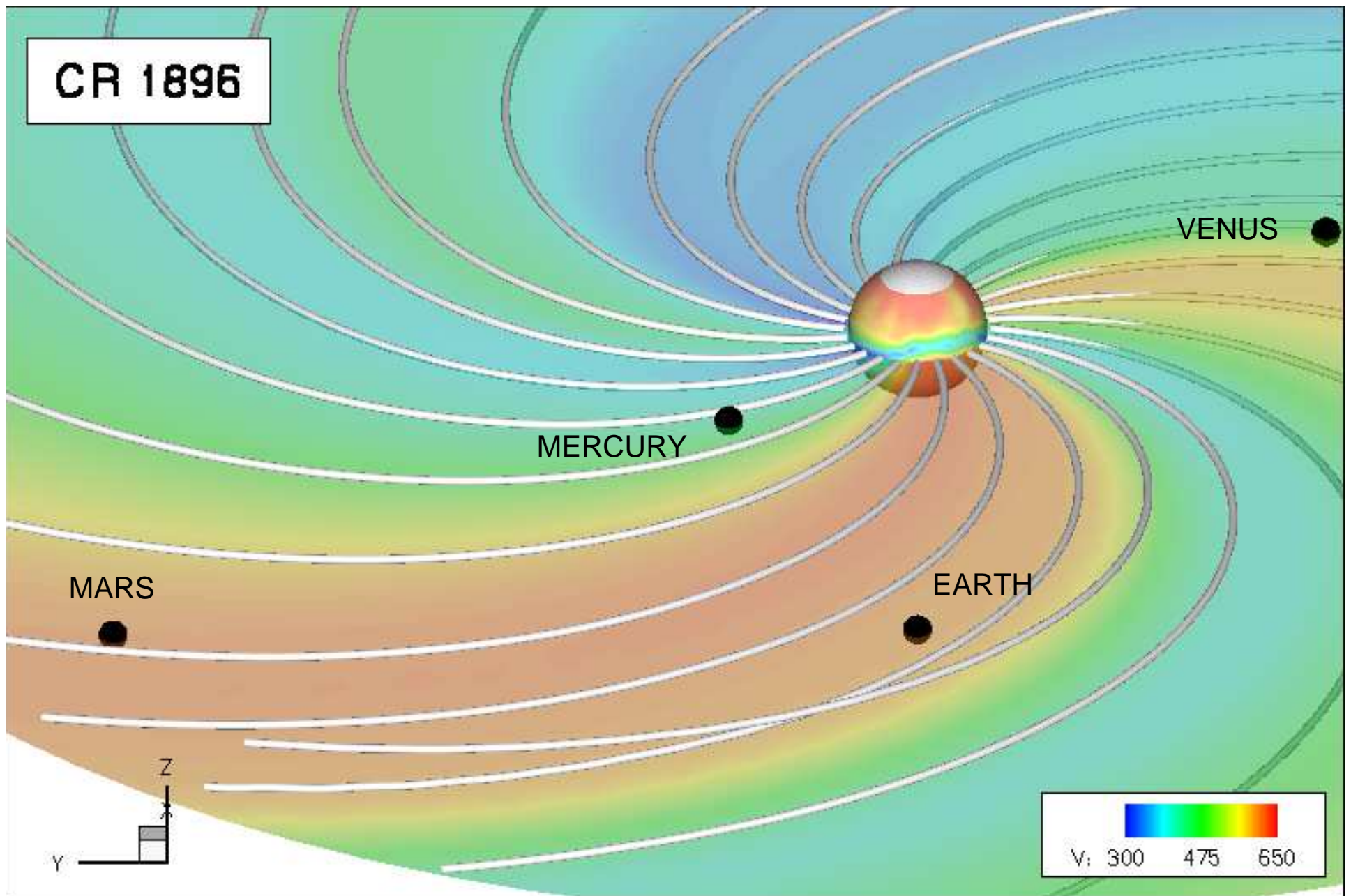
Solar Wind at Inner Boundary



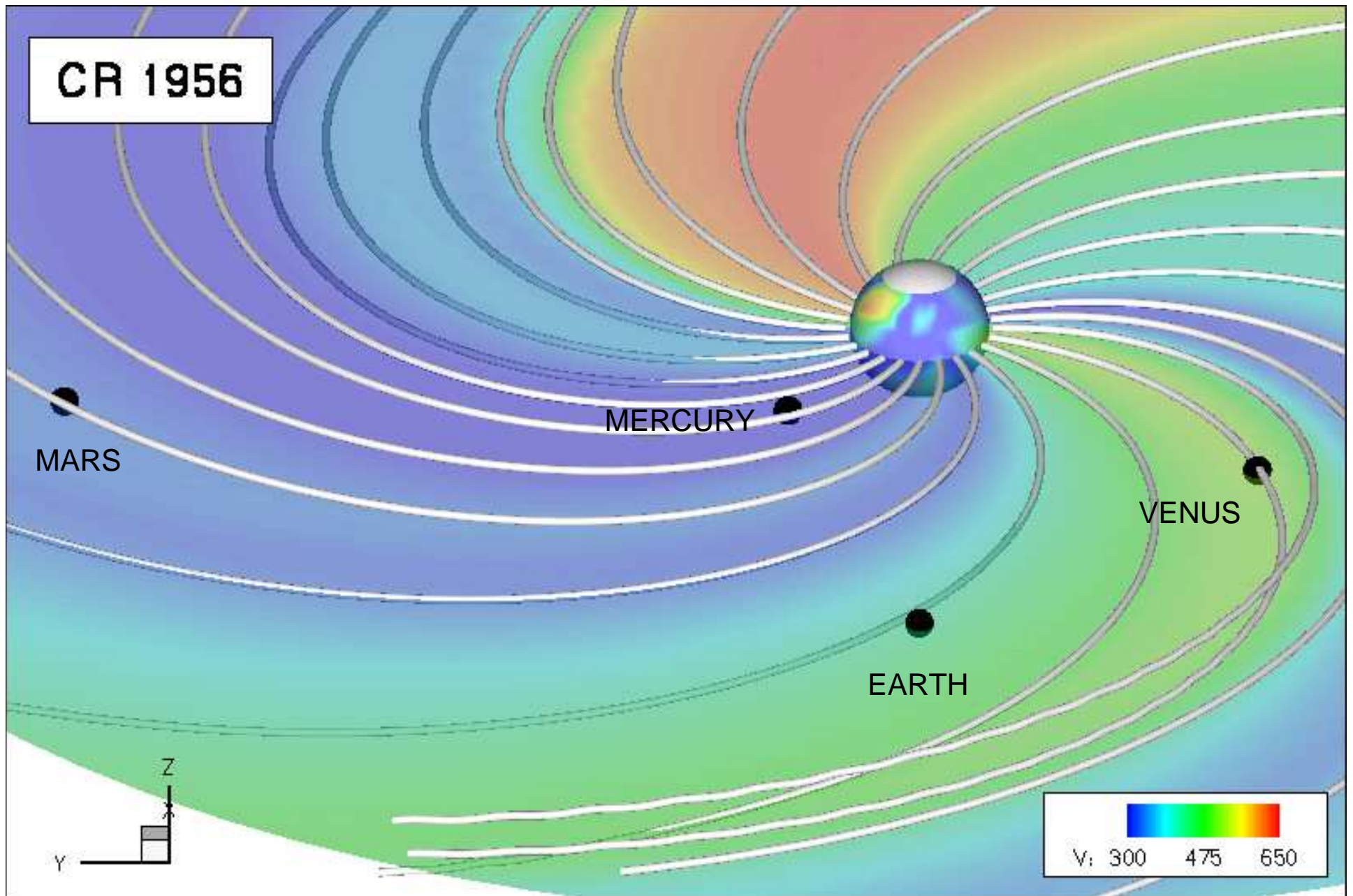
Solar Wind at the Mid-Heliosphere



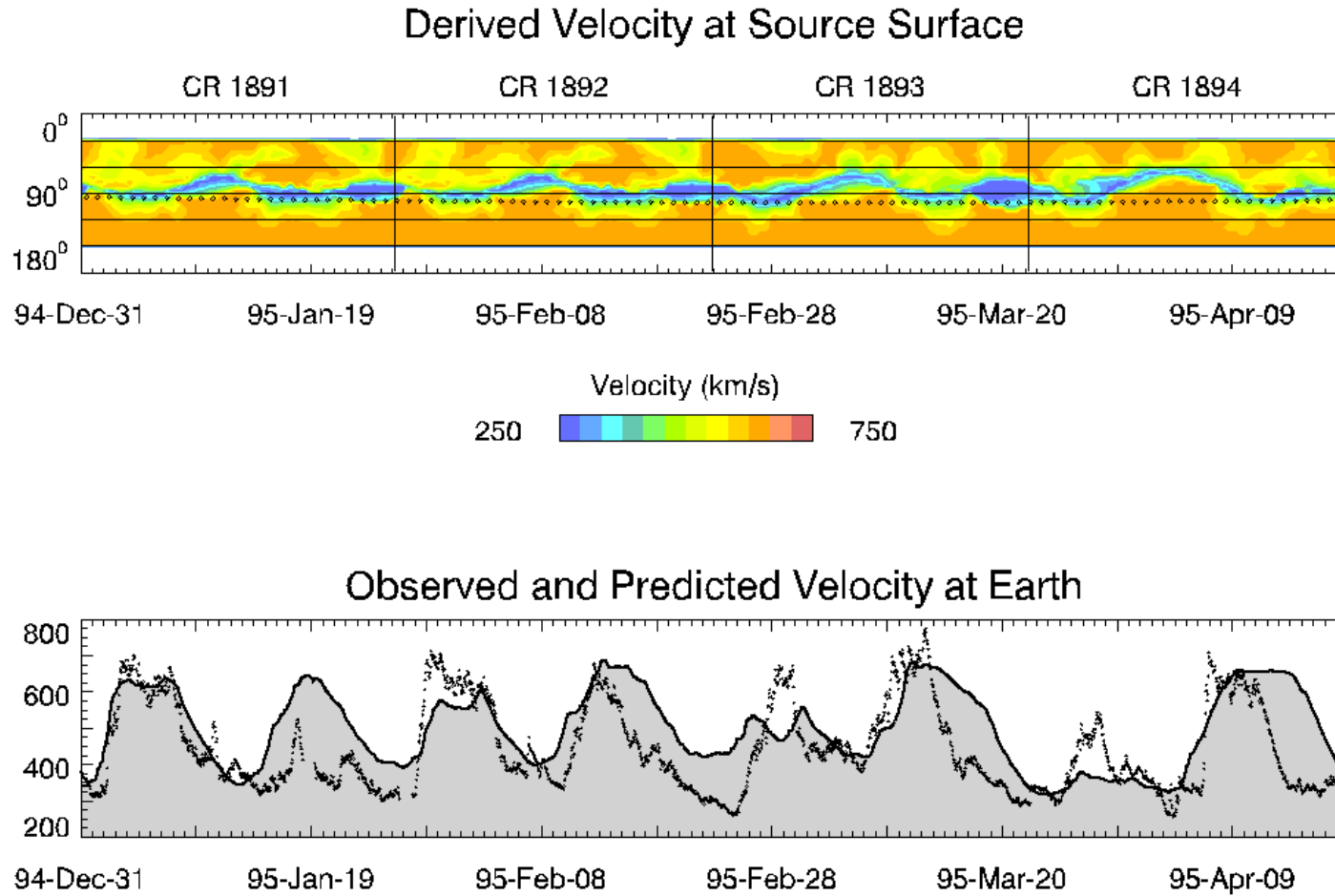
Near Solar Minimum



Near Solar Maximum



Ambient Solar Wind Parameters



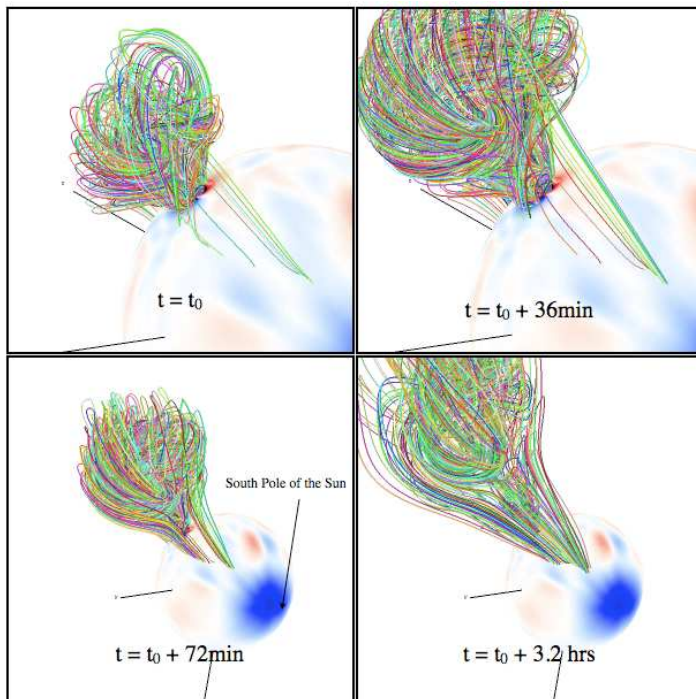
Simulation of ambient solar wind driven by modified daily-updated WSA model:

- Latitudinal distribution of the outflow velocity at 21.5 Rs (top panel)
- Predicted evolution at Earth (solid line) together with actually observed values(dots) by Wind spacecraft (bottom panel)

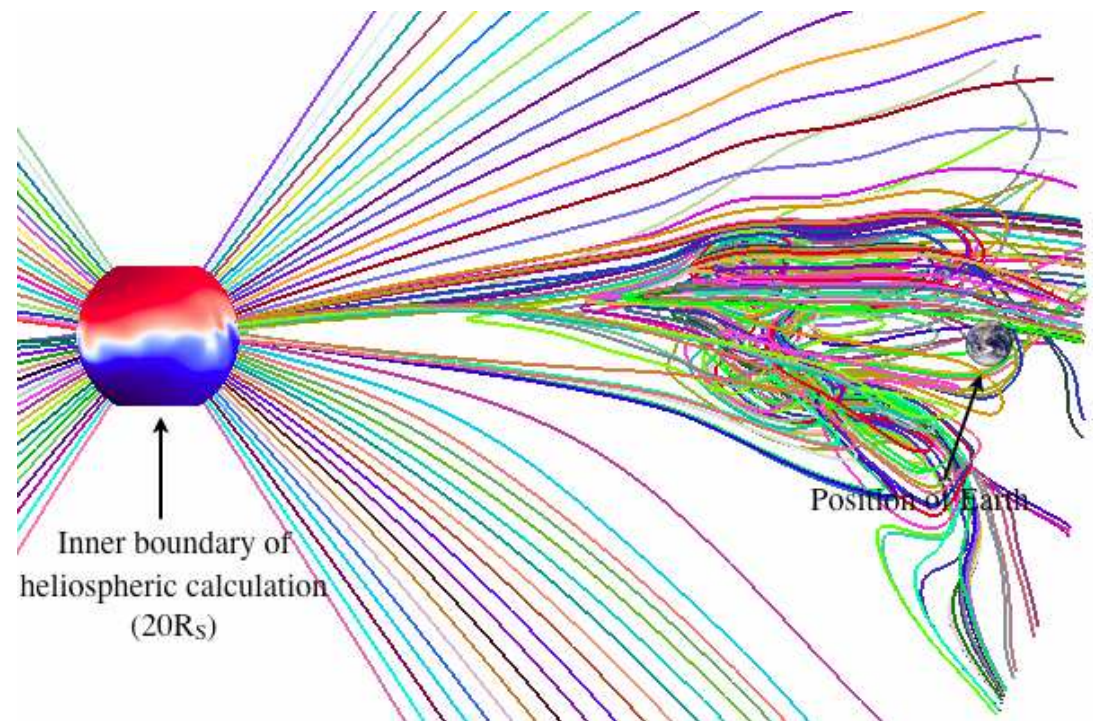
May 12, 1997 Interplanetary CME

(Collaboration with SAIC)

MAS coronal model (SAIC)

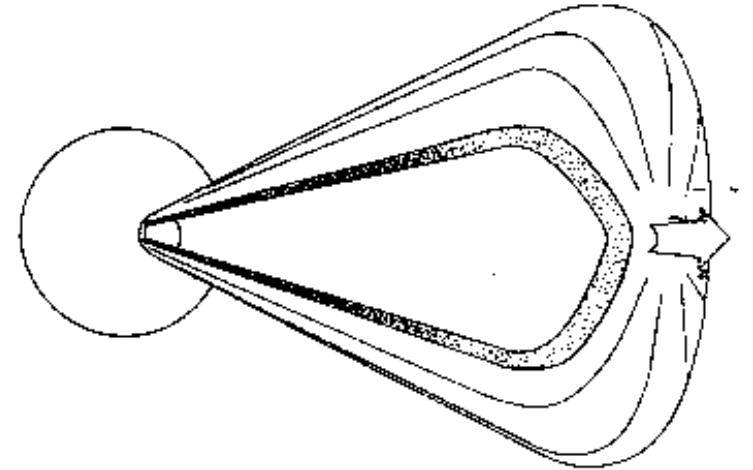
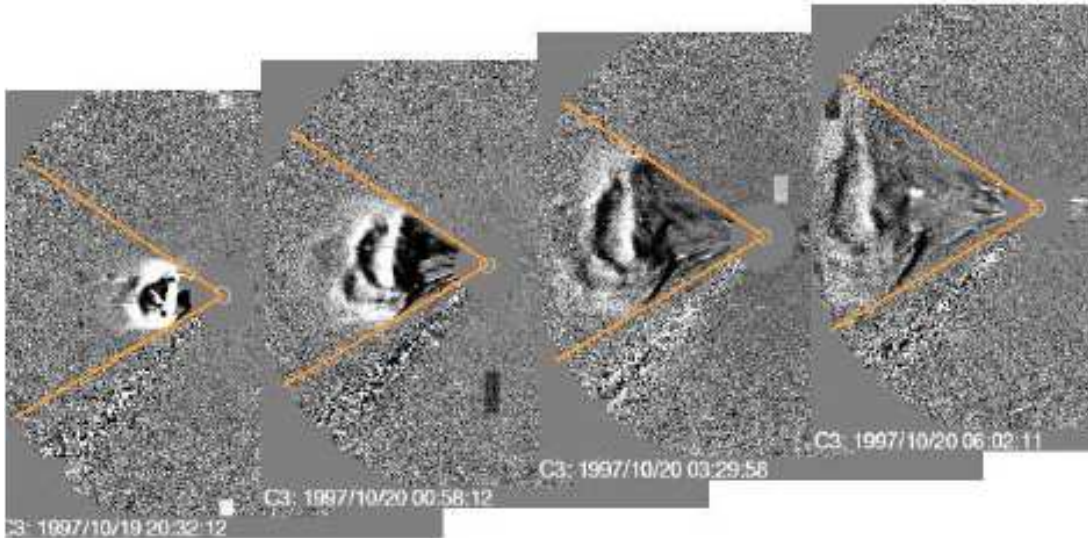


ENLIL heliospheric model
(CU/CIRES & NOAA/SWPC)



Self-consistent end-to-end numerical simulation of space weather event
(NSF/CISM effort in progress)

CME Cone Model



Observational evidence:

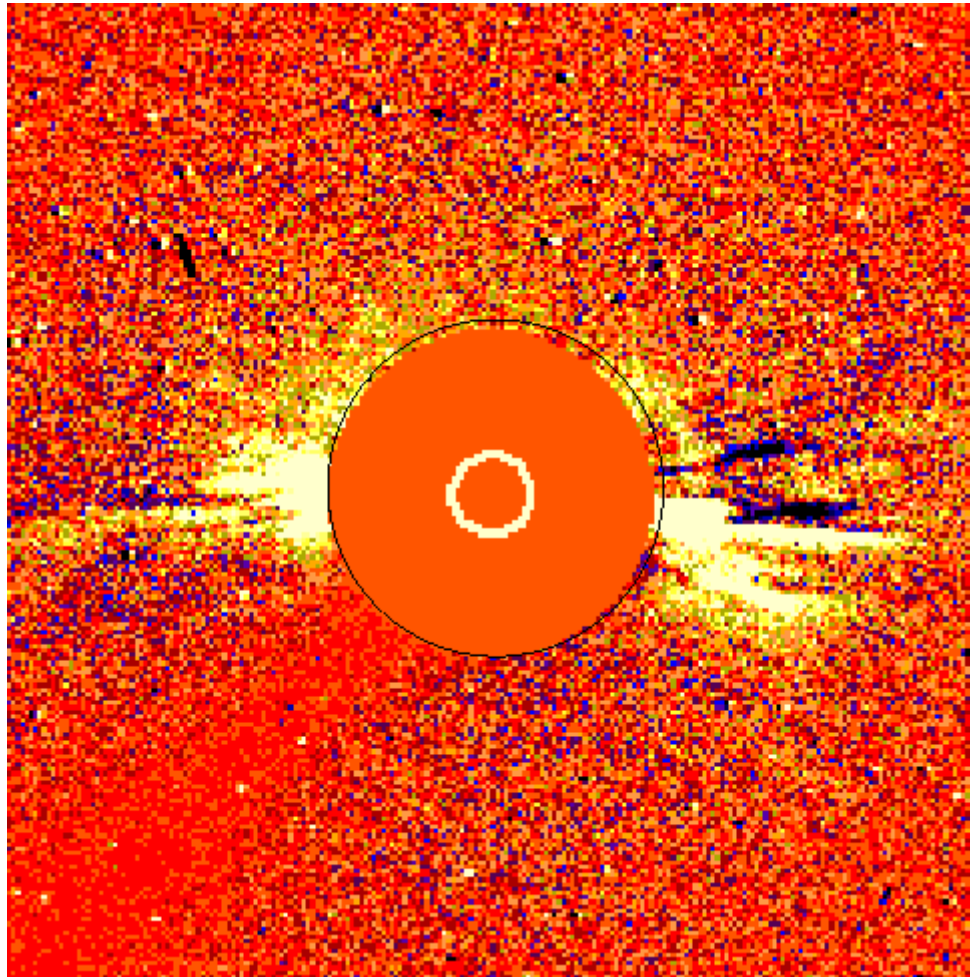
- CME expands self-similarly
- Angular extent is constant

Conceptual model:

- CME as a shell-like region of enhanced density

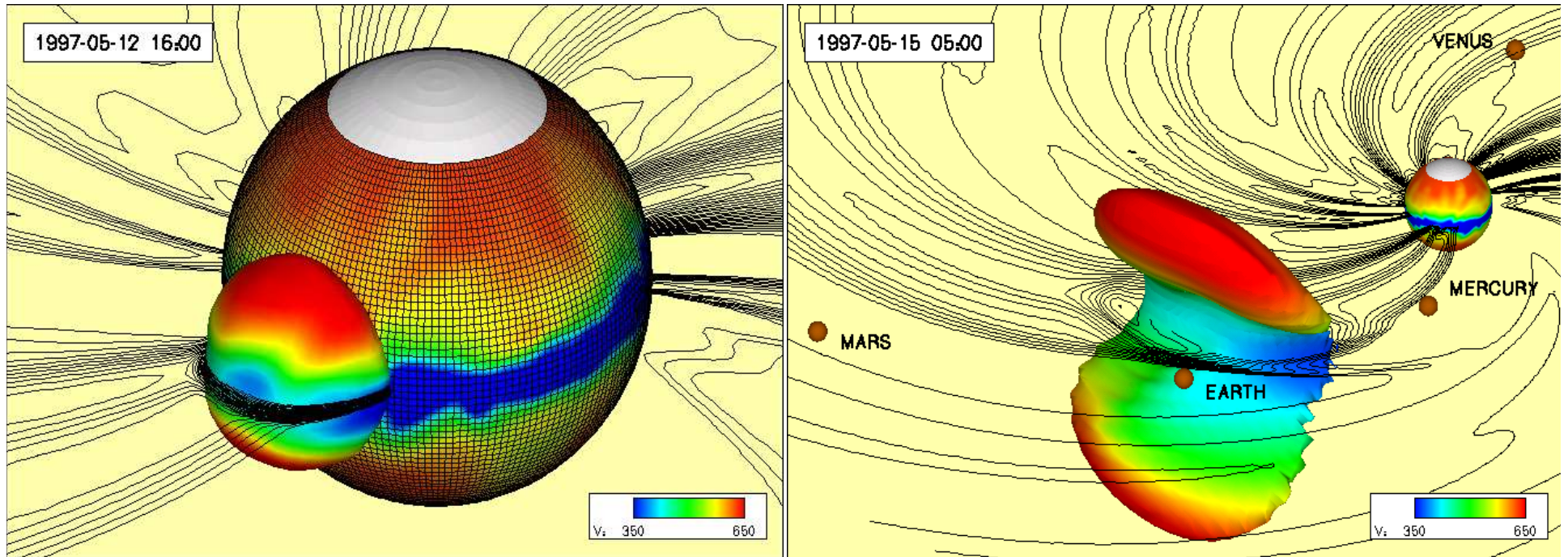
[*Howard et al, 1982; Fisher & Munro, 1984*]

May 12, 1997 Halo CME



Running difference images fitted by the cone model [*Zhao et al.*, 2002]

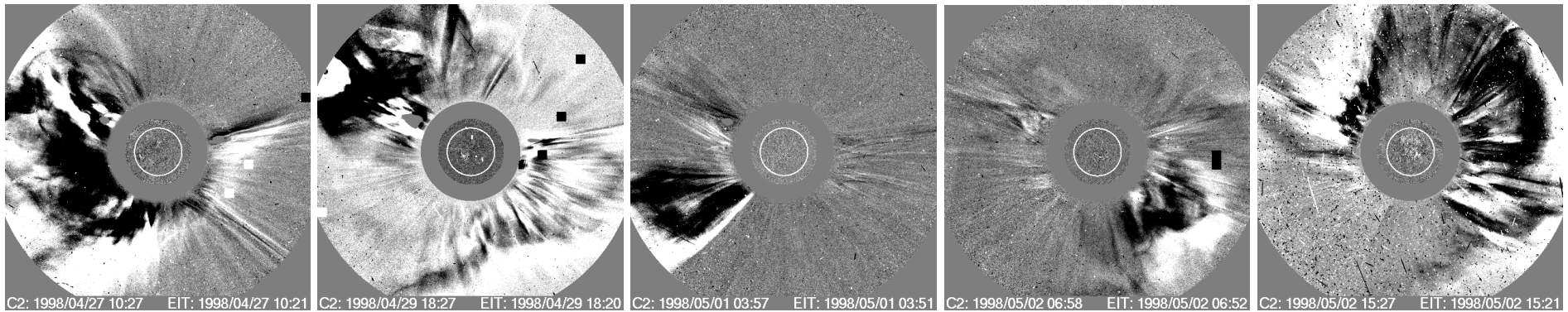
Transient Disturbances



Modeling of the origin of CMEs is still in the research phases and it is not expected that real events can be routinely simulated in near future. Therefore, we have developed an intermediate modeling system which uses the WSA coronal maps, fitted coronagraph observations, specifies 3D ejecta, and drives 3D numerical code ENLIL.

Solar and Coronal Activity

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



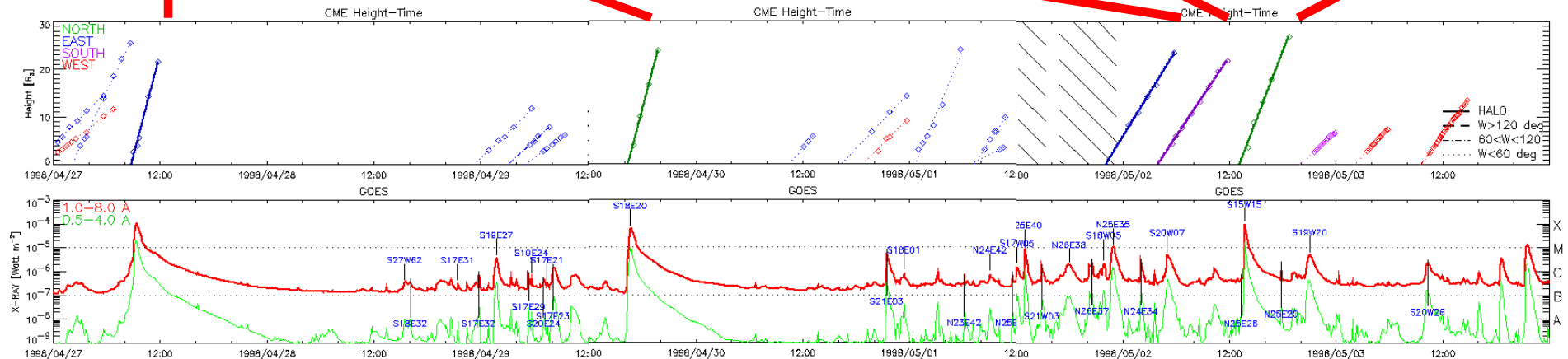
CME-1

CME-2

CME-3

CME-4

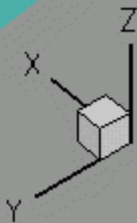
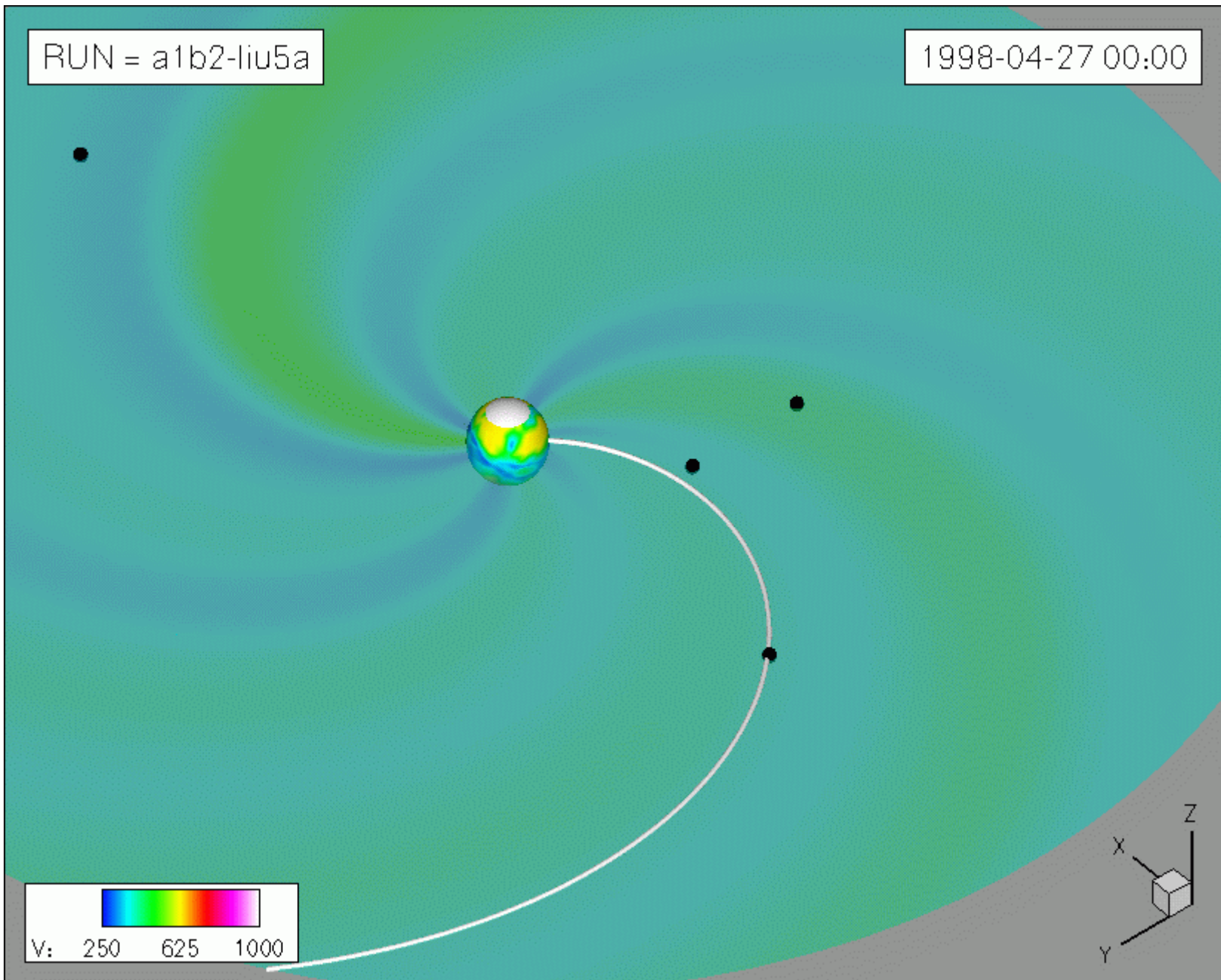
CME-5



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

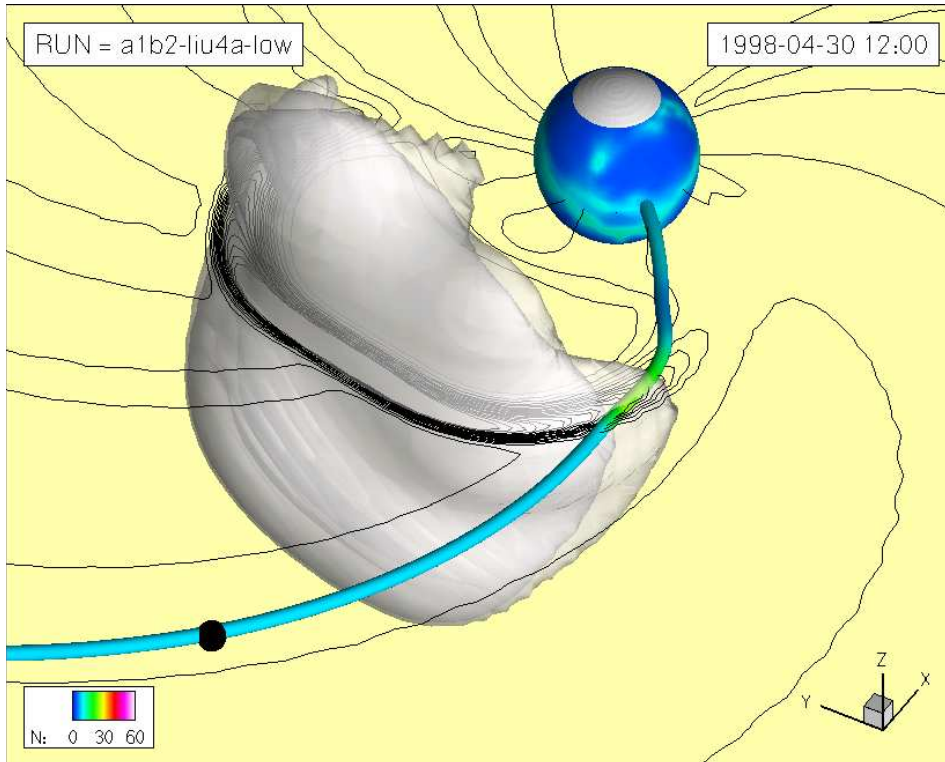
RUN = a1b2-liu5a

1998-04-27 00:00

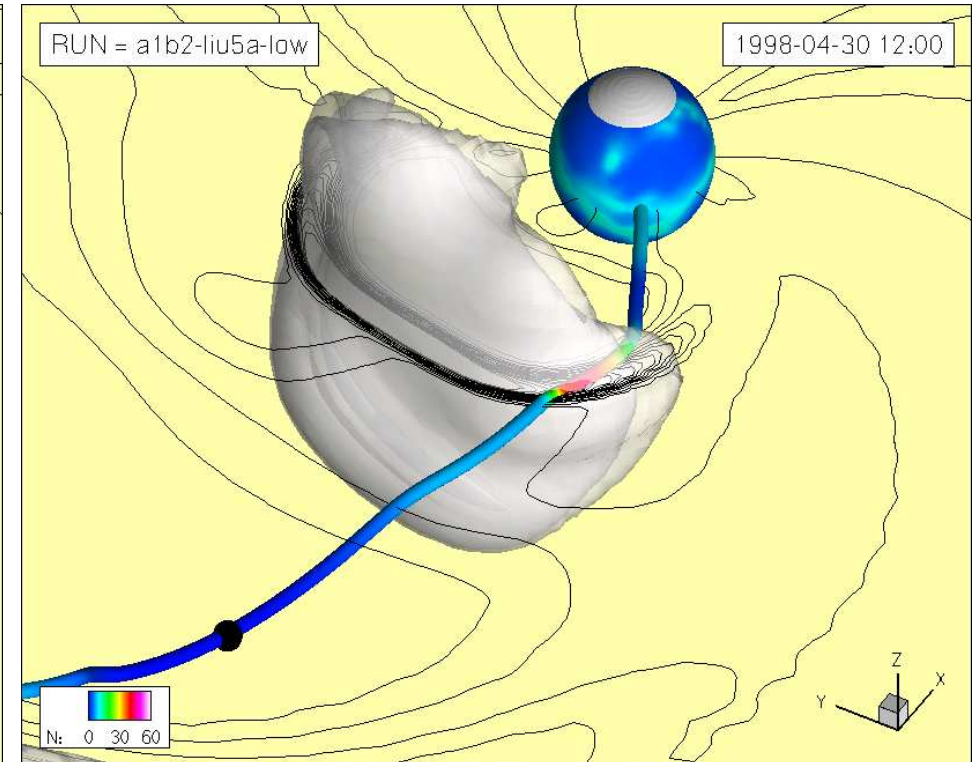


ICMEs and IMF Connectivity

ICME in undisturbed SW

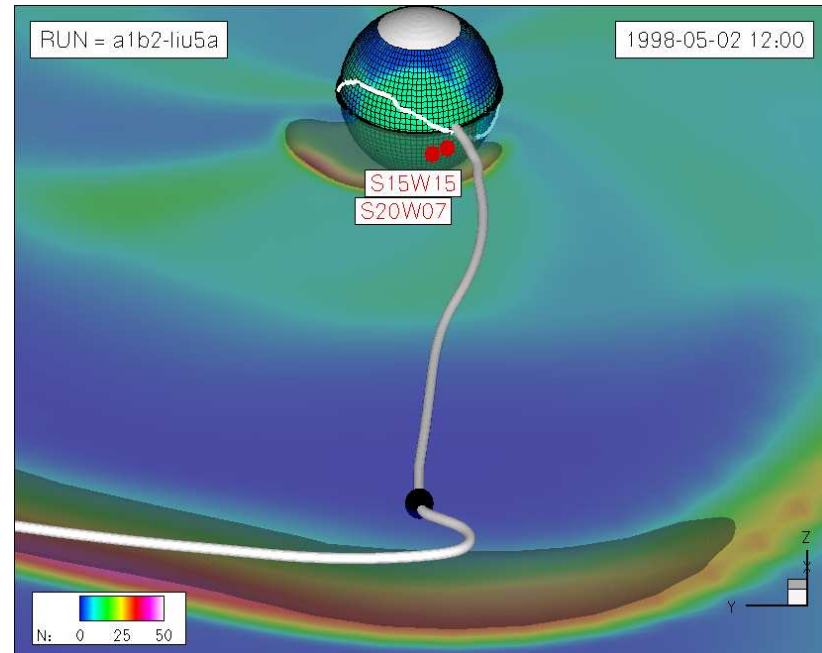
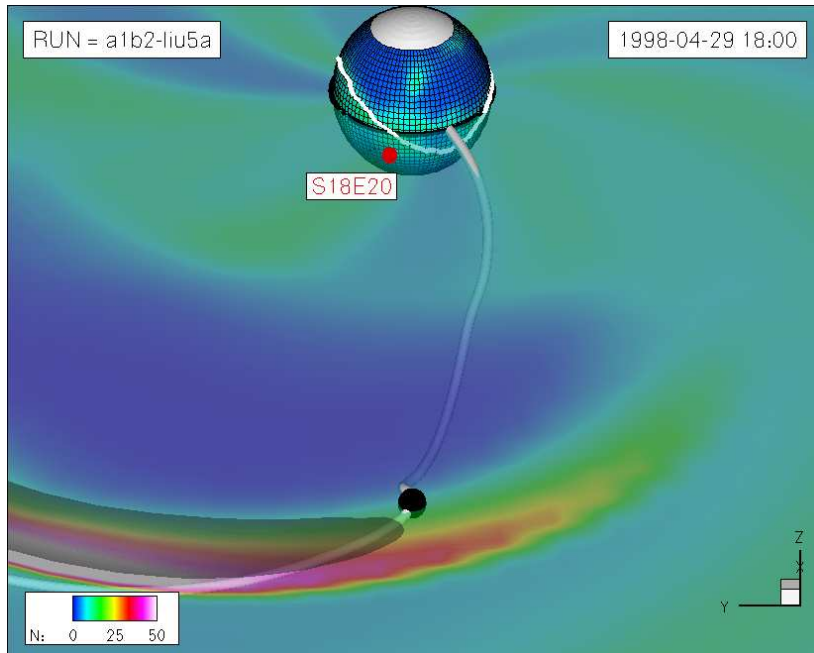
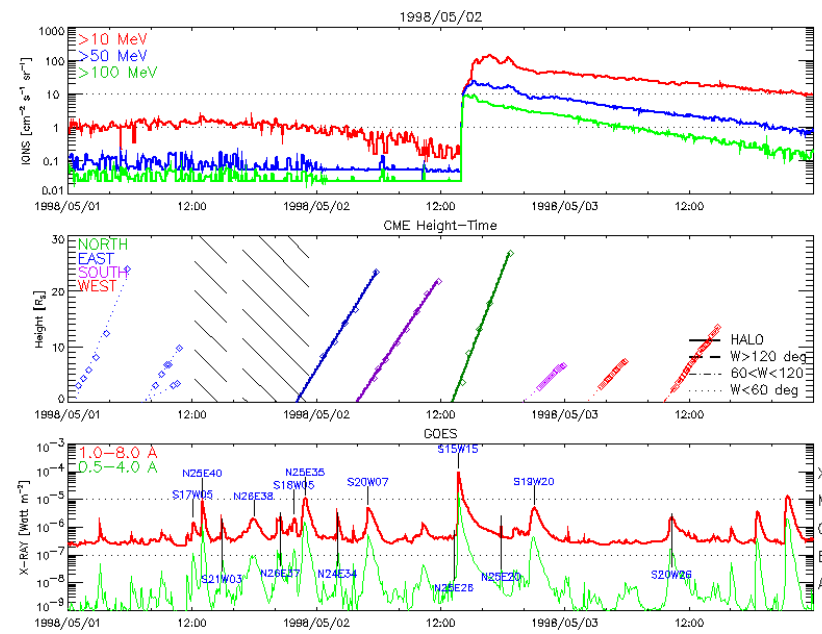
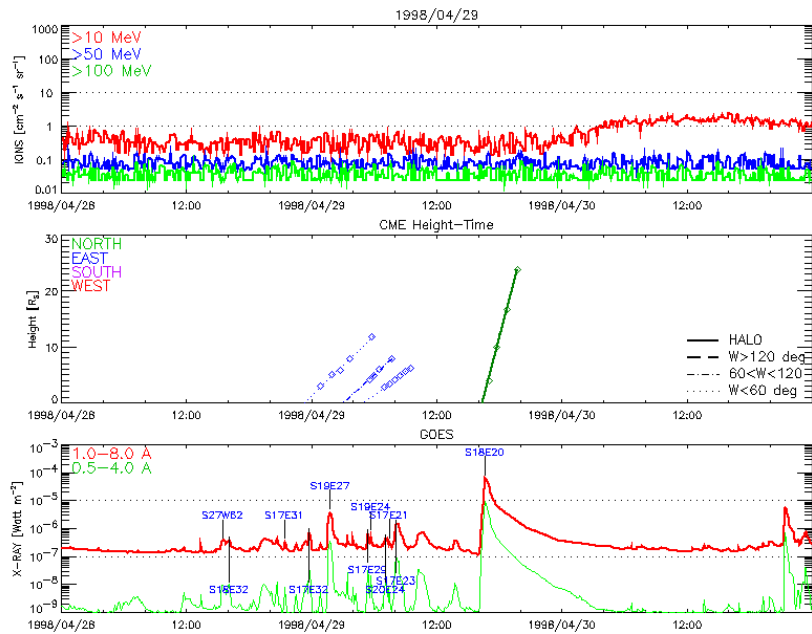


ICME in disturbed SW
by a preceding ICME

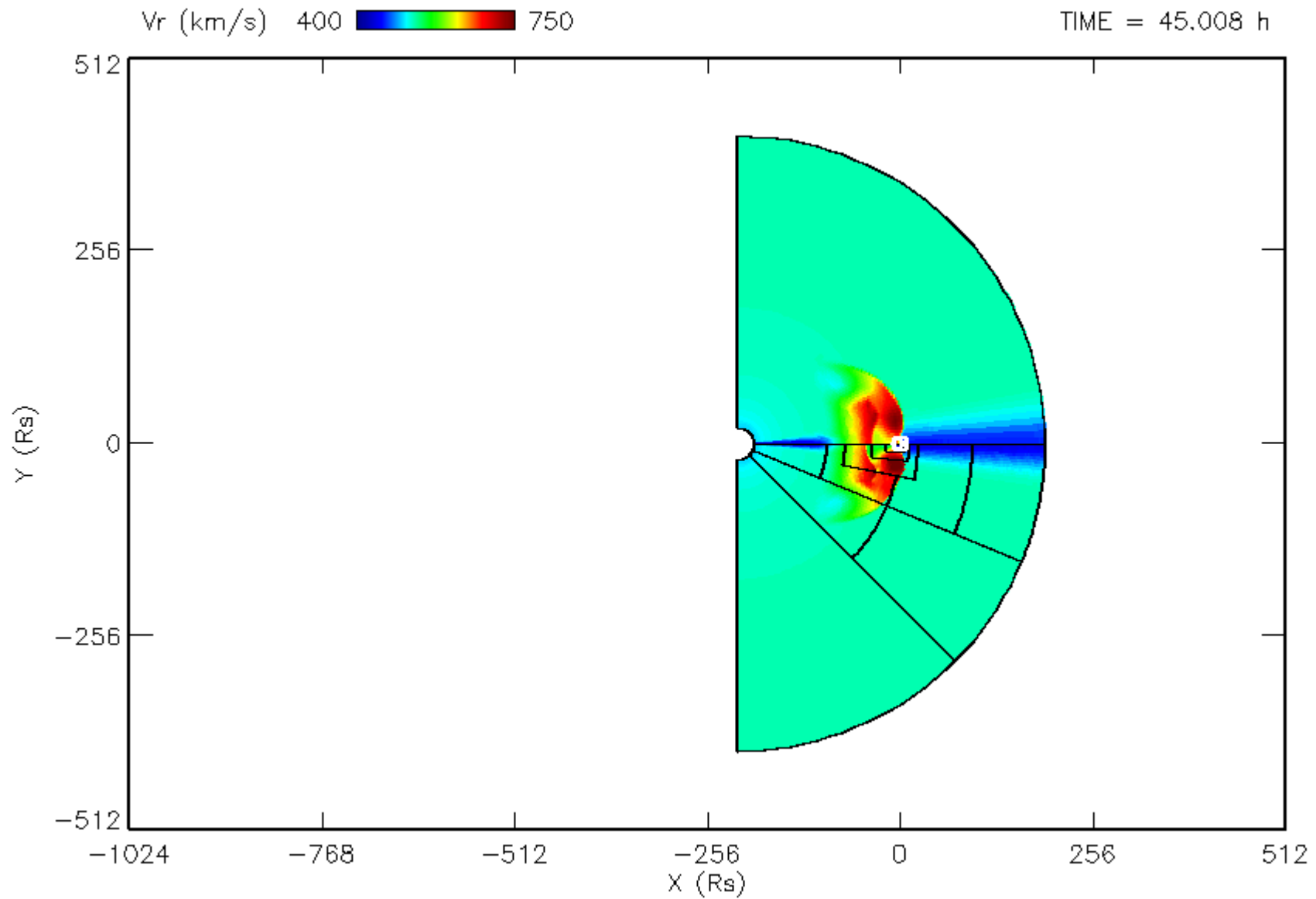


Interplanetary CMEs (white shaded structure), interplanetary magnetic field (IMF) lies (colored by normalized density), during the April/May 1998 events. Geospace is magnetically connected to weak or strong shock front depending on rarefaction caused by preceding ICME.

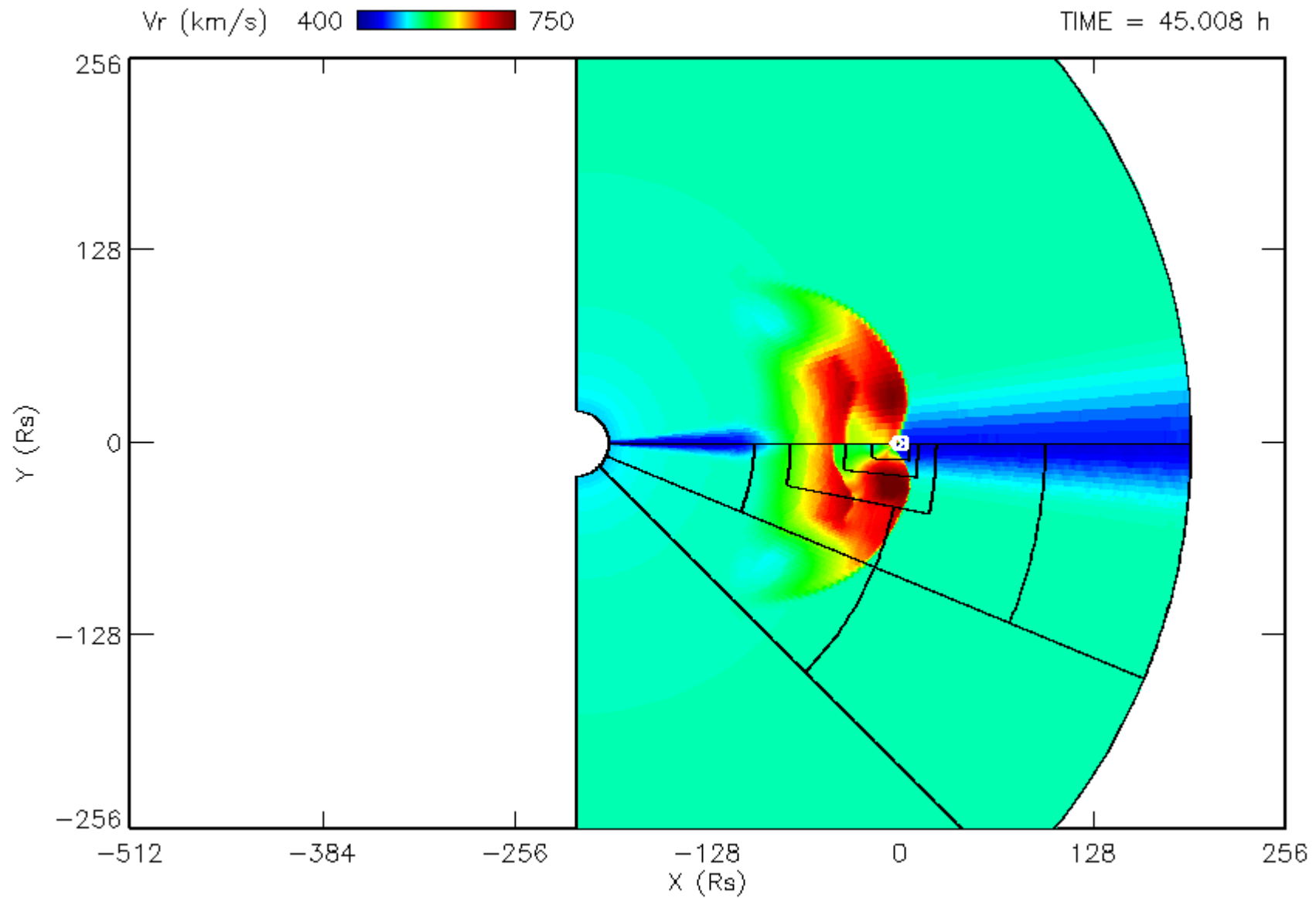
Connectivity of Magnetic Field Line



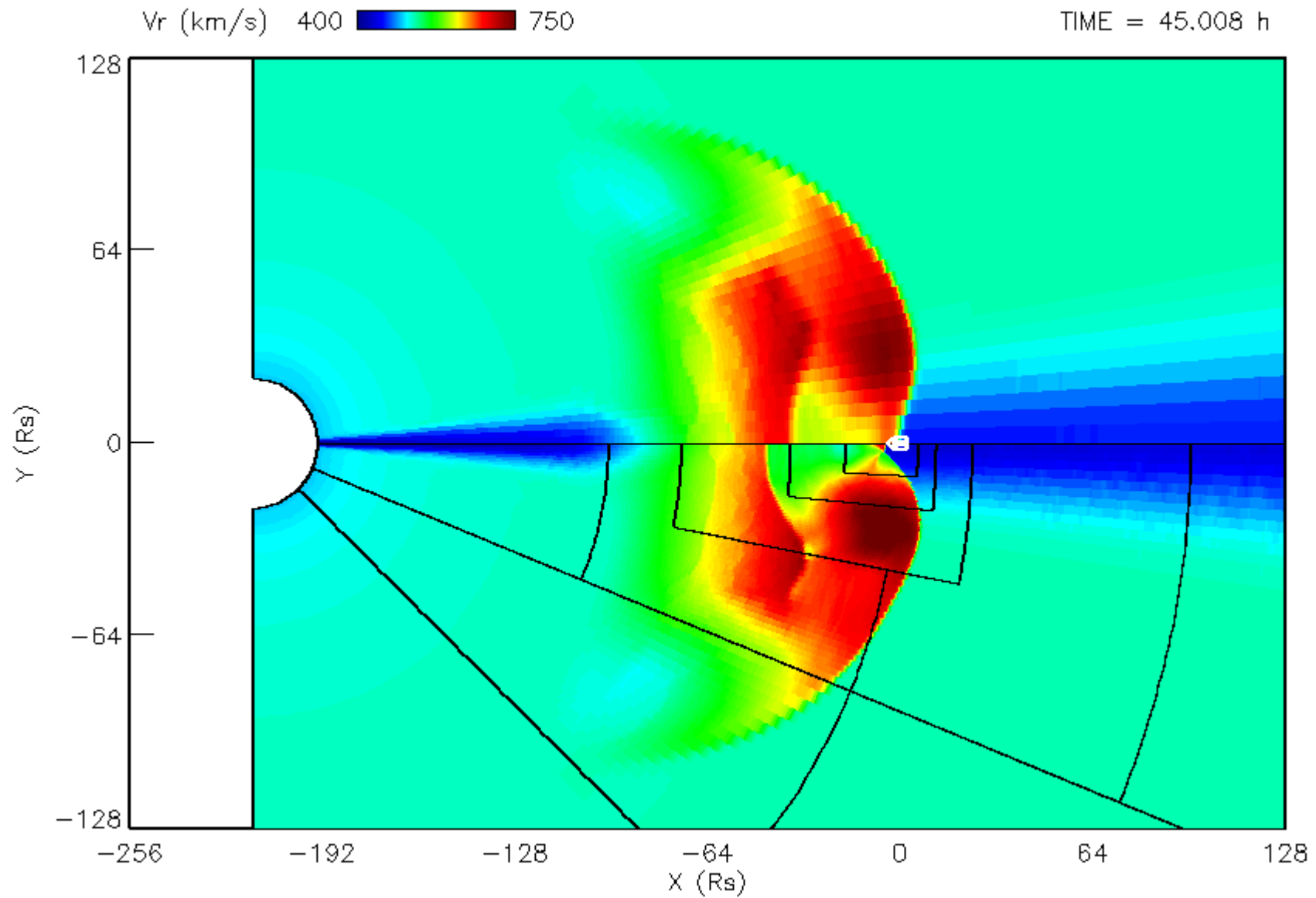
High Resolution of Shocks at Geospace



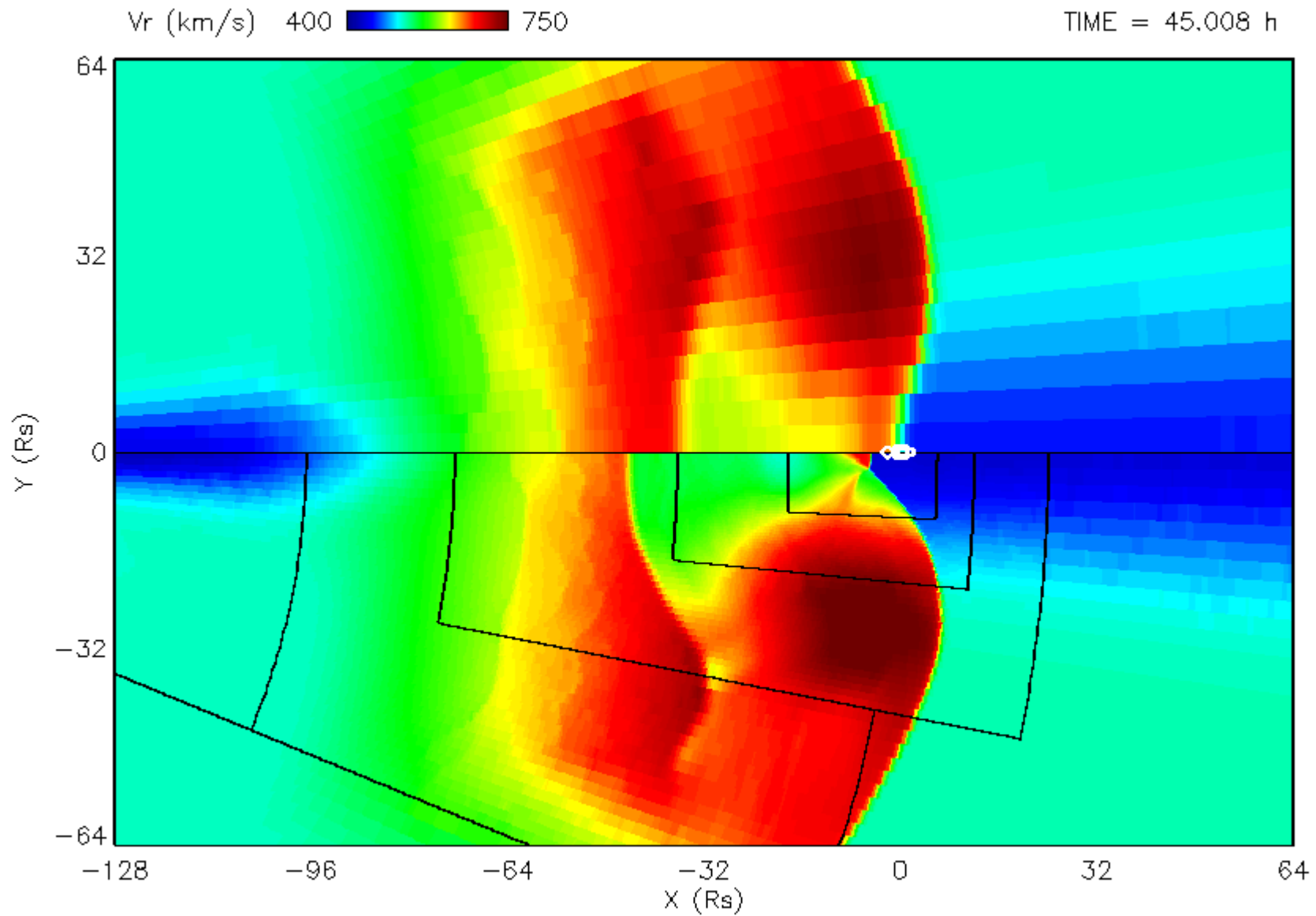
High Resolution of Shocks at Geospace



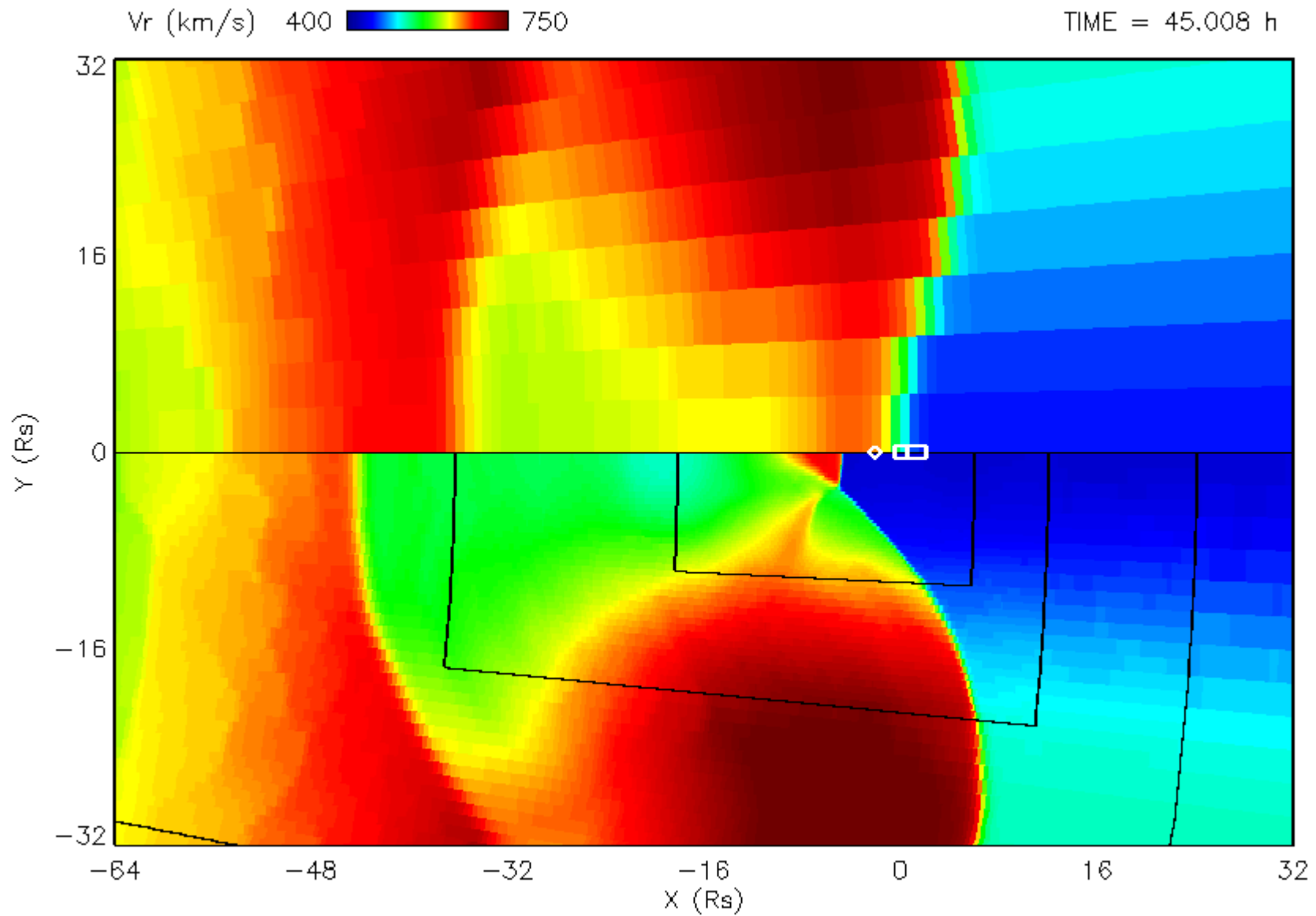
High Resolution of Shocks at Geospace



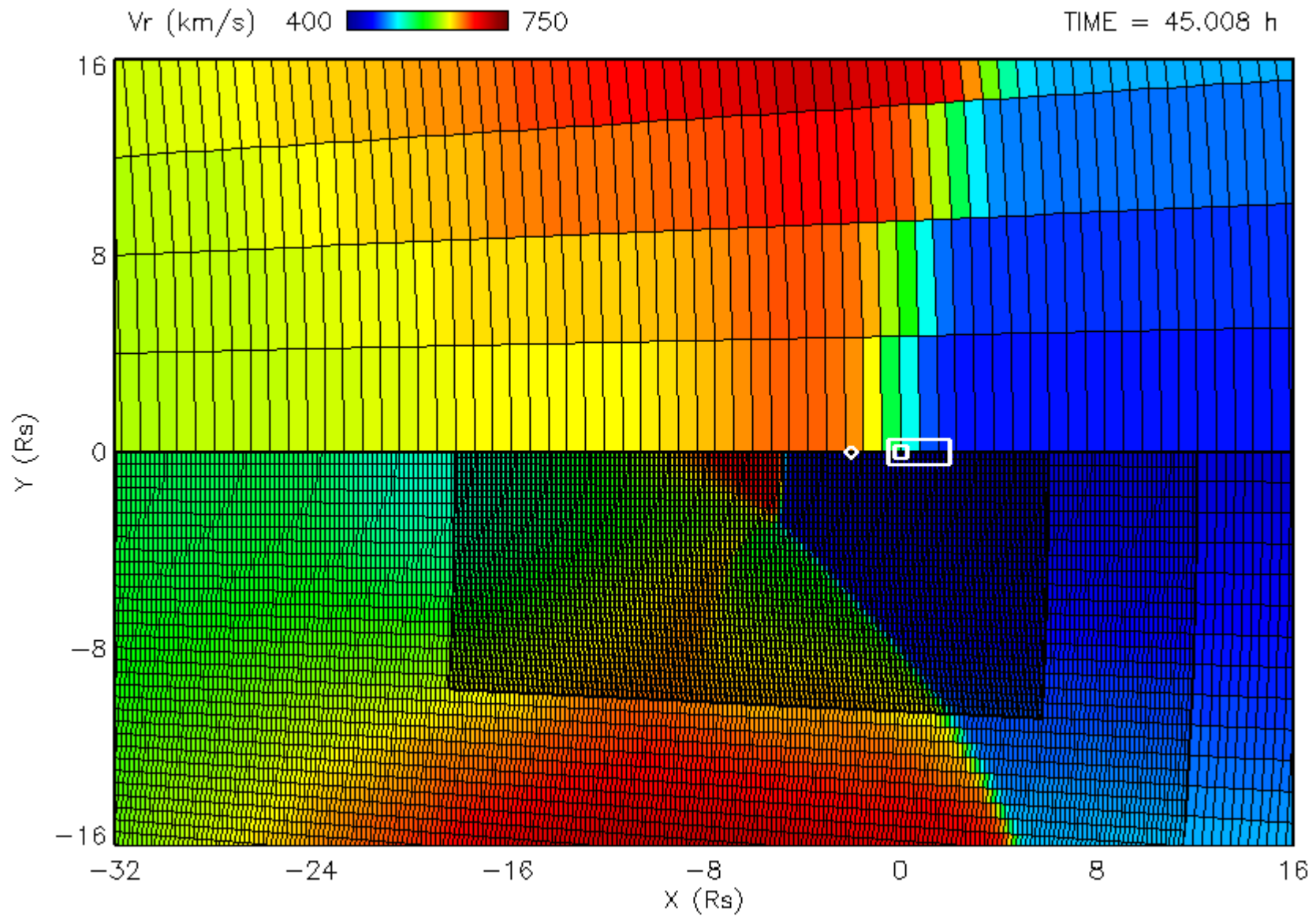
High Resolution of Shocks at Geospace



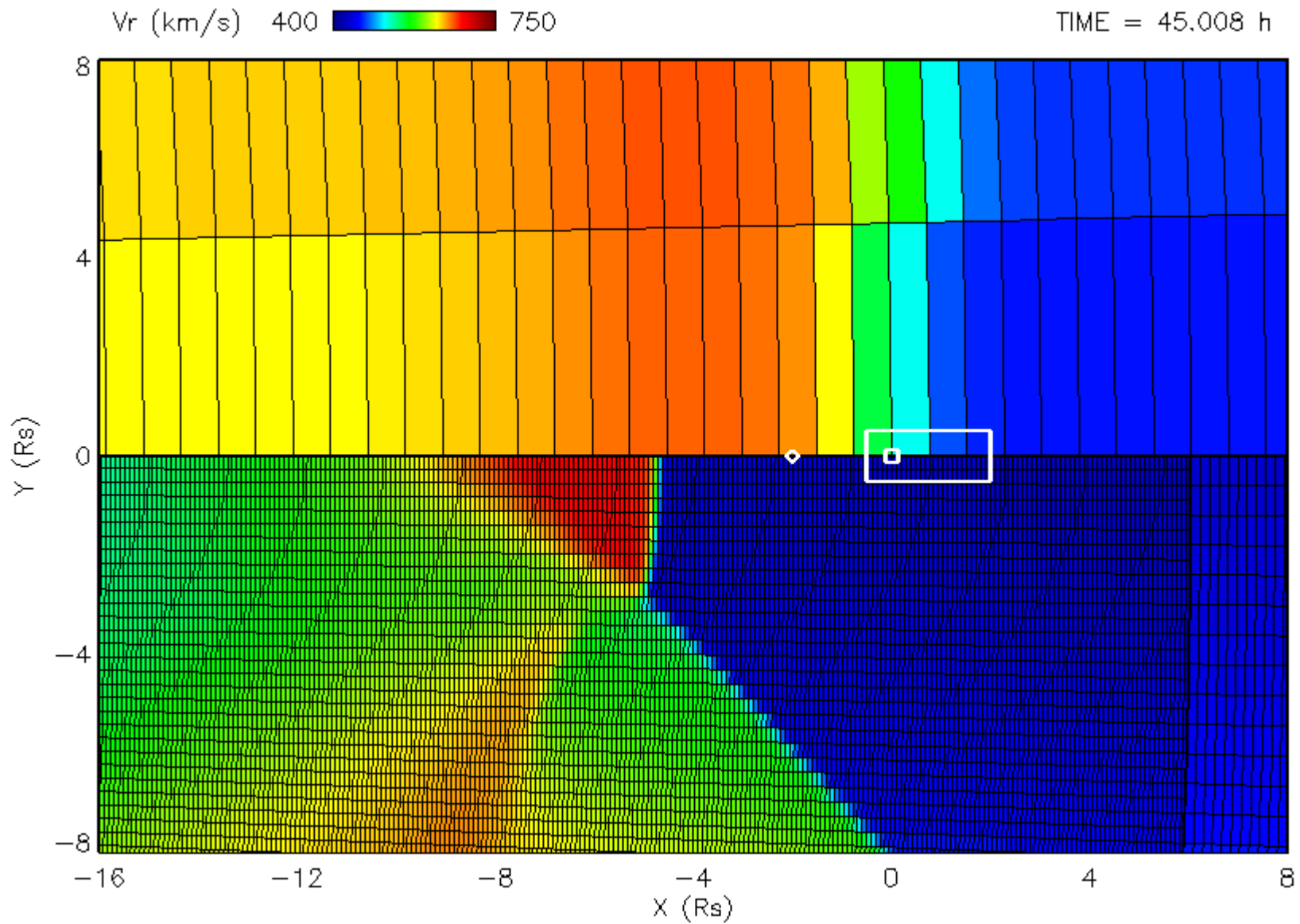
High Resolution of Shocks at Geospace



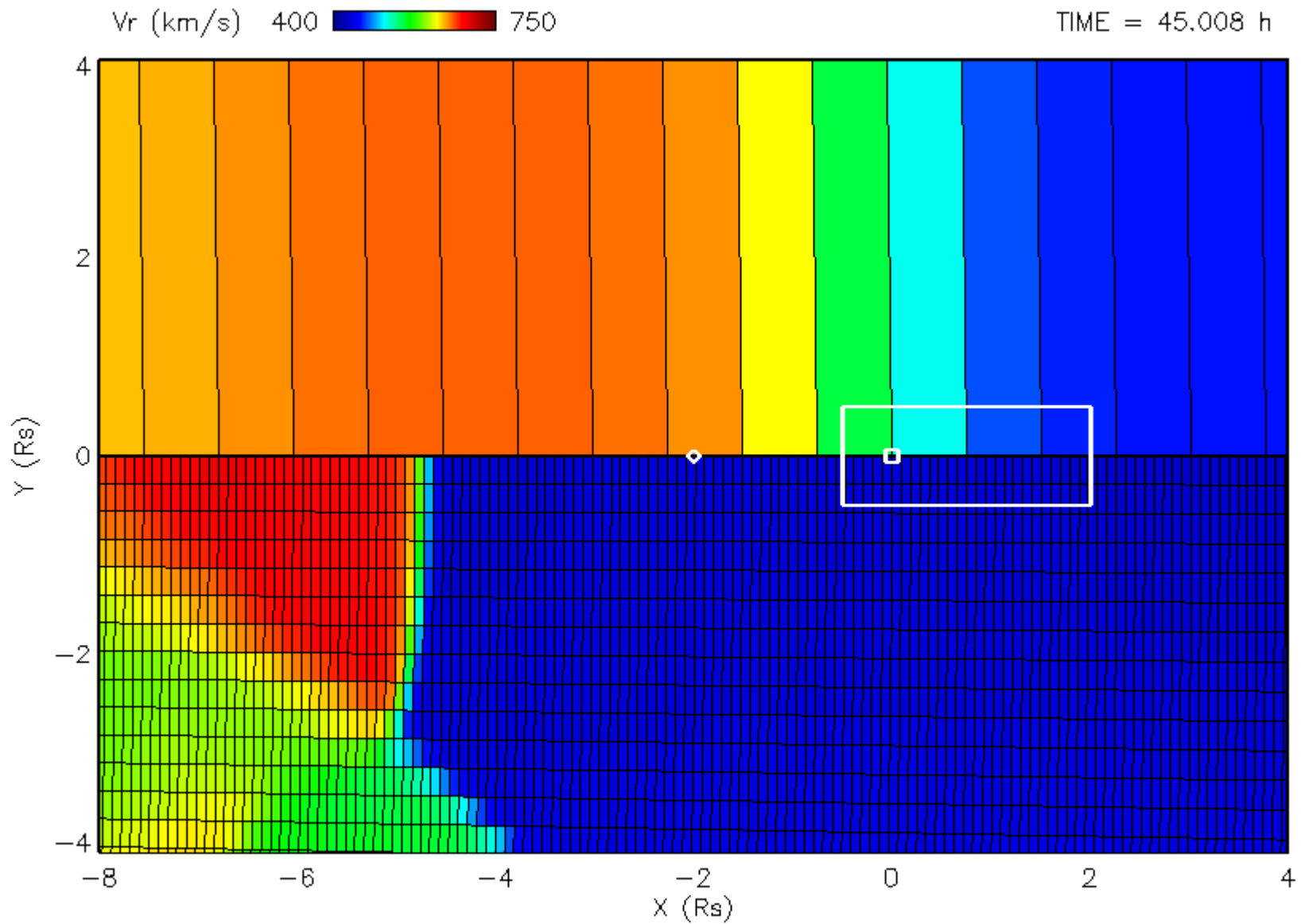
High Resolution of Shocks at Geospace



High Resolution of Shocks at Geospace

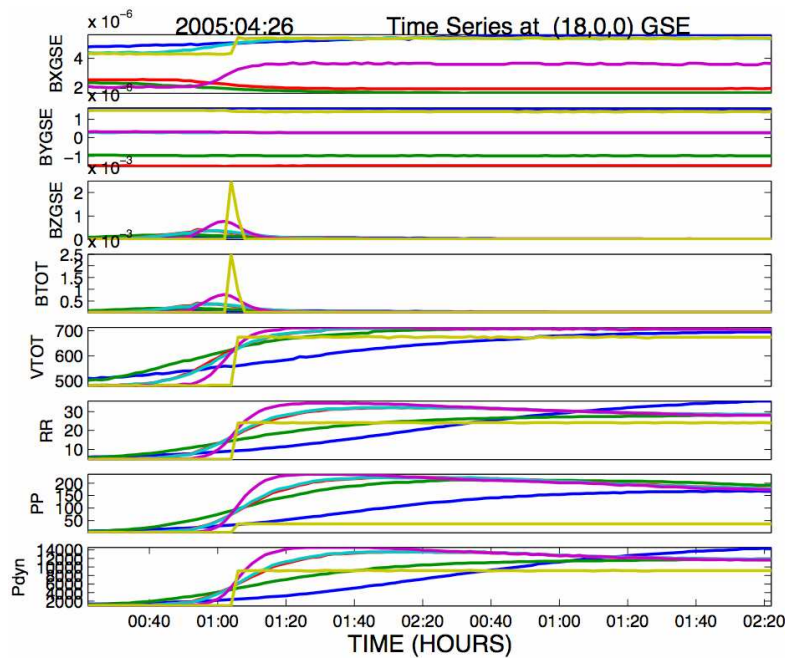


High Resolution of Shocks at Geospace

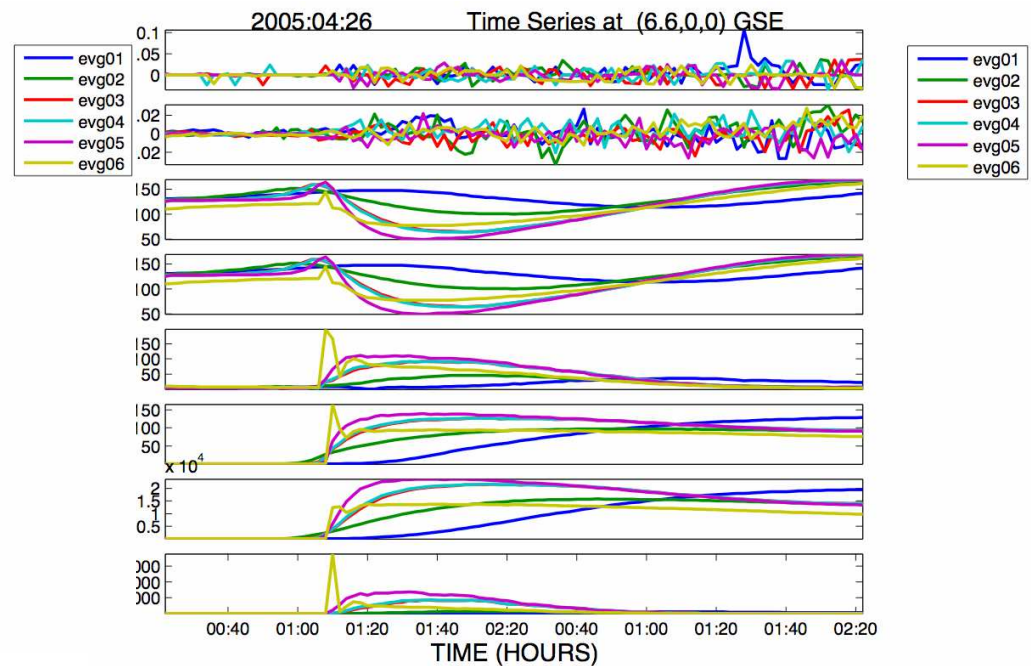


Preliminary Results of ENLIL-OpenGGCM Coupling

- Several runs from Dusan with embedded refined grid of various resolution.
- IP shock case. For the MSP the shock must be properly resolved.
- No IMF yet.



Upstream of bow shock



Magnetosphere dayside geosynchronous

Predicting the IMF Connectivity

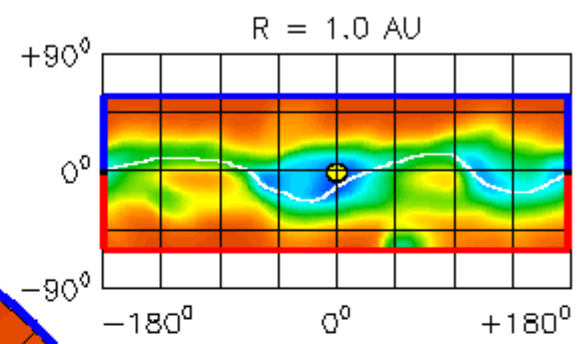
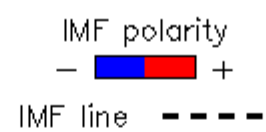
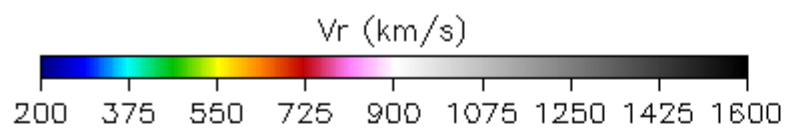
06dec/vsafir-eld/neo-2051-a1b2-sa1.256x30x90.1-mcp1um1mt-1.g15q0

2008-02-06 18:22:32

ENLIL-2.5 lowres WSA-1.5 NSO 2051

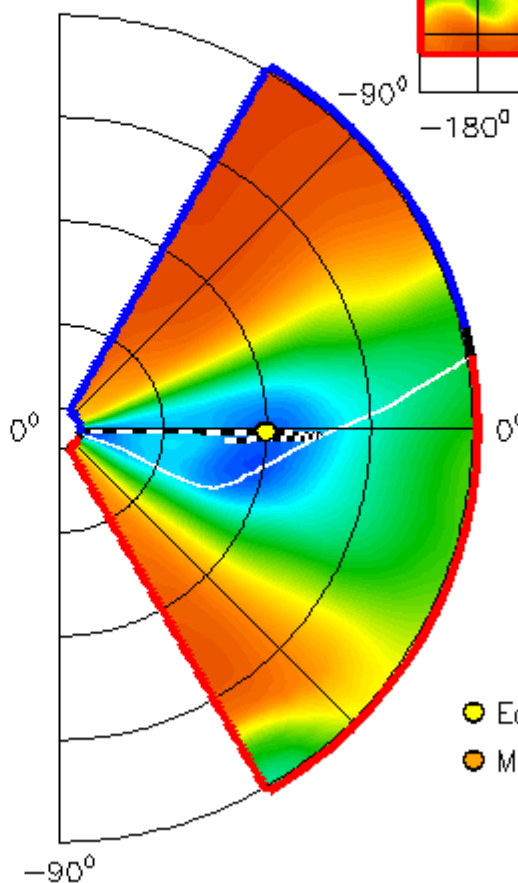
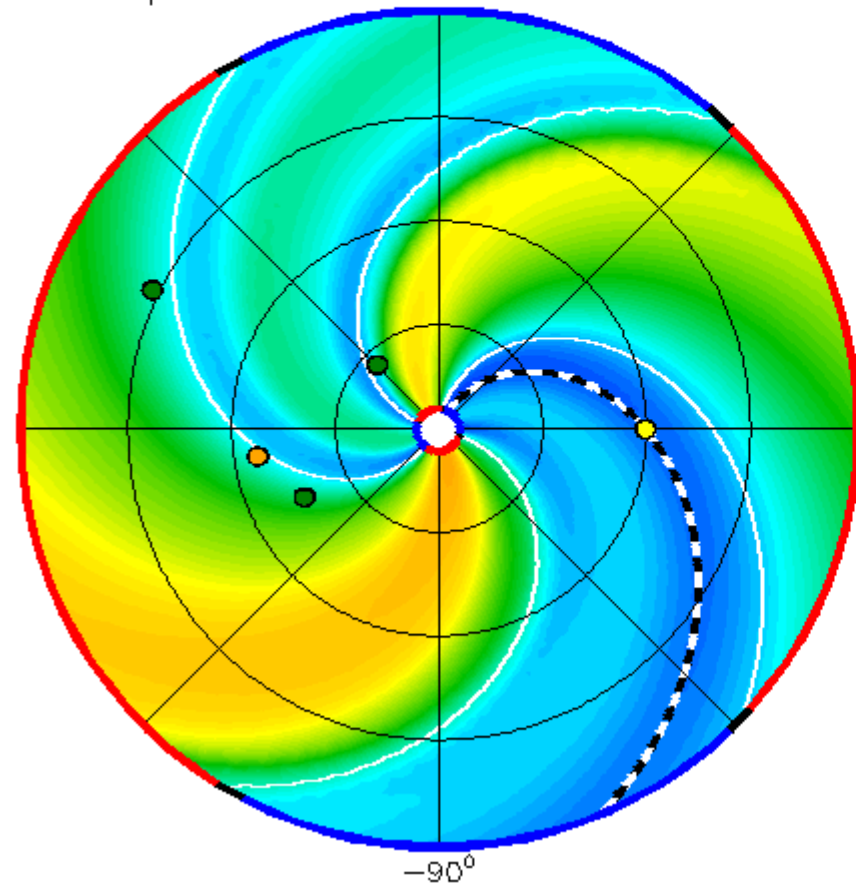
2006-12-13 00:00:57

2006-12-13 + 0.00 days



Equatorial Cone +90° LAT = -0.62°

+90° LON = 0°



VALUES AT EARTH:
N = 15.5 cm⁻³
T = 23.4 kK
Vr = 320. km/s
Pdyn = 2.67 nPa

VALUES AT 0.10 AU:
IMF len = 1.21 AU
IMF lat = +0.7°
IMF lon = +62.4°

- OBJECTS:
- Earth
 - Planets
 - Messenger

Supporting the NASA Spacecraft Missions

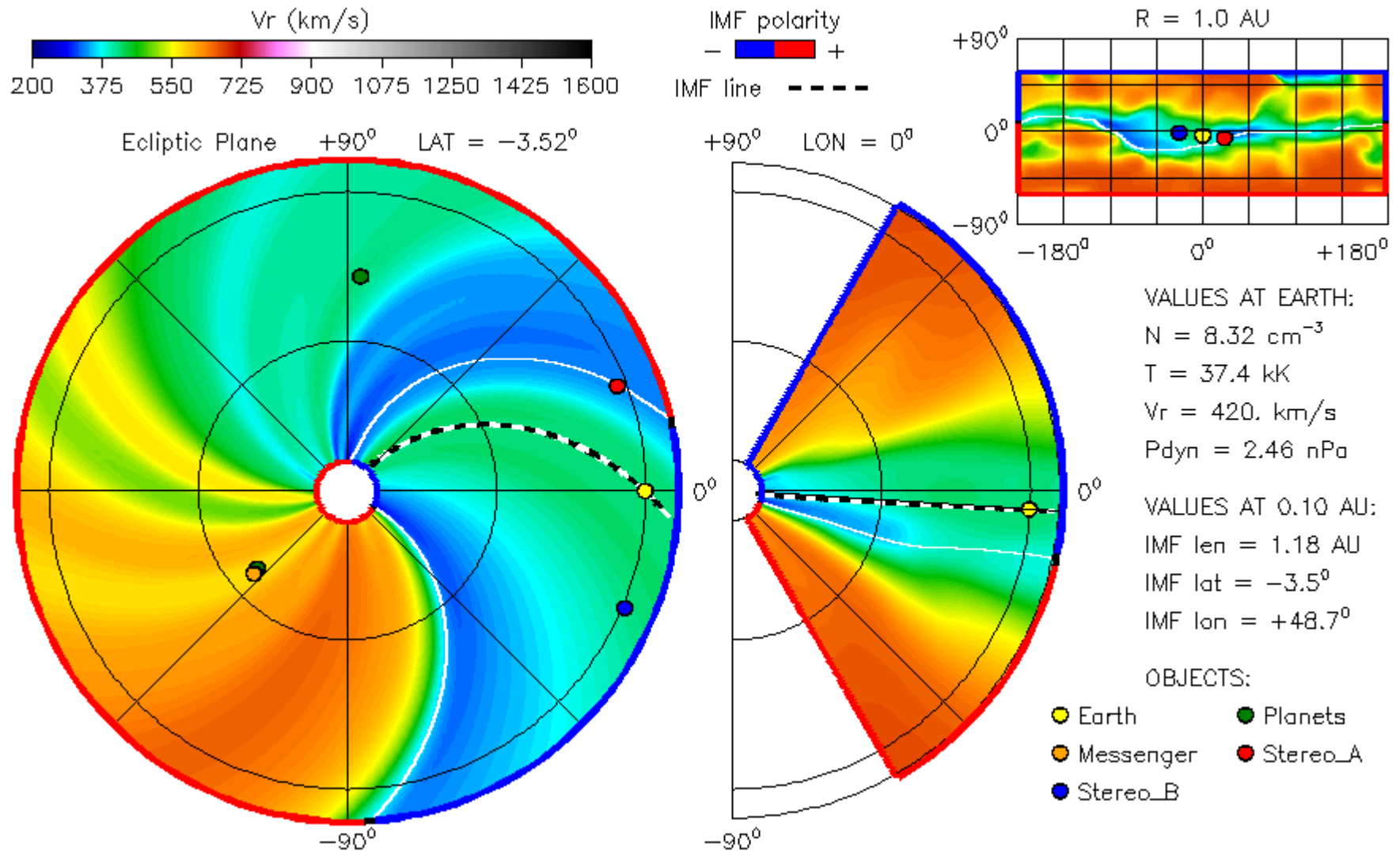
swpc/wsafr/kao-2065-31b2.256x60x180.1-mp1um1mt-1.g15q0

2008-02-23 22:17:19

ENLIL-2.5 medres WSA-1.5 NSO 2065

2008-01-06 00:08:35

2007-12-29 + 7.87 days

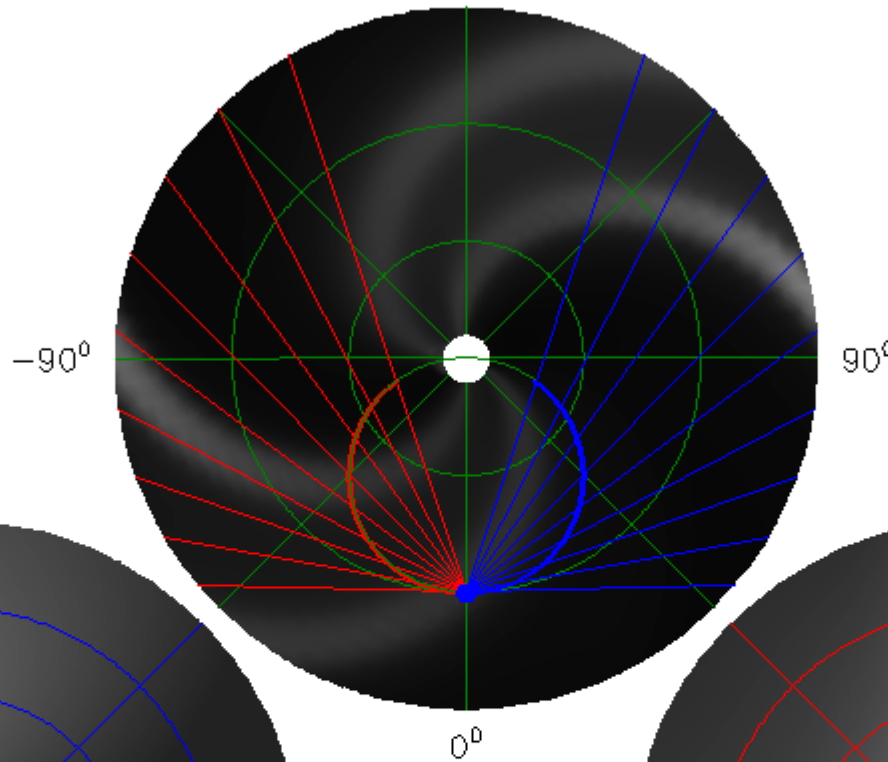
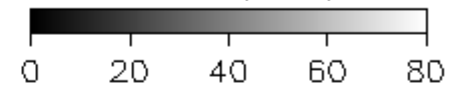


2007-01-24 00:03:04

- Earth
- Planets
- Stereo_A
- Stereo_B

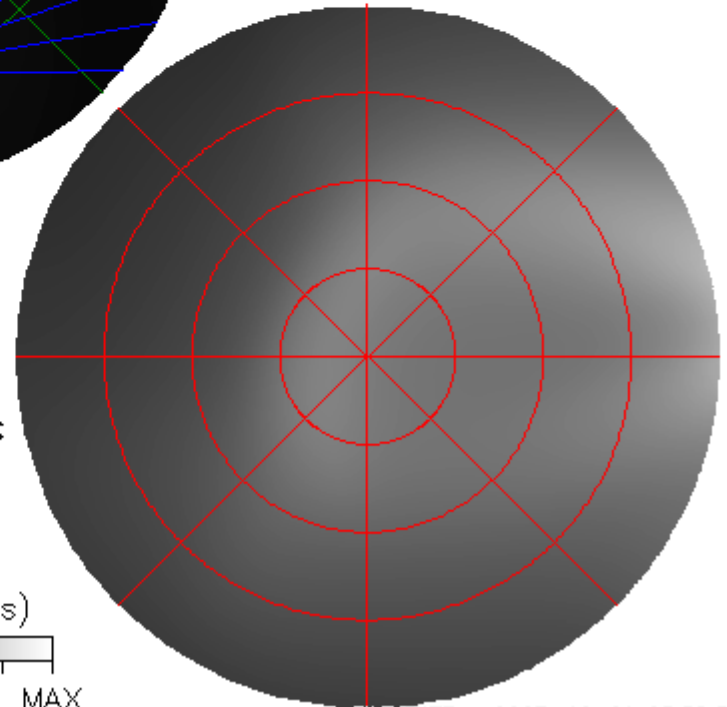
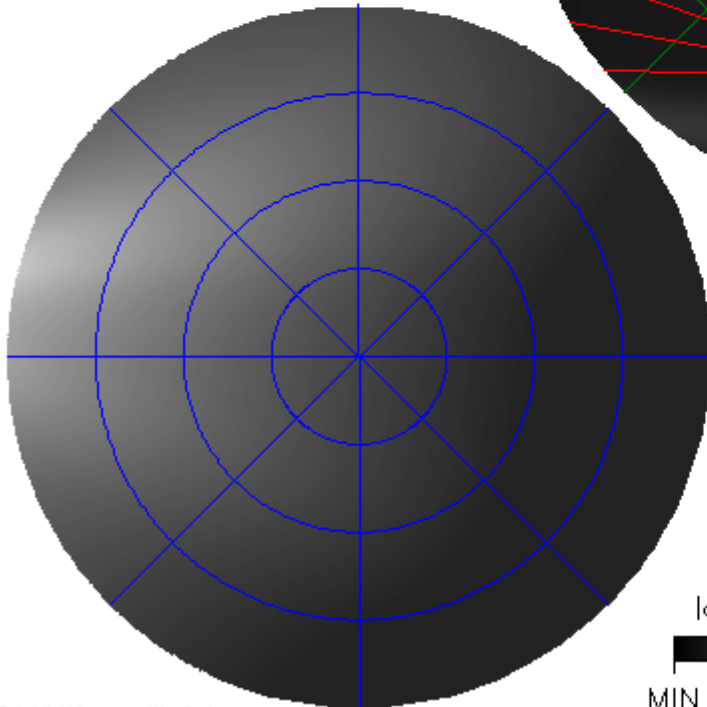
← Equatorial Plane:

$R^2 * N \text{ (cm}^{-3}\text{)}$



North

North



White-Light Image:

Stereo_A →

← Stereo_B

$\log_{10}(\text{Total Brightness})$



Using the UCSD-IPS/SMEI Observations

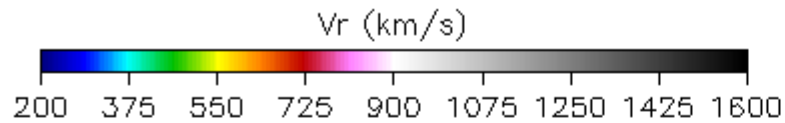
smei/04nov/a1x4.256x30x90.1-h1um1m-1.g53q0

2008-02-06 23:37:55

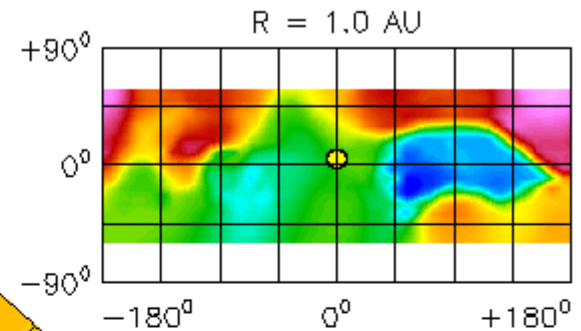
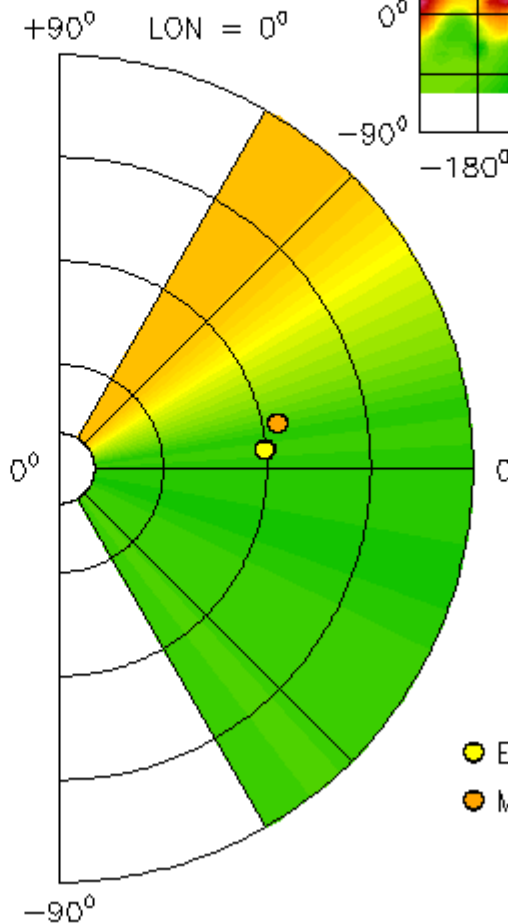
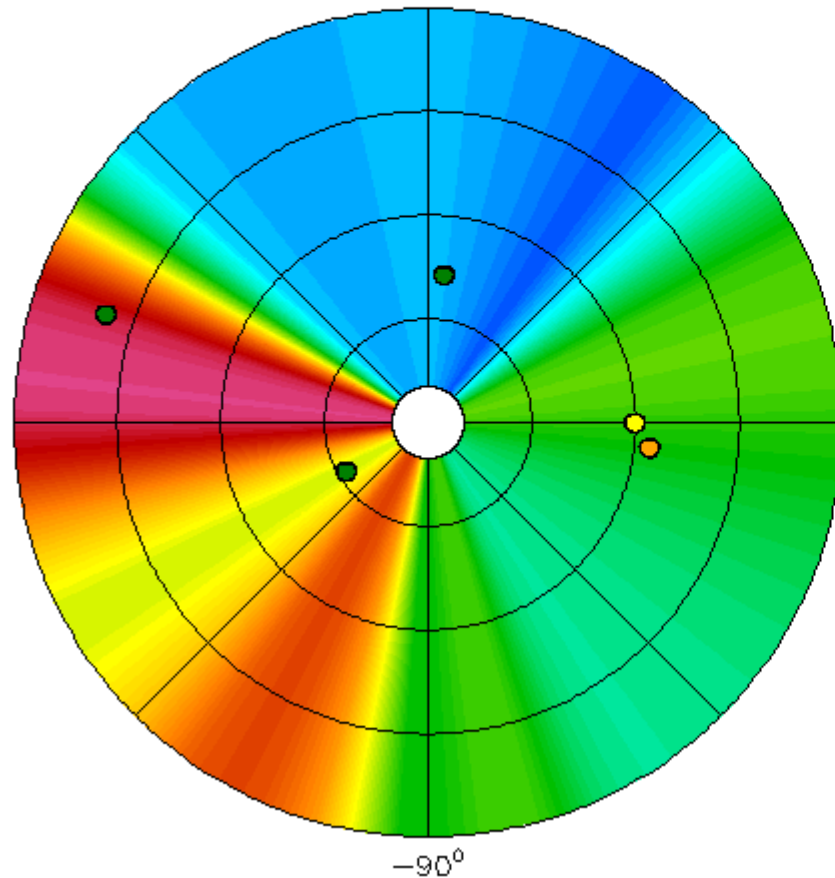
ENLIL-2.5 lowres

2004-10-20 09:00:00

+ 0.00 days



Equatorial Cone +90° LAT = 5.423°



VALUES AT EARTH:

$N = 3.32 \text{ cm}^{-3}$

$T = 76.8 \text{ kK}$

$V_r = 475. \text{ km/s}$

$P_{\text{dyn}} = 1.26 \text{ nPa}$

OBJECTS:

● Earth

● Planets

● Messenger

Conclusions

- Routine modeling of solar wind and predicting its parameters is possible for global structures.
- Run-on-request service available at <http://ccmc.gsfc.nasa.gov>
- Experimental prediction service available at <http://helios.swpc.noaa.gov>
- More effort is necessary to increase accuracy and robustness of the code, validate results, and incorporate additional remote and in-situ observations