Towards coupled heliosphere and SEP models

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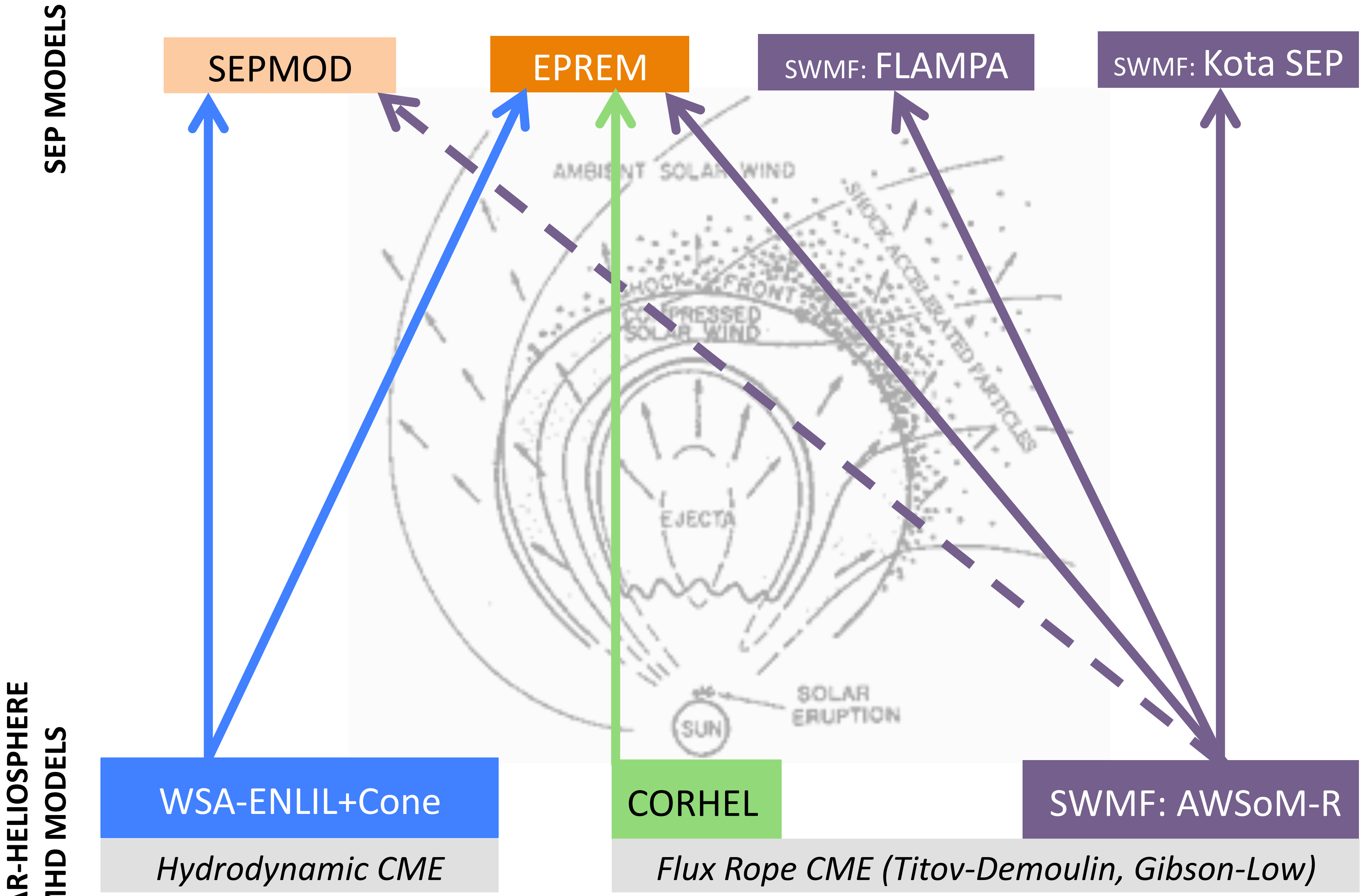
CCMC Workshop 11-15 April 2016

SEP modeling at the CCMC

- Heliospheric model outputs are an important ingredient for SEP simulations.
- The CCMC is making steps towards offering a system to run SEP models driven by a variety of heliospheric models available at CCMC such as CORHEL, ENLIL, and SWMF.
- Models can be combined as a chain, or coupled in parallel together

Towards coupled heliosphere and SEP models



Modelers: N. Arge, D. Odstrcil, J. Luhmann, J. Linker, N.Schwadron, M. Gorby, I.Sokolov

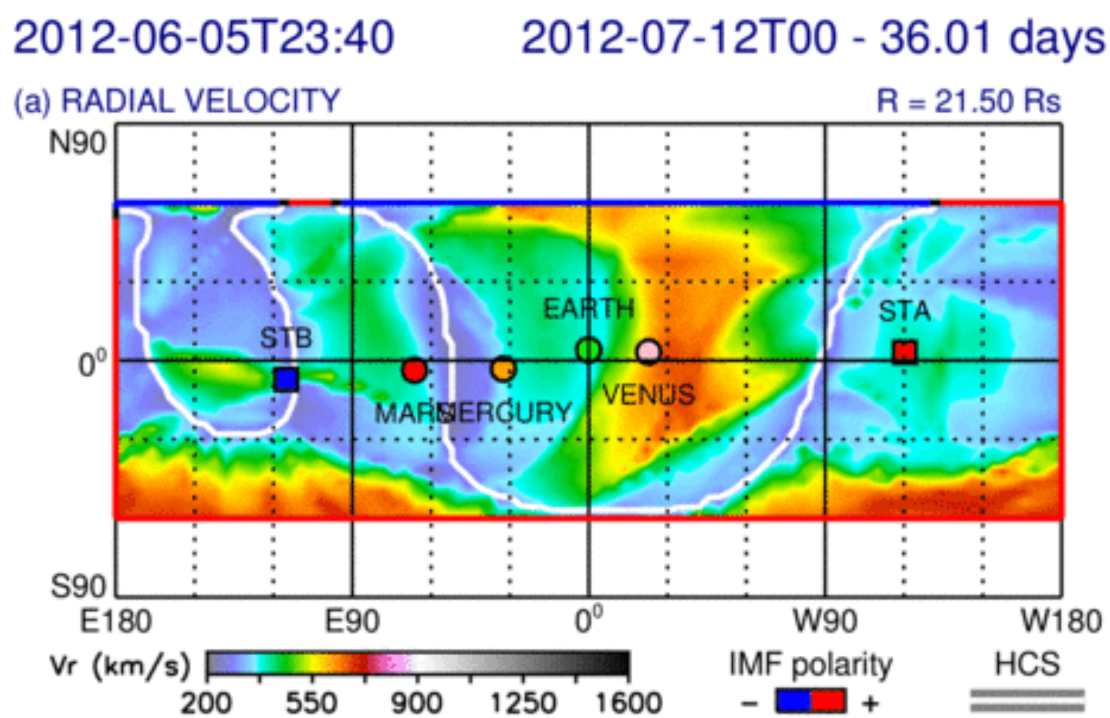
Coupled SEP modeling at the CCMC

CCMC is facilitating some first steps to prepare Runs on Request options:

- Coupling of ENLIL with **EPREM** with model developers D. Odstrcil, N. Schwadron and M. Gorby
- Coupling ENLIL and **SEPMOD** with model developers D. Odstrcil and J. Luhmann

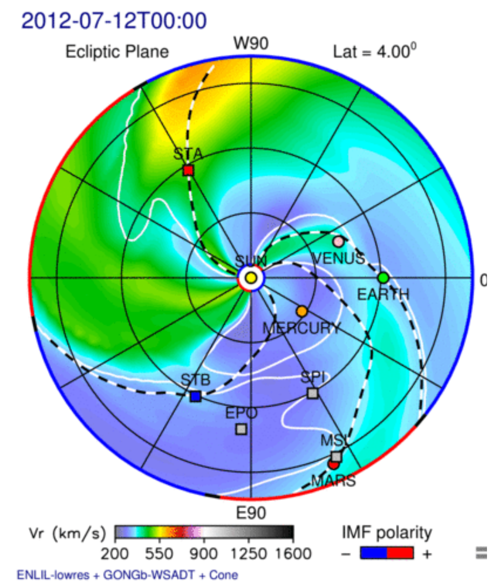
Modeling CMEs with WSA-ENLIL+Cone

- WSA-ENLIL is a global 3D MHD model which provides a time-dependent description of the background solar wind plasma and magnetic field into which a spherical or ellipsoid shaped CME can be inserted.
- A CME-like hydrodynamic structure is launched into the solar wind and magnetic field computed from the WSA coronal model at 21.5 R_s.
- WSA coronal maps generated from synoptic magnetograms provide the magnetic field and solar wind speed at the boundary between coronal PFSS and heliospheric models
- Other coronal models can also be coupled with ENLIL (e.g. MAS, heliospheric tomography).



Model References: Arge and Pizzo, 2000; Arge et al., 2004.
Odstrcil et al. 1996; Odstrcil and Pizzo, 1990a,b; Odstrcil, 2003.

Considerations for SEP modeling with WSA-ENLIL+Cone



- Understanding gradual SEP events requires a realistic picture of the global background solar wind.
- During active periods there can be multiple CMEs driving shocks which can merge and produce SEPs over a wide range in longitude.
- To characterize observed SEP profiles it is essential to include all of the relevant CMEs and allow enough time for the events to propagate and interact.
- Using a larger outer boundary of 5.3 AU is also needed when the spacecraft:
  - may be magnetically connected to the shock from behind
  - observes particles from magnetic mirroring or from a reflecting boundary from behind.
- Accurate descriptions of the heliosphere, and hence modeled SEPs, are achieved by ENLIL only when the background solar wind is well-reproduced and CME parameters are accurate.

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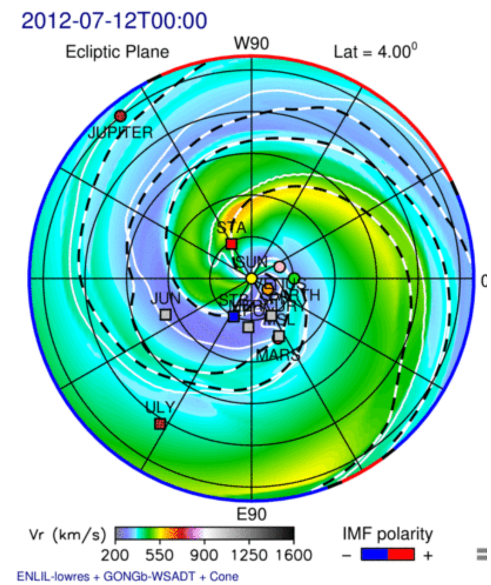

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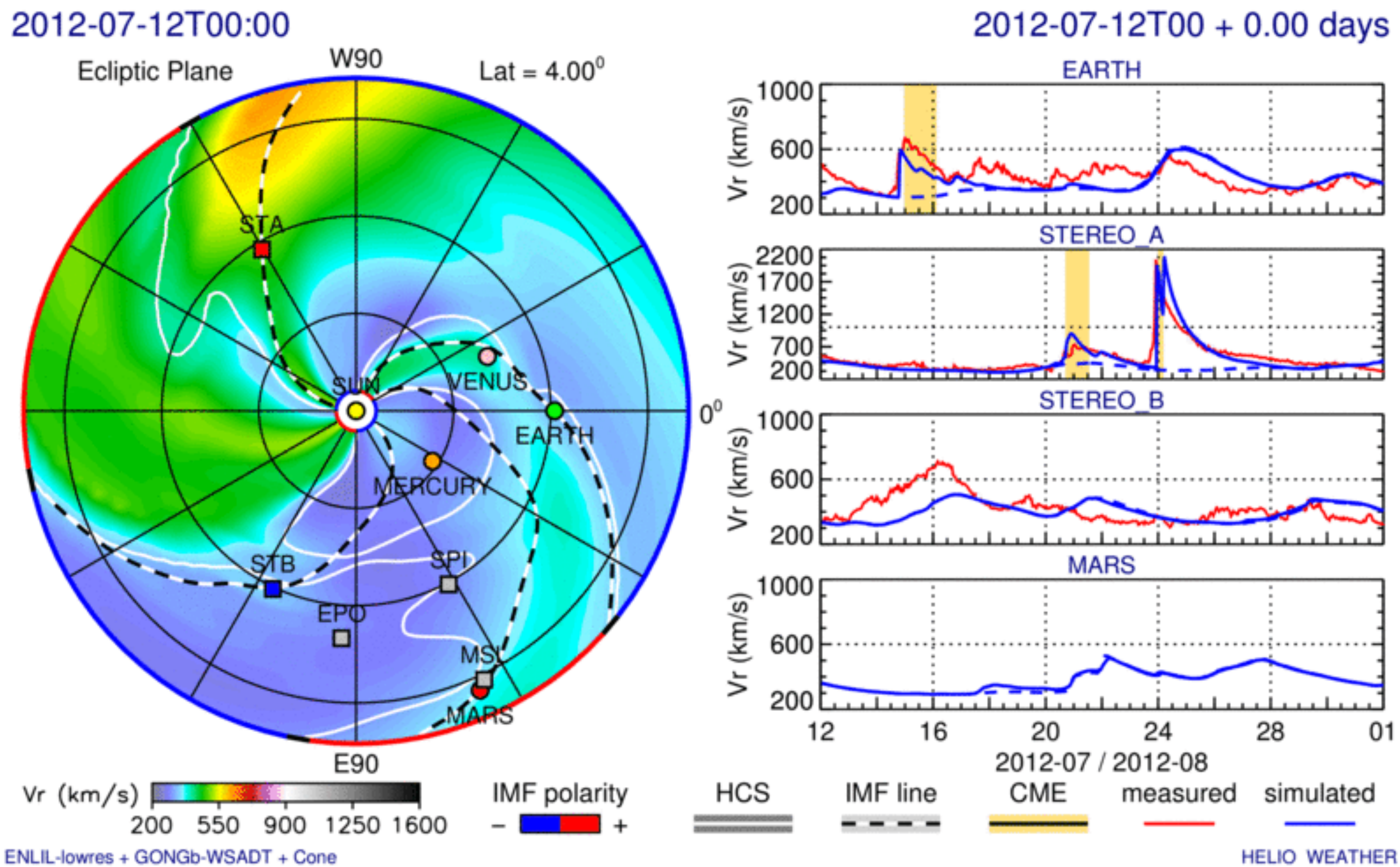
July 2012

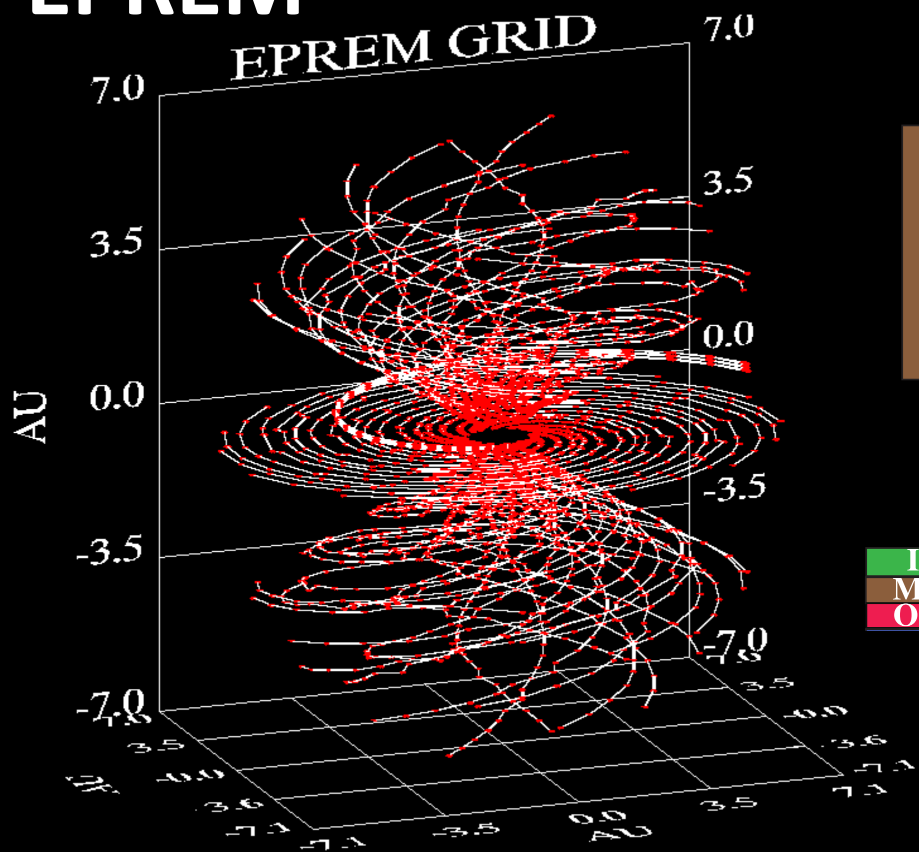


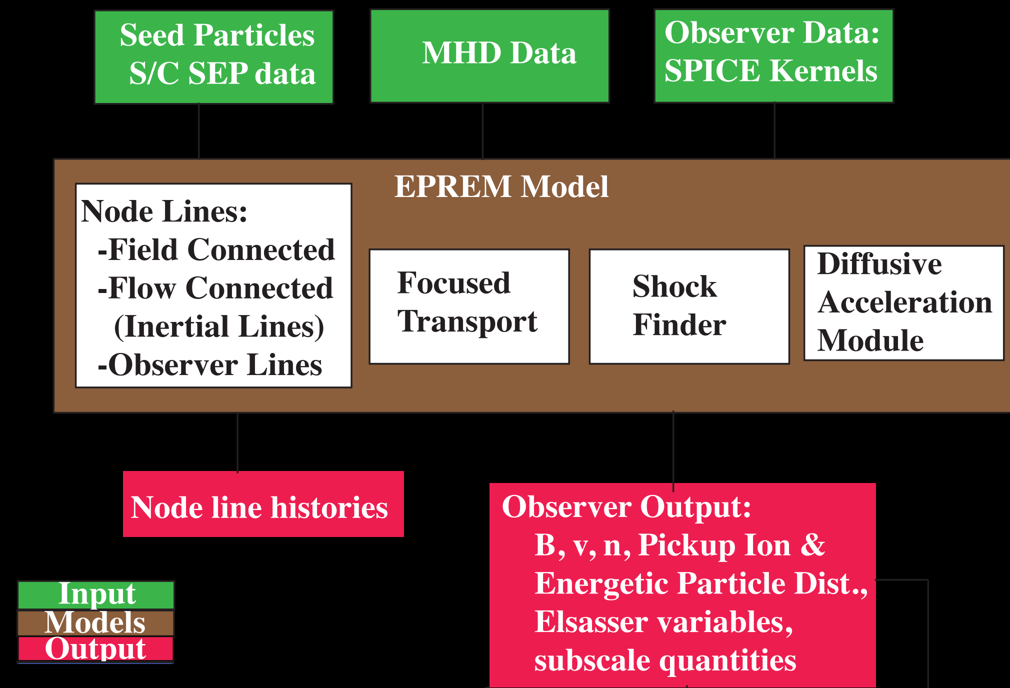
WSA-ENLIL+Cone velocity contour plot

Bain et al., *ApJ*, 2015, in revision

EMMREM System

EPREM





Schwadron et al., SW, 2010

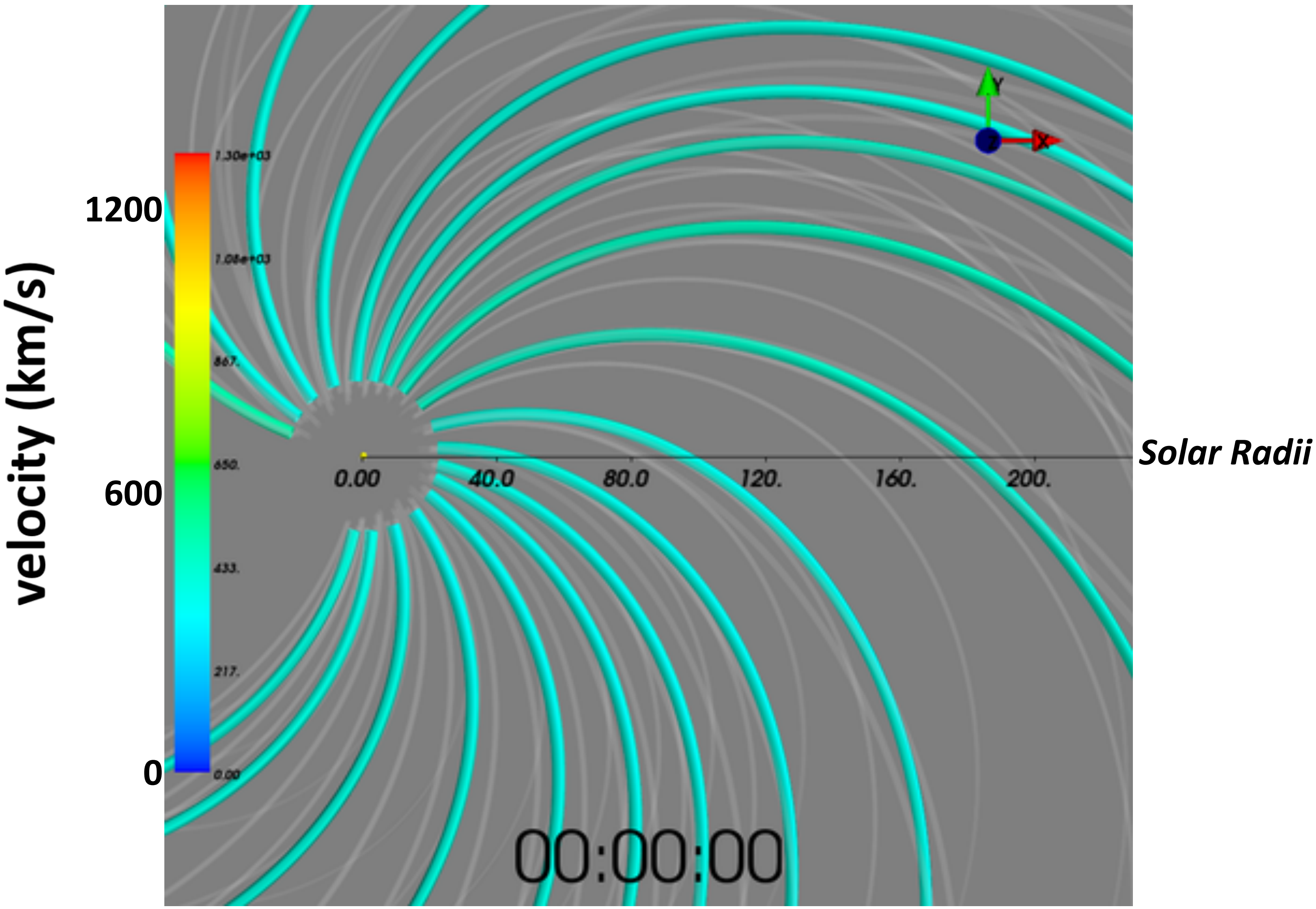
Focused Transport in Lagrangian Frame (Kota, 2005)

$$\left(1-\frac{(\vec{u}\cdot e_b)v\mu}{c^2}\right)\frac{df}{dt} + v\mu\frac{\partial f}{\partial z} + \frac{(1-\mu^2)}{2}\left[v\frac{\partial \ln B}{\partial z} - \frac{2}{v}e_b\cdot\frac{d\vec{u}}{dt} + \mu\frac{d\ln(n^2/B^3)}{dt}\right]\frac{\partial f}{\partial \mu} +$$

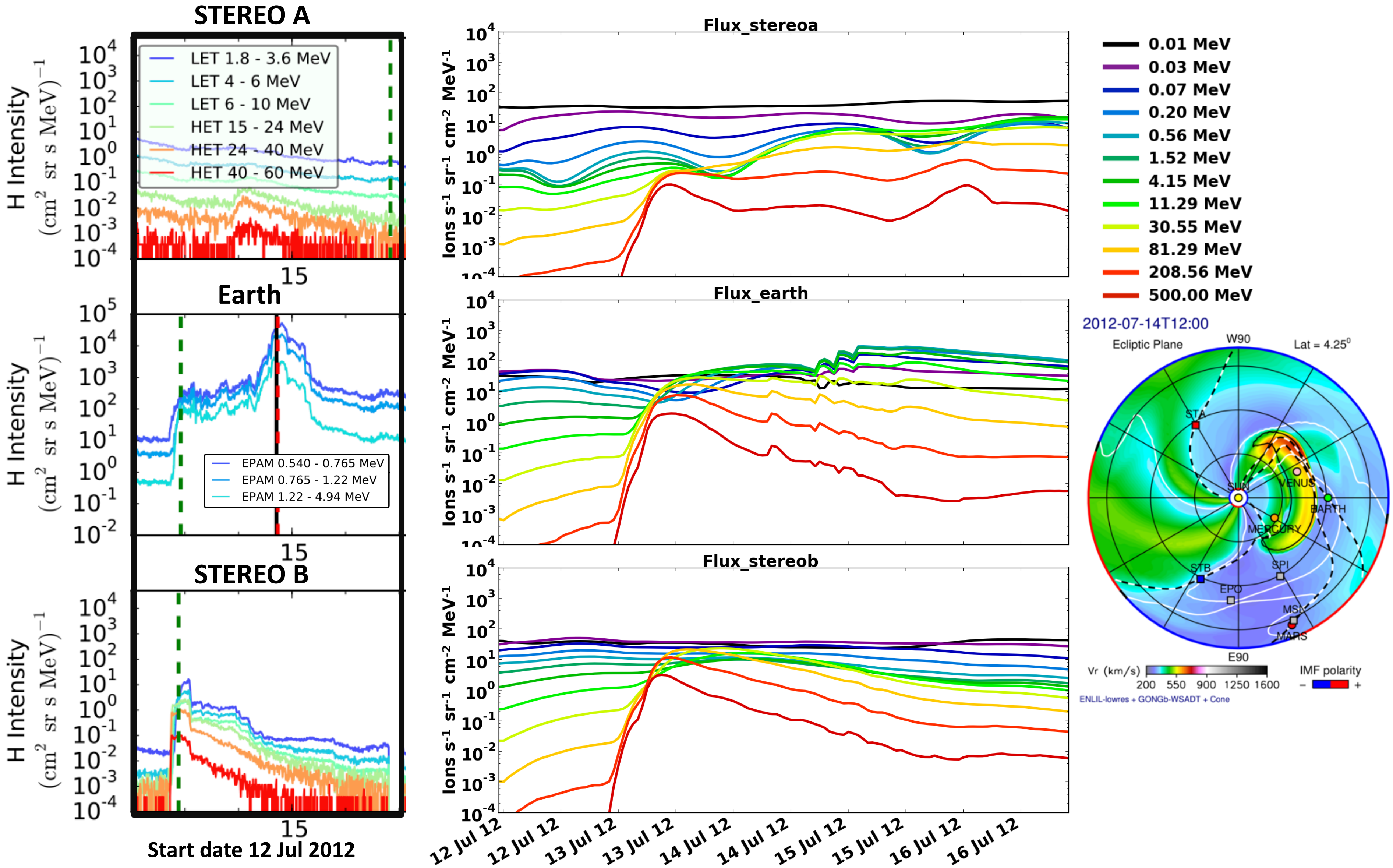
$$\left[-\frac{\mu e_b}{v}\cdot\frac{d\vec{u}}{dt} + \mu^2\frac{d\ln(n/B)}{dt} + \frac{(1-\mu^2)}{2}\frac{d\ln B}{dt}\right]\frac{\partial f}{\partial \ln p} = \frac{\partial}{\partial\mu}\left(\frac{D_{\mu\mu}}{2}\frac{\partial f}{\partial\mu}\right) + S$$

- **Cross-field Diffusion**
- **Drift**

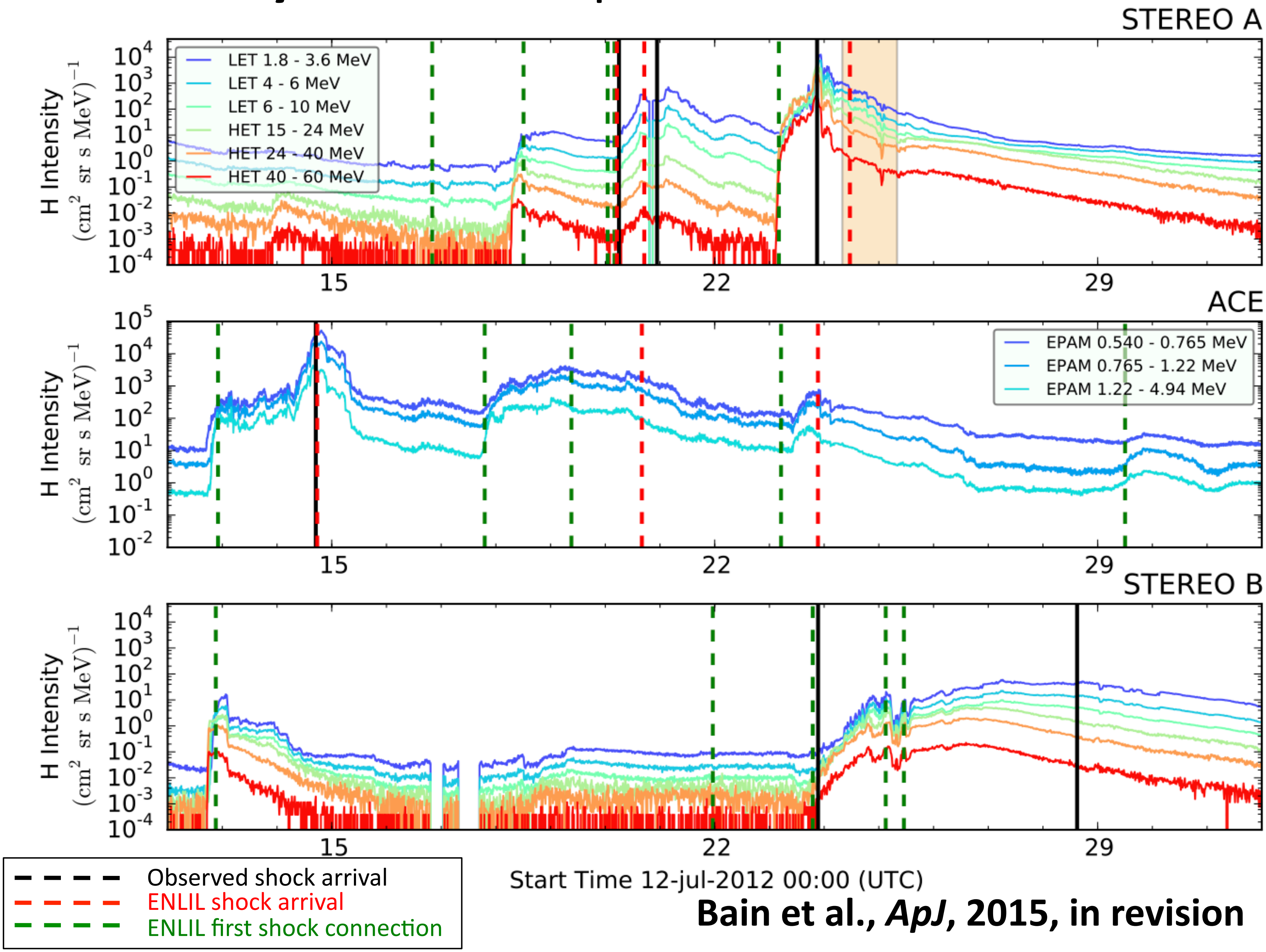
12 July 2012: ENLIL+EPREM domain



12 July 2012 CME
Preliminary ENLIL+EPREM results

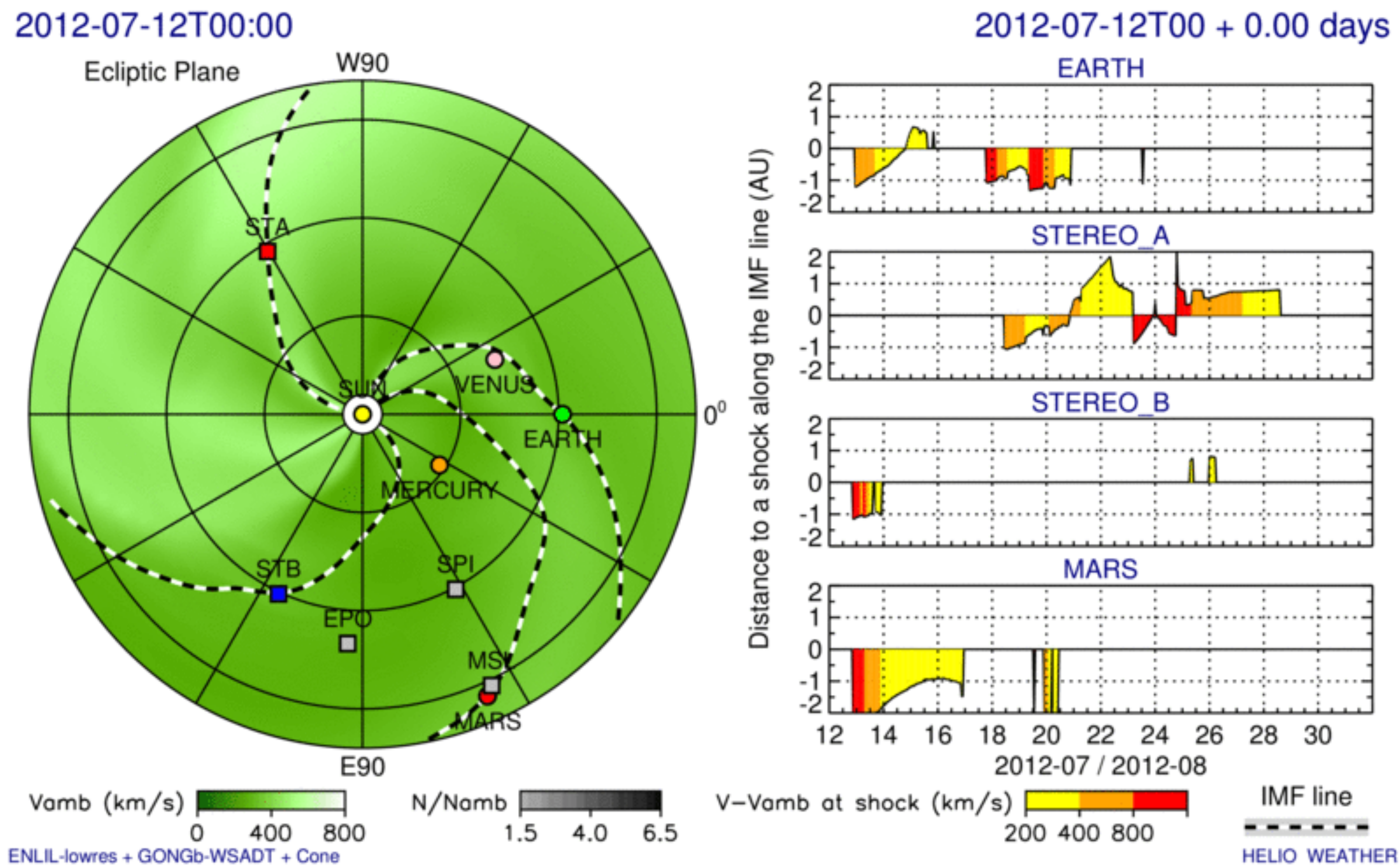


July 2012- Multiple SEP events observed



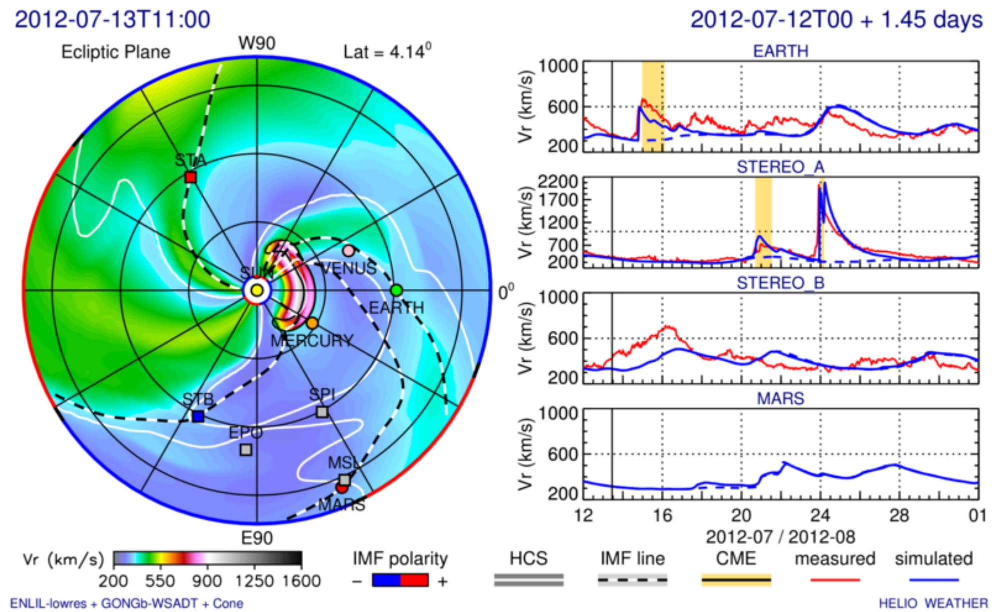
Bain et al., *ApJ*, 2015, in revision

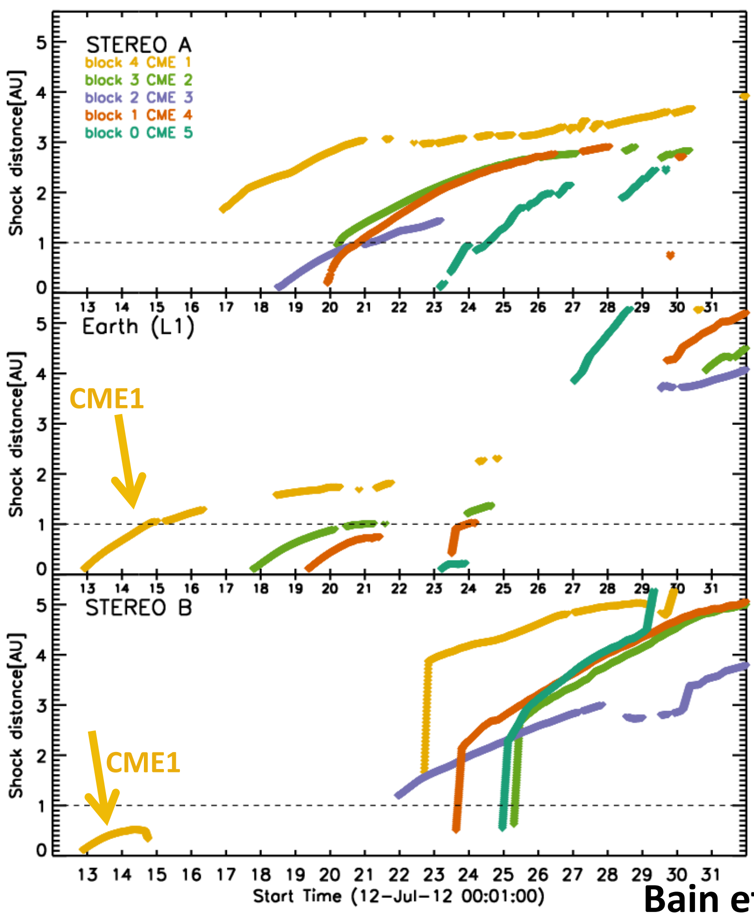
Interplanetary Shocks — "All Clear/Alert" SEP Event Predictions

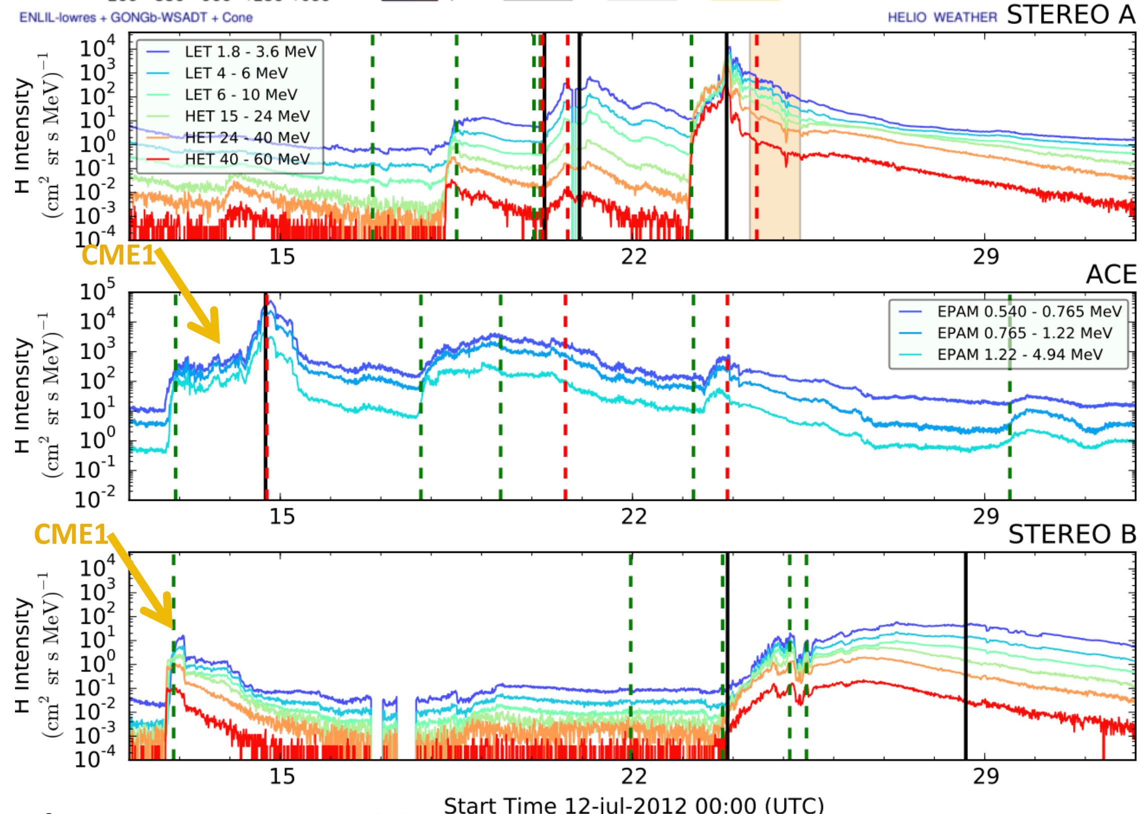


July 2012

ENLIL shock connectivity







Bain et al., *ApJ*, 2015, in revision

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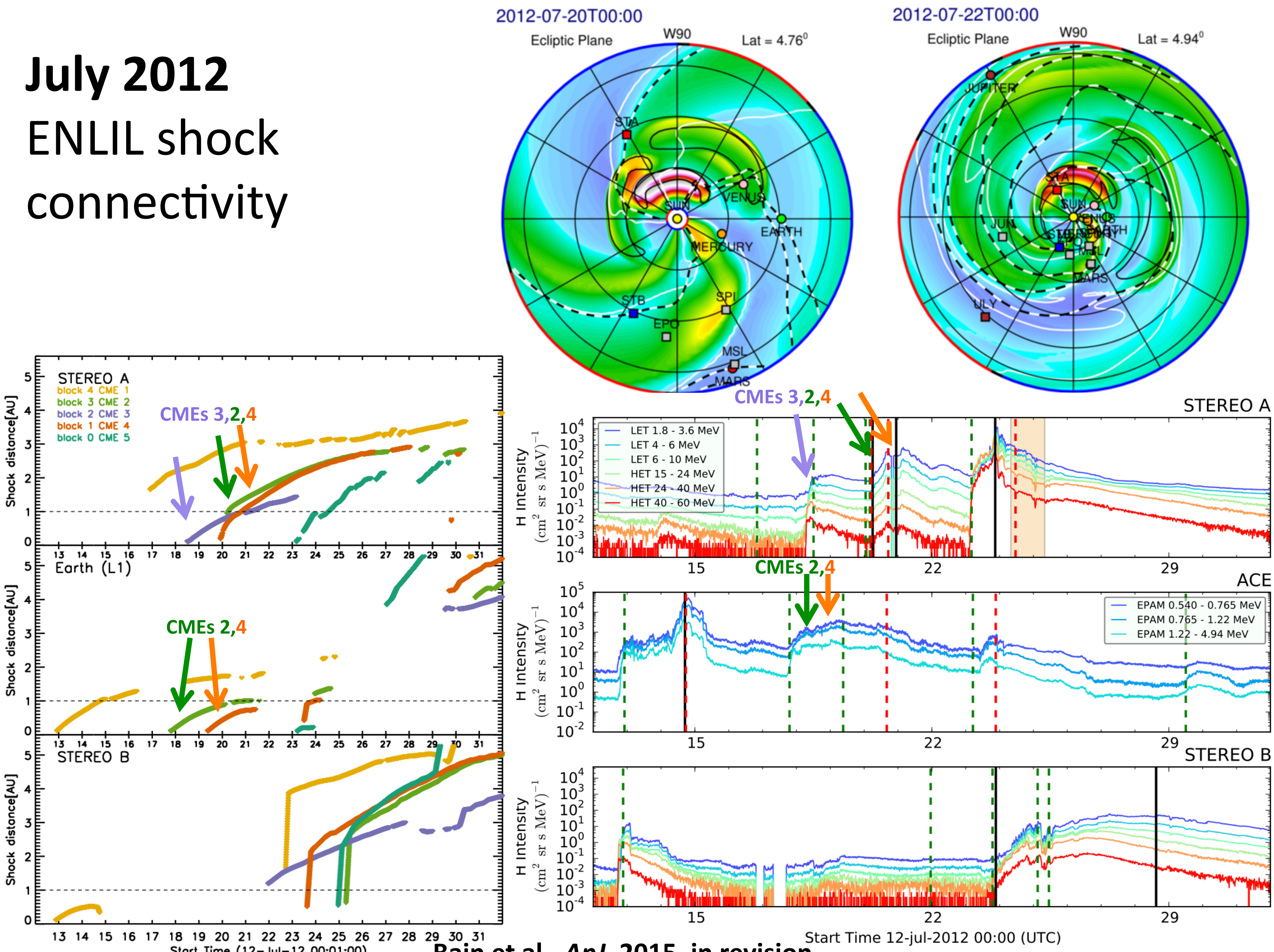
ENLIL shock connectivity



Bain et al., *ApJ*, 2015, in revision

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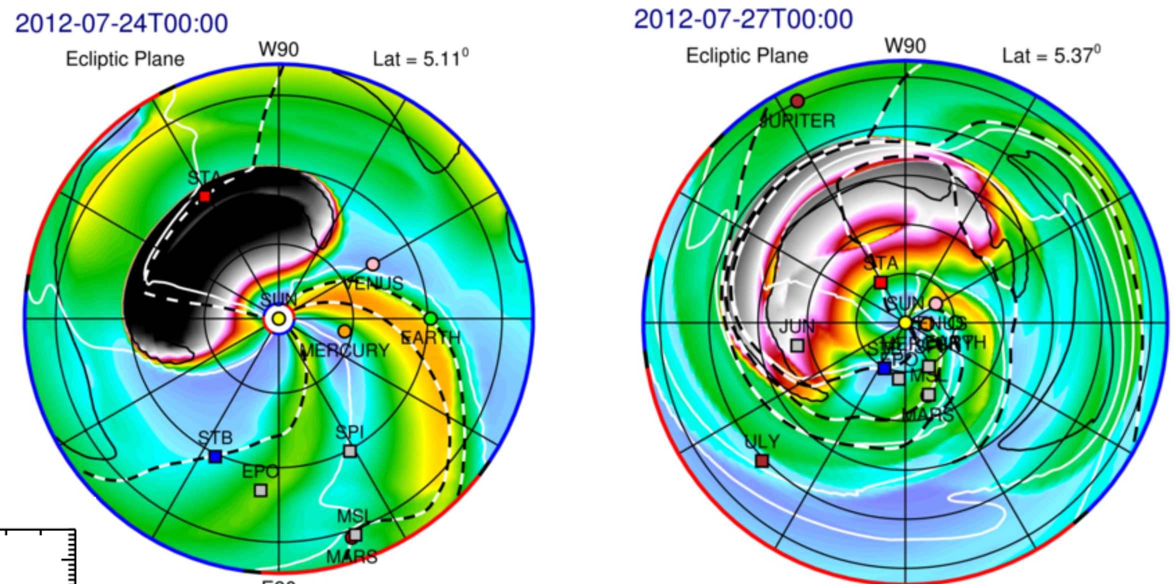
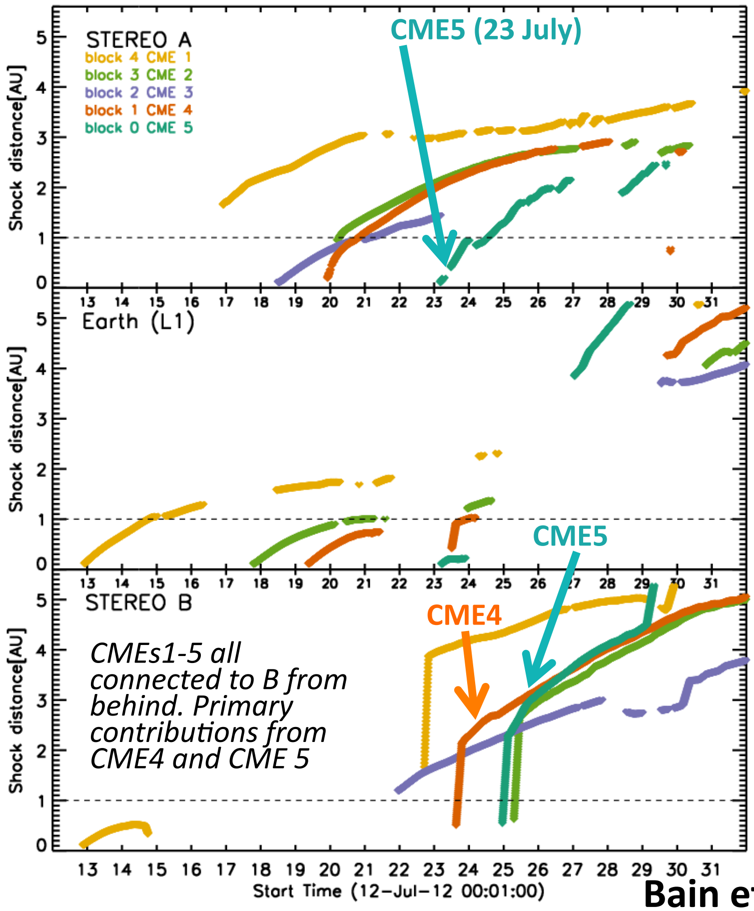
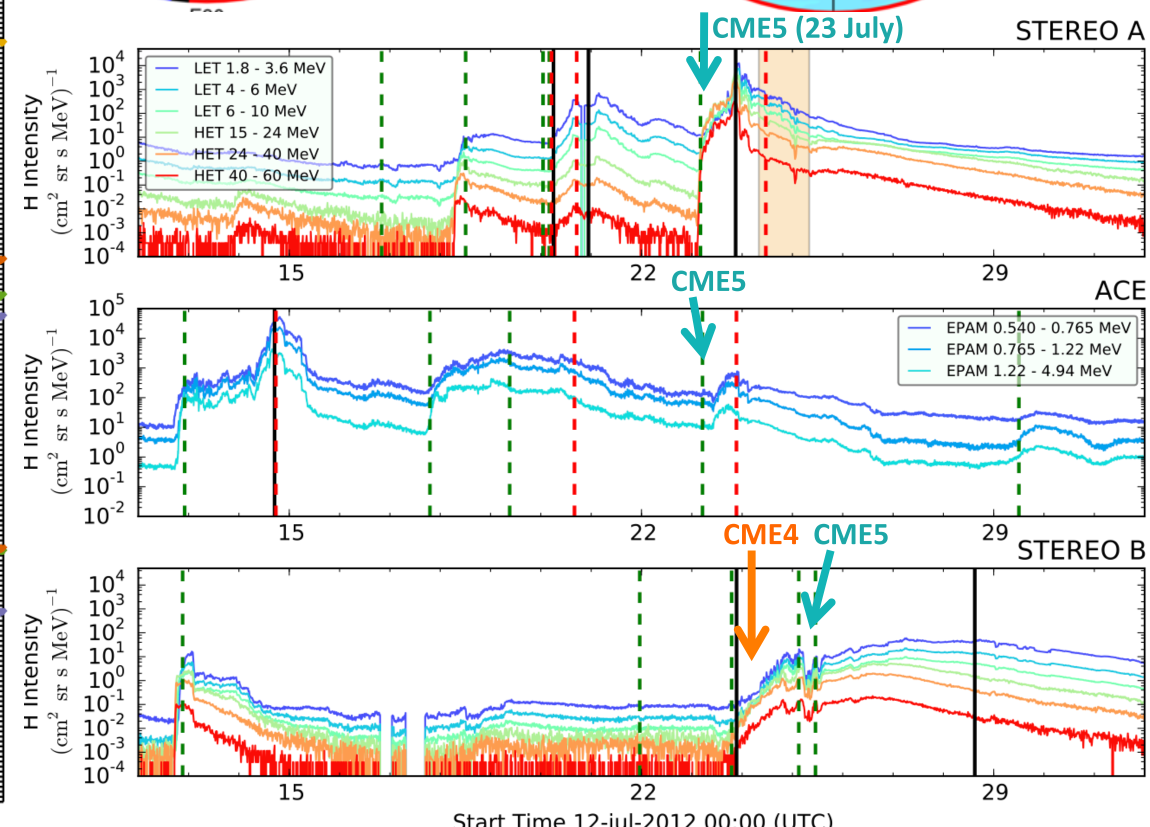
ENLIL shock connectivity

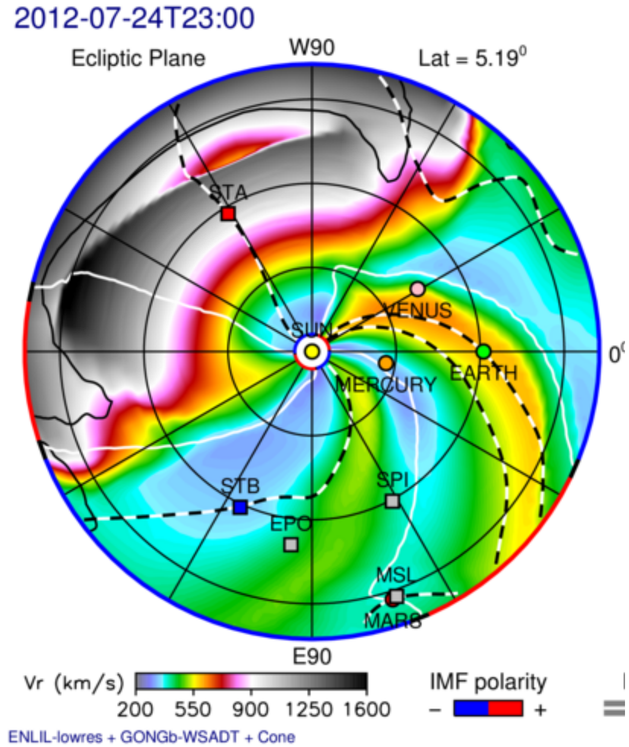


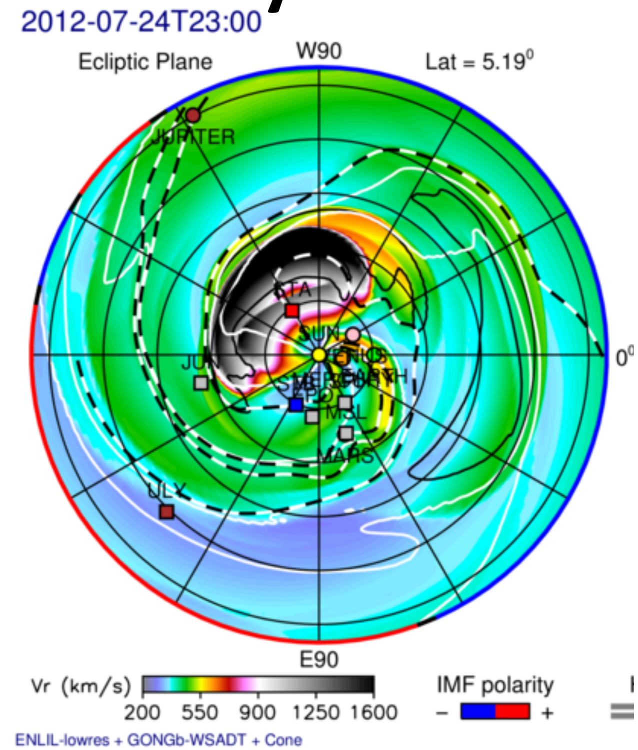




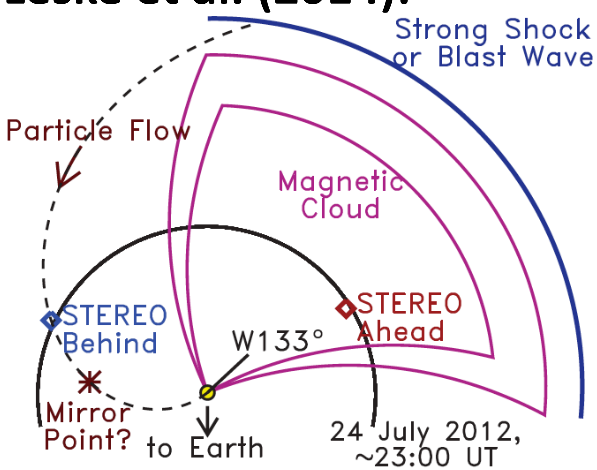
Bain et al., *ApJ*, 2015, in revision

SEP at STEREO B on 24 July 2012





Leske et al. (2014):



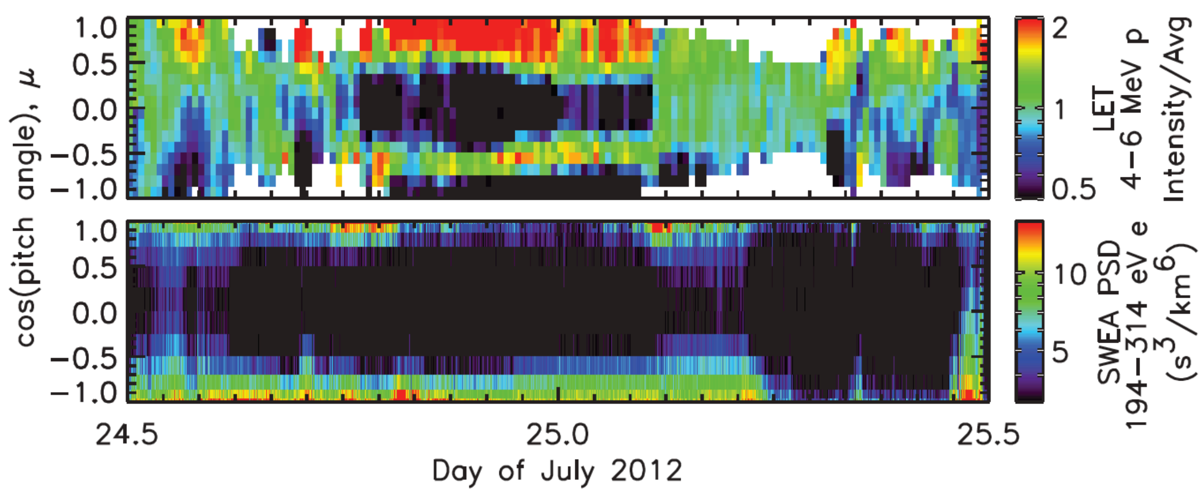
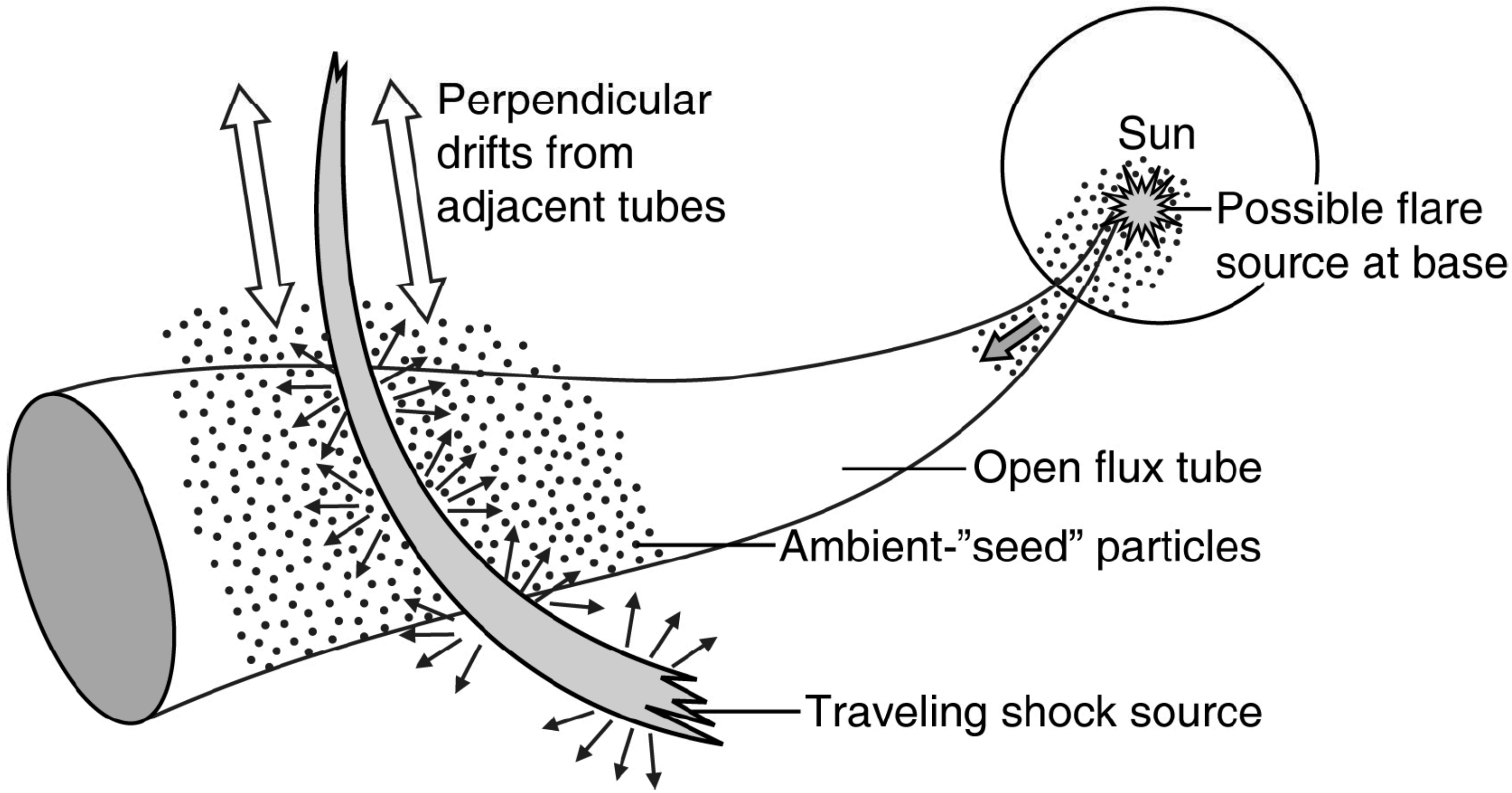


Figure 1. *Left panel:* Positions in the ecliptic of both STEREO spacecraft late on 2012 July 24, near a circle with radius of 1 AU. Also shown schematically is the

SEPMOD

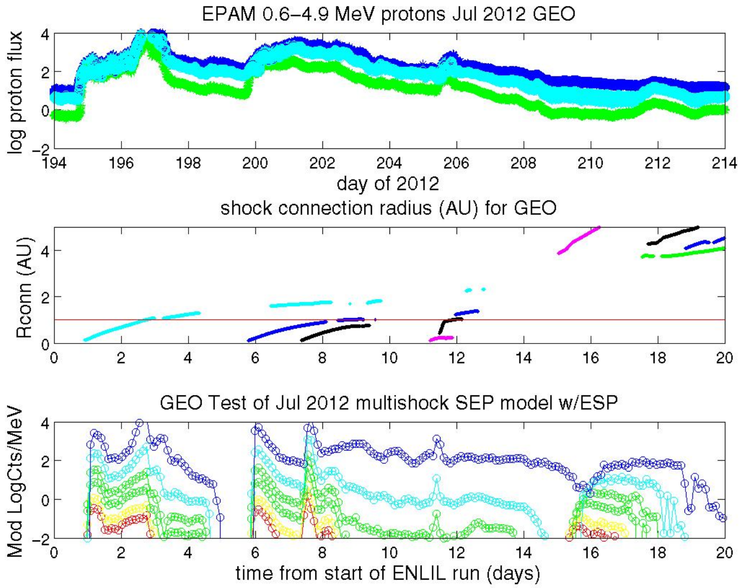
SEPMOD injects SEPs onto the observer's field line at intensities dependent on the connected shock source strength



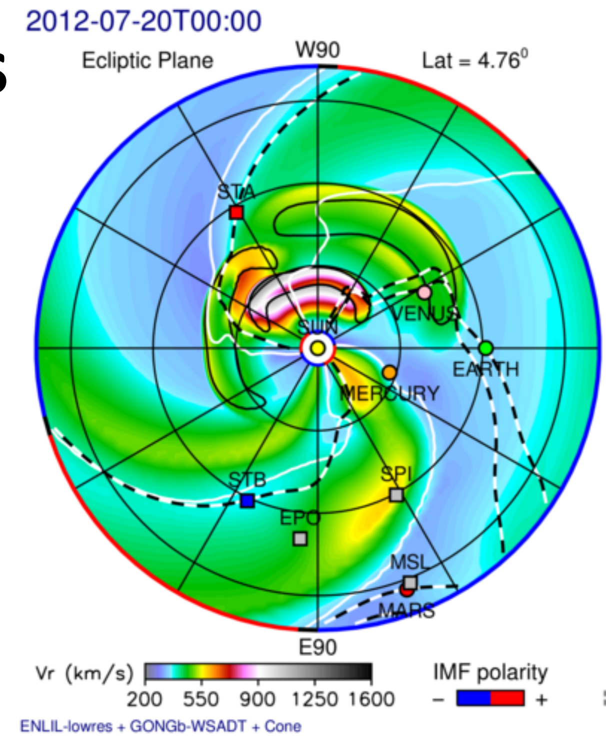
Assumes that field-aligned propagation determines what is detected.
The observer can be located anywhere within the ENLIL model domain.

July 2012: ENLIL+SEPMOD results

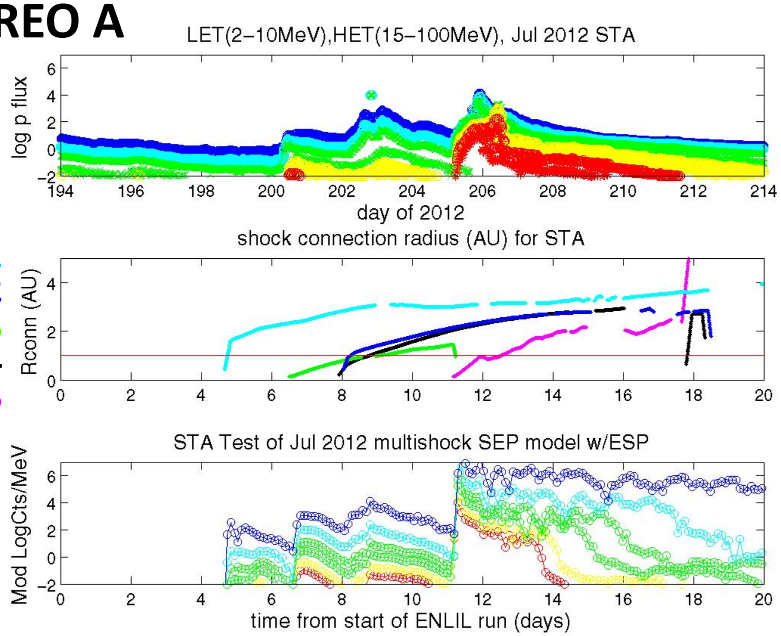
Earth



CME1
CME2
CME3
CME4
CME5

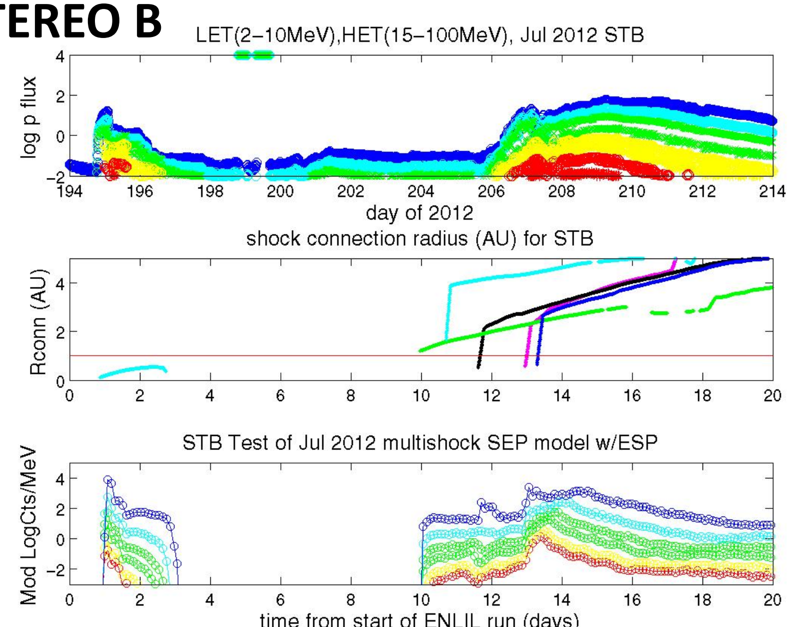


STEREO A



CME1
CME2
CME3
CME4
CME5

STEREO B



CME1
CME2
CME3
CME4
CME5

(from J. Luhmann)

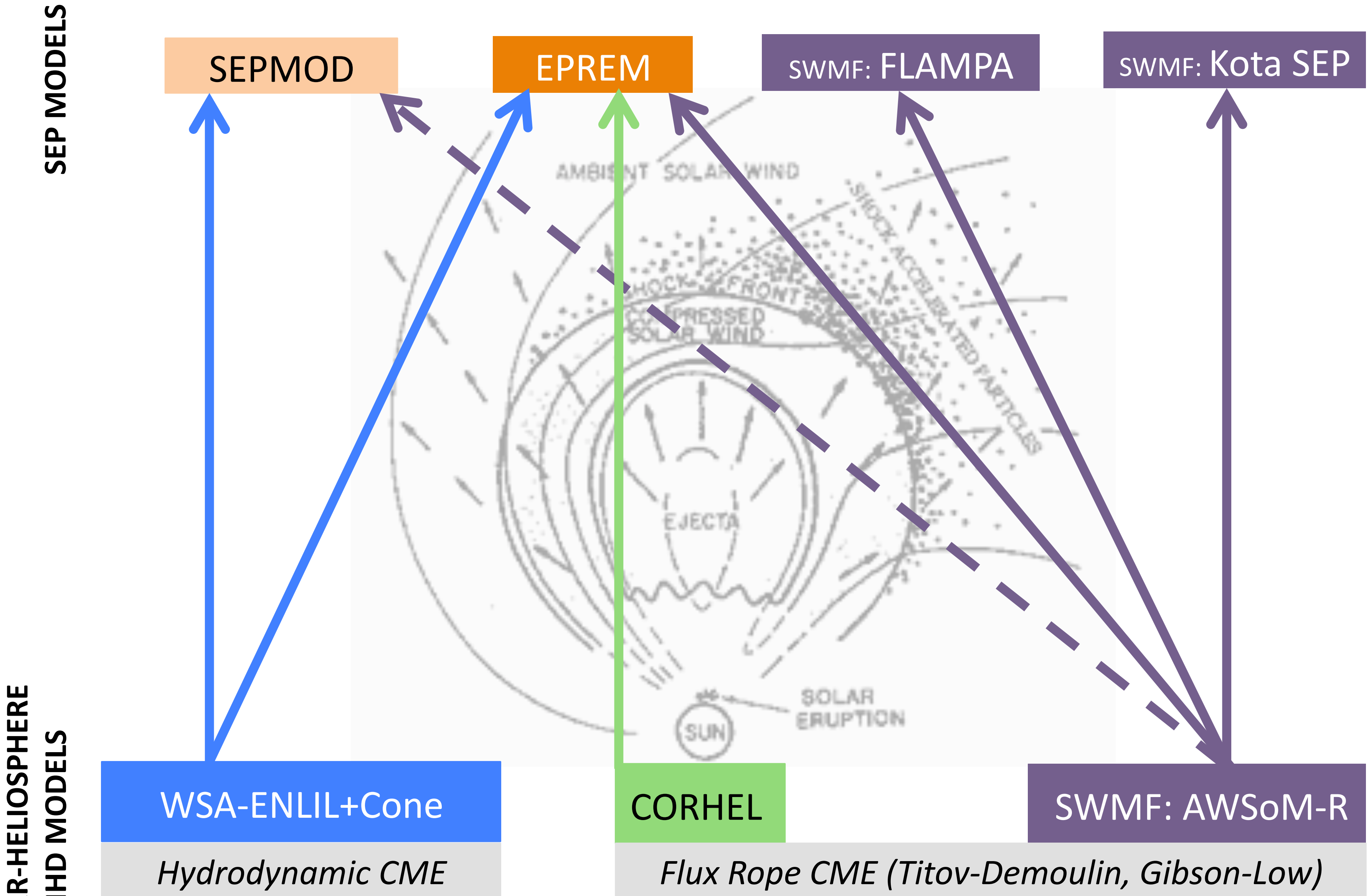
SEP modeling with WSA-ENLIL+Cone: Next Steps

- SEP modeling based on global MHD models provides important context to SEP observations
- Continue case studies of SEP observations and SEPMOD and EPREM modeling using ENLIL modeling as input.
- Investigating which magnetograms to use to best reproduce the heliospheric conditions (collaboration with European FP7 HELCATS project).
- Determining the effects of ENLIL inner and outer boundaries and resolution on producing useful output for SEPMOD and EPREM
- Will begin to make routine ENLIL runs with similar fidelity and model shock information for testing with SEPMOD and EPREM as a **regular product option.**
- Model developers are continuously working on updates better reproduce SEP observations.
- **Both SEPMOD and EPREM can also be used in combination with other heliospheric models. (e.g. CORHEL-EPREM discussed earlier this week, see *Schwadron et al. ApJ, 2015; Schwadron et al. SW, 2014*).**

SEP modeling at the CCMC

- CCMC is making steps towards offering a system to run SEP models driven by a variety of heliospheric models available at CCMC such as CORHEL, ENLIL, and SWMF.
- **Full rotation ENLIL v2.8 simulations are available on Runs on Request.** The interface for time dependent inner boundary simulations will be available in a couple months. **Users may submit special requests now.**
- **Coming very soon:** CCMC will provide the new ENLIL shock and fieldline output to users, for the use of SEP models which require shock parameters along observer-connected field lines. Full 3D MHD output at a required time cadence will be available for other models. (e.g. see run ID `Leila_Mays_070215_SH_1`)
- **EPREM, EPREM + cone CME, and ENLIL+EPREM will be available on Runs on Request soon.** Preliminary runs posted at: http://ccmc.gsfc.nasa.gov/community/LWS/lws_cswepa.php
- We invite heliospheric and SEP model developers to participate in this testing and provide us with their computational requirements for coupling/combination different models.
- **We would like to hear about what aspects are necessary for making the system a useful tool for developers and users.**

Towards coupled heliosphere and SEP models



Modelers: N. Arge, D. Odstrcil, J. Luhmann, J. Linker, N.Schwadron, M. Gorby, I.Sokolov

Leila_Mays_052715_SH_1

July 2012 simulation page

Key Word: 2012-07-12 to 2012-08-01 five CMEs. 12jul_6_sxd1. ENLIL v2.8e. SEPMOD. DREAM2. EPREM coupling.

new format

Model Type: Heliosphere
Model & Version: ENLIL 2.8e
Boundary Condition Type: Single Daily Update Map (du)
Inner Boundary Condition: from_WSA_V2.2_model
Run Objective: cone_model
Observatory: GONGB (Standard QuickReduce Magnetogram Synoptic Map - mrbqs)
Carrington Rotation Start: 2099 **Carrington Longitude Start:** 142°
Start computation date (rundate_cal): 2010-07-30T00:00:00
Coronal observations date (obsdate_cal): 2010-08-05T00
Time unit = 3600. seconds **Relaxation start time relative to rundate (tstart):** -876. time units
Simulation stop time (tstop): 600 time units **Full 3D output cadence (tstep):** 1 time units
Outer Boundary: 5.3 AU (Jupiter inclusive; **radial span:** 5.2 AU, **region** 5 AU)
Simulation Grid: 832x30x90 (0.1 to 5.3 AU radius; ±60° latitude, 30° to 150° co-latitude; 0° to 360° longitude)
Geometry: Spherical and Uniform **Coordinate System:** HEEQ+180°
Resolution: low **Number of Simulation blocks (nblk):** 7
Ambient wind conditions setting: a3b1 **ratio of specific heats (gamma):** 1.6666667 **runpar**=g53q5
(**vfast**=700., **vslow**=200., **vrfast**=0., **vrslow**=75., **bfast**=350., **bscl**=4., **dfast**=125., **tfast**=1.5, **xalpha**=0.05, **nbrad**=1)
Rotation of the inner boundary: synodic

CME Input File: cmes-2010-aug-v13.dat **Number of CMEs:** 6
Hydrodynamic cloud setting: sa1
(**dcld**=4,4,8,4,4,4, **tcld**=1., **xcld**=1., **ncld**=2)
Cavity setting: radcav=0., **dcav**=1., **tcav**=4.

- View the CME input file.
- View the file listing of inner boundary filenames.
- View 3D Data
- View control file with input parameters for the run.
- Download output .dat files.
- View quick look graphics for the run | list of quicklook graphics links
  Note: Quick look graphics has been designed by the model developer to enable quick evaluation of the result
  more information regarding this option please contact the CCMC staff.


Leila_Mays_052715_SH_1
Temporal profile output files (ASCII):
Leila_Mays_052715_SH_1_evo_Earth_20120712T00.dat.gz
Leila_Mays_052715_SH_1_evo_Epoxi_20120712T00.dat.gz
Leila_Mays_052715_SH_1_evo_Juno_2
Leila_Mays_052715_SH_1_evo_Jupiter
Leila_Mays_052715_SH_1_evo_Mars_2
Leila_Mays_052715_SH_1_evo_Mercur
Leila_Mays_052715_SH_1_evo_Msl_20
Leila_Mays_052715_SH_1_evo_Spitzer
Leila_Mays_052715_SH_1_evo_Stereo-
Leila_Mays_052715_SH_1_evo_Stereo-
Leila_Mays_052715_SH_1_evo_Ulysses
Leila_Mays_052715_SH_1_evo_Venus
Derived shock information along field lines (ASCII):
Leila_Mays_052715_SH_1_12jul_5_sxd1-dat-geo-fld00.tgz
Leila_Mays_052715_SH_1_12jul_5_sxd1-dat-geo-sho00-04.tgz
Leila_Mays_052715_SH_1_12jul_5_sxd1-dat-mars-fld00.tgz
Leila_Mays_052715_SH_1_12jul_5_sxd1-dat-mars-sho00-04.tgz
Leila_Mays_052715_SH_1_12jul_5_sxd1-dat-merc-fld00.tgz
Leila_Mays_052715_SH_1_12jul_5_sxd1-dat-merc-sho00-04.tgz
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