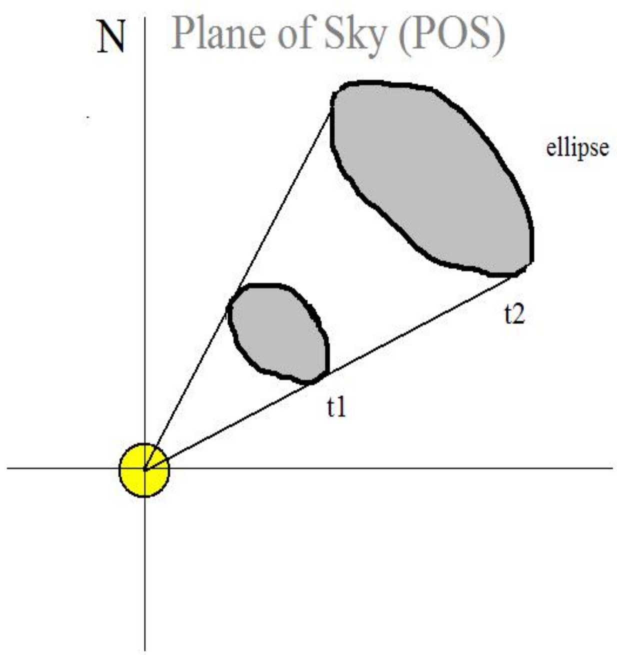
RT Modelling of CMEs Using WSA-ENLIL Cone Model

2012-08-14

Outline

- Basic Principles behind cone modeling of CMEs.
- Brief description of the models
- Analyzing CME impact
- Modeling setup on pele1
- Respond to modeling request - Collaboration with AFWA

Cone Model for Halo CME



The projection of the cone on the POS is an ellipse

Zhao et al, 2002, Cone Model:

The CME cone model is based on observational evidence that CME has more or less constant angular diameter in corona, being confined by the external magnetic field, so that CME does not expand in latitude in the lower corona, but expands in interplanetary space because of the weaker external field

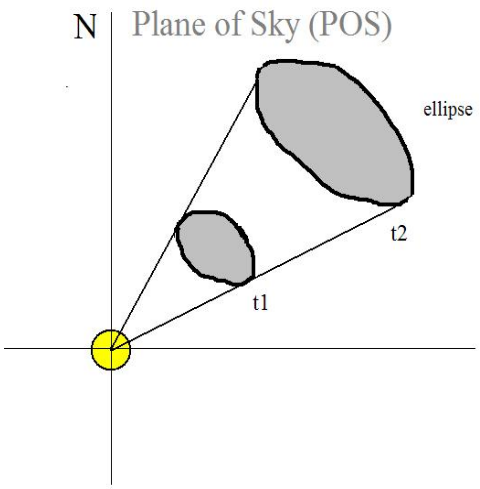
- CME propagates with nearly constant angular width in a radial direction
- CME bulk velocity is radial and the expansion is isotropic

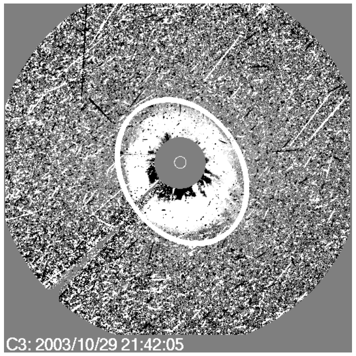
Xie et al, 2004, Cone Model for Halo CMEs – analytical method:

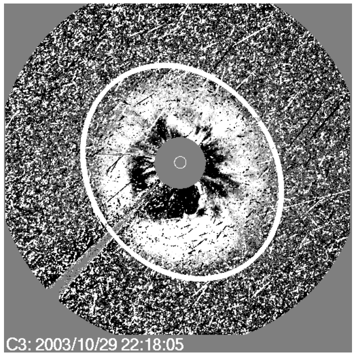
Overly simplistic approximation to describe halo CME

Cone Modelling for Halo CMEs

SOHO LASCO C3 difference images



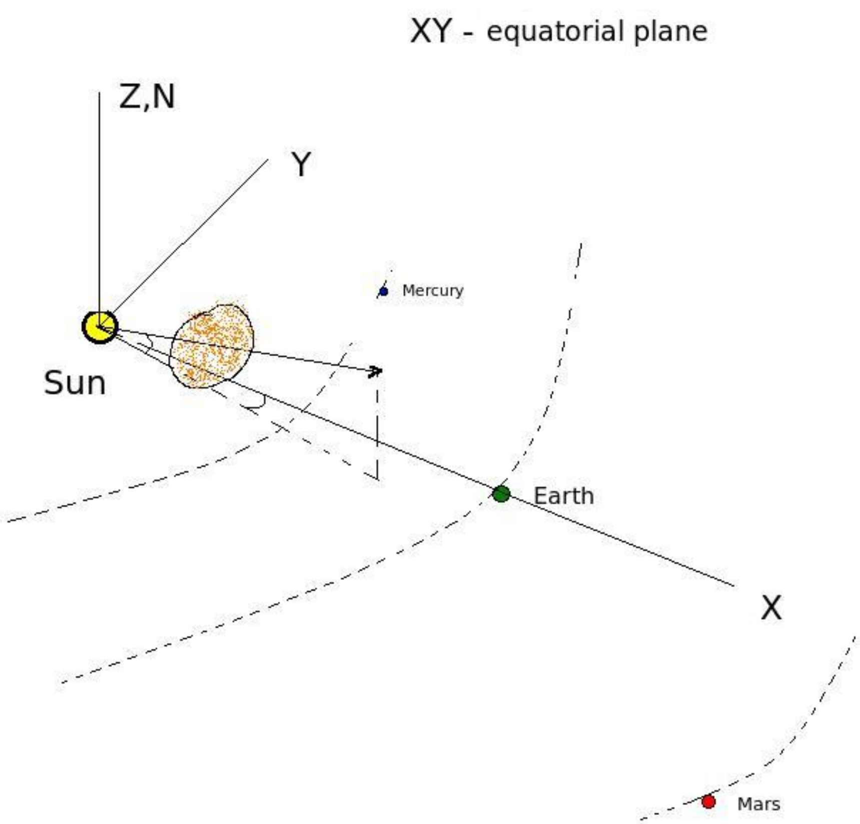




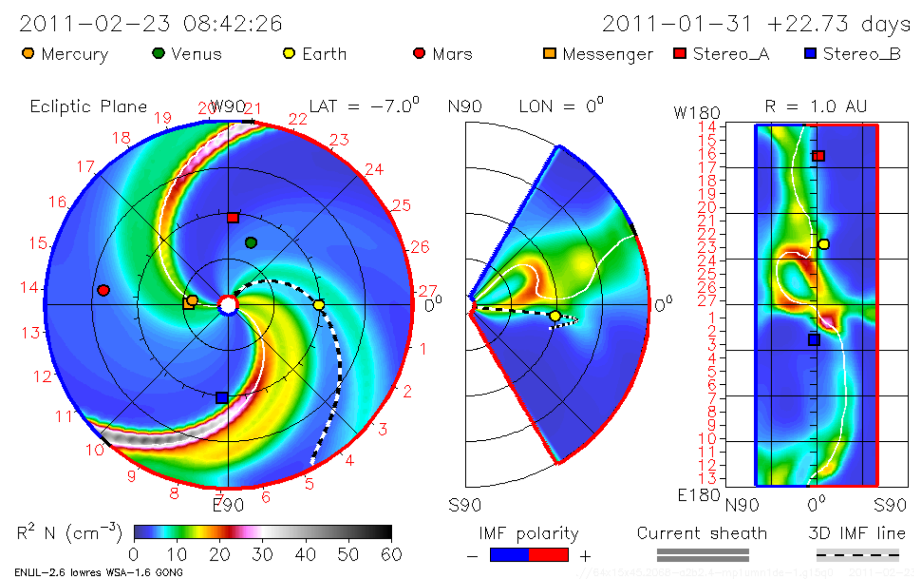
CME V and orientation

Input to WSA-ENLIL

Sun, Planets, CME



Heliocentric Earth Equatorial Coordinates - Heliographic

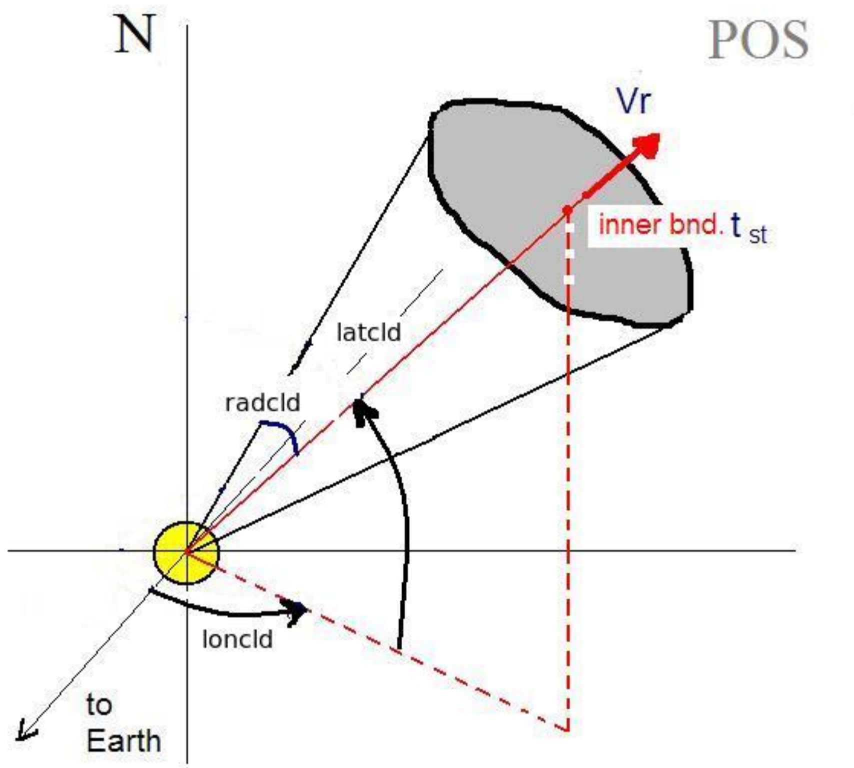


Constant Latitude Plane passing through Earth

Meridional Plane

1AU quasi-sphere

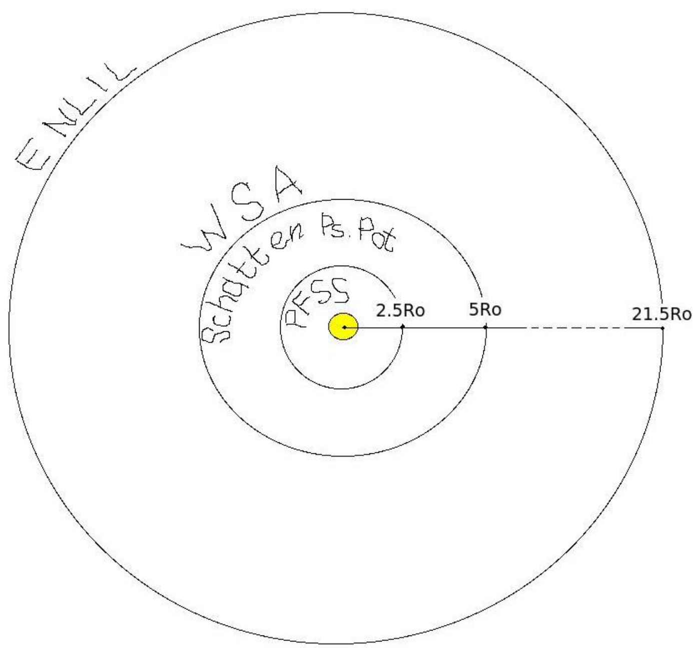
Cone model parameters



- tstart - when cloud at 21.5Rs
- Latitude
- Longitude
- Radius (angular width)
- Vr - radial velocity

Input to ENLIL cone model run

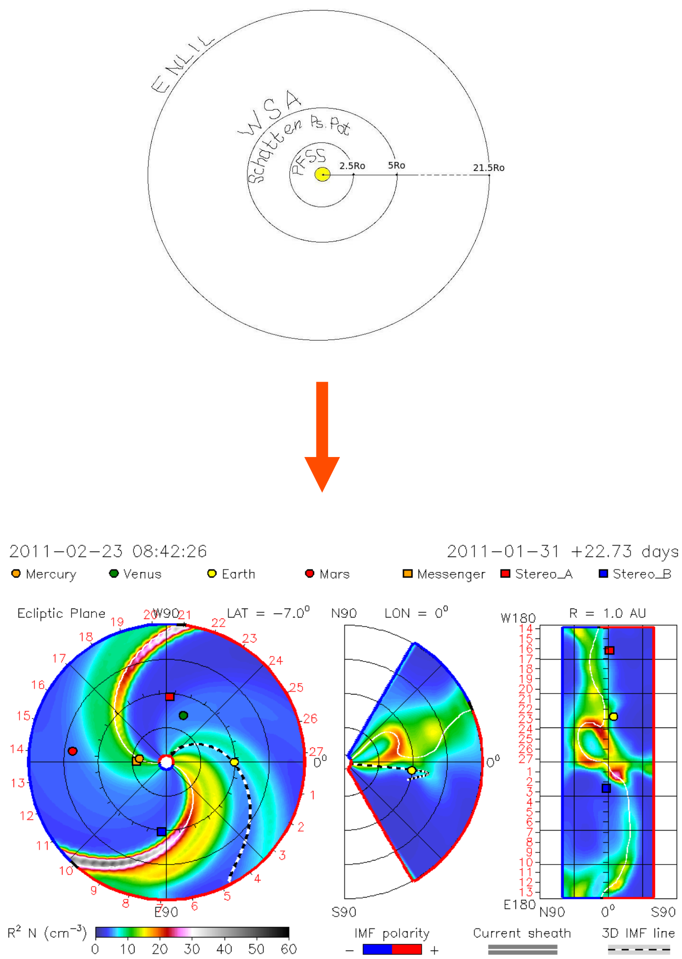
WSA- Input to ENLIL



WSA (Wang-Sheeley-Arge, AFRL):

- **PFSS** (Potential Field Source Surface)**.**
  Input: synoptic map photospheric magnetogram.
  Force free (even current free) solution with radial field at 2.5 Ro.
- **Schatten Current Sheet**.
  Input: PFSS.
  Modifies the sign of radial field to positive to prevent reconnection, creates potential solution with radial boundary conditions, restores the sign in the new solution at 5 Ro.
- **WSA.**
  Input: Schatten CS.
  Assuming radial constant speed flow at 5 Ro uses empirical formula for speed, determined by the rate of divergence of the magnetic field at 5 Ro and proximity of the given field line to the coronal hole boundary.

ENLIL - Schematic Description



ENLIL – *Sumerian God of Winds and Storms*

Dusan Odstrcil, GMU & GSFC

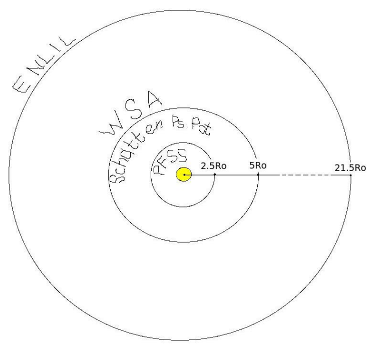
Input: WSA (coronal maps of Br and Vr updated 4 times a day). For toroidal components at the inner boundary- Parker spiral.

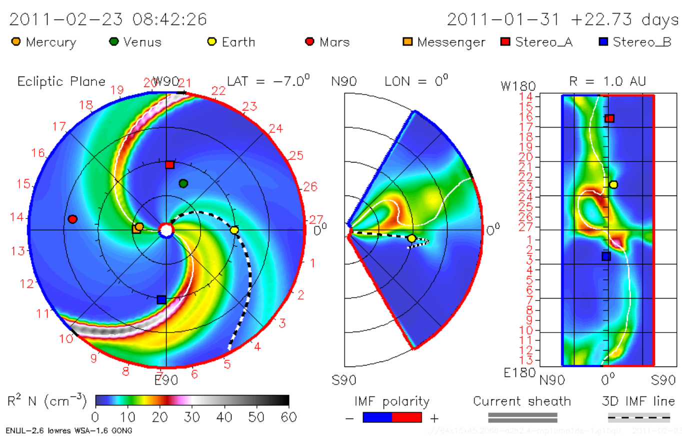
ENLIL's inner radial boundary is located beyond the sonic point: the solar wind flow is supersonic in ENLIL.

Computes a time evolution of the global solar wind for the inner heliosphere, driven by corotating background structure and transient disturbances (CMEs) at it's inner radial boundary at 21.5 Ro.

Solves ideal fully ionized plasma MHD equations in 3D with two additional continuity equations: for density of transient and polarity of the radial component of B.

ENLIL Schematic Description





ENLIL model does not take into account the realistic complex magnetic field structure of the CME magnetic cloud and the CME as a plasma cloud has a uniform velocity.

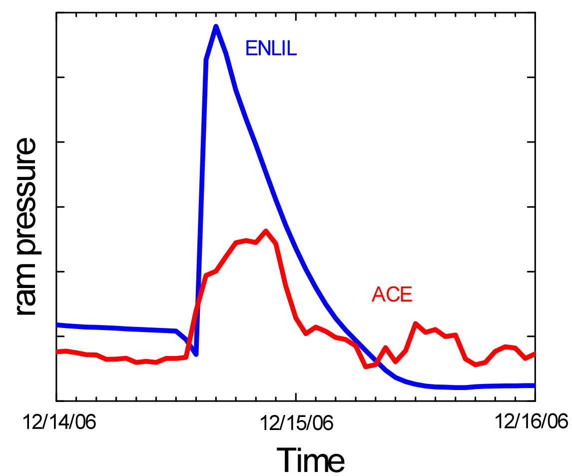
It is assumed that the CME density is 4 times larger than the ambient fast solar wind density, the temperature is the same. Thus, the CME has about four times larger pressure than the ambient fast wind. The CME cone model is based on observational evidence that CME has more or less constant angular diameter in corona, being confined by the external magnetic field, so that CME does not expand in latitude in the lower corona, but expands in interplanetary space because of the weaker external field. This is naturally a simplification, but launching of an overpressured plasma cloud at 21.5 **Rs,** roughly represents CME eruption scenario

Output:

3D distribution of the SW parameters at spacecrafts and planets and topology of IMF.

CME Impact

CME shock arrival – a sharp jump in the dynamic pressure derivative



Magnetic field required to stop SW

$$\frac{B_{stop}^2}{2\mu_0} = Knm_pV^2$$

→

Magnetopause standoff distance

$$\frac{r_{mp}}{R_e} = \left(\frac{B_0}{B_{stop}}\right)^{1/3}$$

Kp Index – P. Newel's Empirical Expression

Magnetic flux opening
rate at the magnetopause

$$\frac{d\Phi_{MP}}{dt} = V^{4/3} B^{2/3} \sin^{8/3}(cl\ ang/2)$$