

# One 2005 User's Feedback on CCMC Solar/Heliosphere Models

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October 2005  
Clearwater CCMC Workshop

# Three Ongoing Activities using CCMC

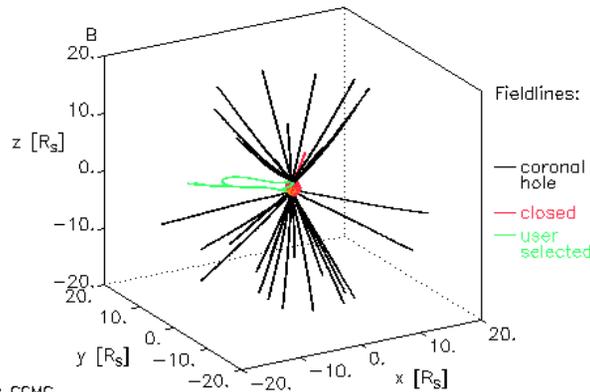
- Keeping track of what's available at CCMC in the areas of solar/heliosphere model options, including CISM model versions
- Tried CCMC code-ingestion and run process with PFSS model and plotter submission
- Referred students Lan Jian (UCLA) and Christina Lee (UCB) to CCMC for projects on solar wind stream interaction structure and solar wind models for Cassini, respectively. Proceeding with \*great\* assistance from Dusan Odstrcil, Peter MacNeice, and the CCMC staff

# Current CISM solar/helio vs. CCMC solar/helio options

- CISM CORHEL -coupled MAS-ENLIL with GUI, many CRs available
- CISM WSA (corona)-ENLIL under devel. at SEC/AFRL/LASP
- Original WSA model
- CISM-DX, an OpenDX-based visualizer
- MAS-ENLIL for 4 CRs
- WSA-ENLIL for many CRs (1890-2011)
- PFSS model
- Original WSA model (no runs on demand yet)
- CCMC 3D visualizer and an additional viz option for MAS by itself
- Helio Tomography model
- Exospheric solar wind

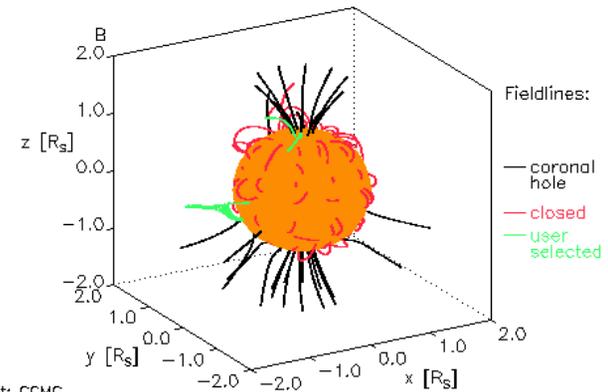
# Some Visualization Capability Comments: Example of CCMC 3D plots showing field lines from MAS, MAS/ENLIL, and PFSS runs

Time = 1:16:00:28



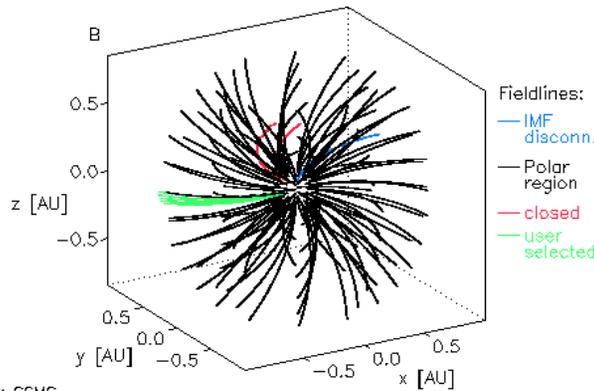
Plot: CCMC  
Model: MAS Region: Sun-Corona

Time = 1:16:00:28



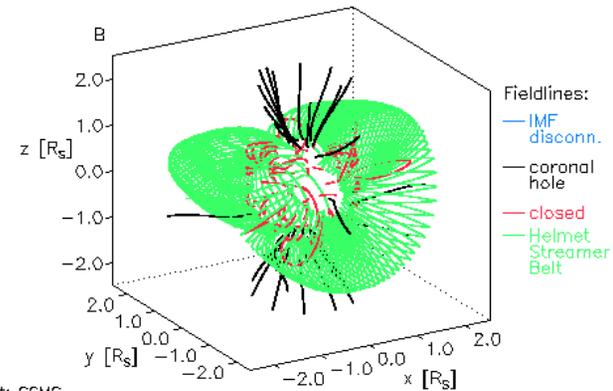
Plot: CCMC  
Model: MAS Region: Sun-Corona

05/22/1997 Time = 00:58:55



Plot: CCMC  
Model: ENLIL Region: Heliosphere

04/23/1978 Time = 03:45:45



Plot: CCMC  
Model: PFSS Region: Sun-Corona

More flexibility/user control of plots, e.g. selection of field line footpoints, would be good! Also common plot styles for similar models.

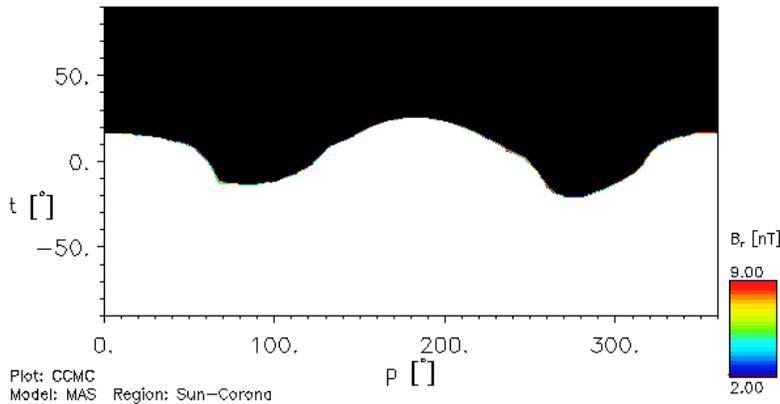
# Suggestions to make 3D visualization package more useful:

- Option for open field line footpoints (coronal holes) on/off toggle (+color coded by radial B sign?)
- Option for open field lines on/off toggle
- Helmet streamer belt and source surface neutral line (or proxy) on/off toggle and/or heliospheric current sheet
- User-selected point for starting field line traces
- Photospheric field map on inner boundary on/off toggle
- Common plot options for MAS, WSA corona, MAS corona, and appropriate variables of PFSS corona. Also common plot options for WSA/ENLIL and MAS/ENLIL helio models(so comparisons are easy)
- Model and CR # on downloadable (high quality) plot!

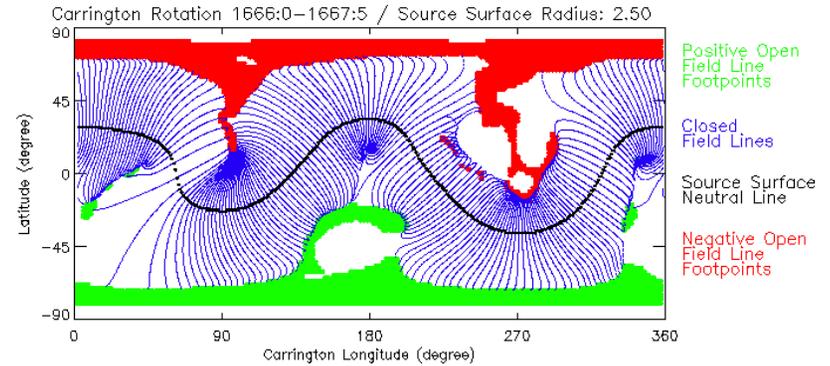
# Synoptic View Plot Options are particularly useful but best if uniform across models

## 3D visualizer-MAS Br

Time = 1:16:00:28  $r = 19.0R_s$

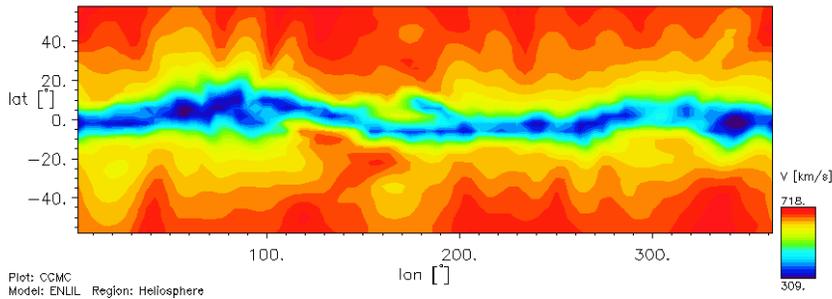


## PFSS only (HSB,SS NL,CH)



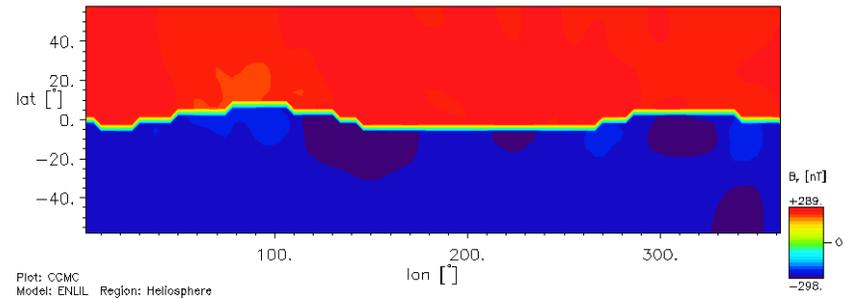
## 3D visualizer-helio V

05/22/1997 Time = 00:53:55  $r = 0.144AU$

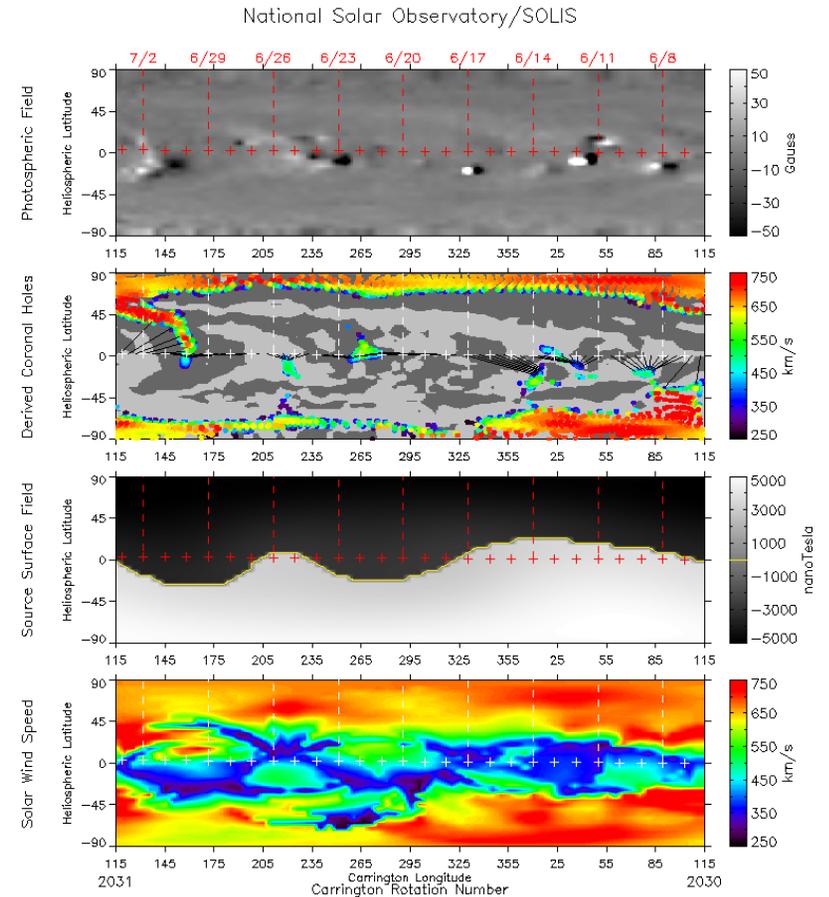
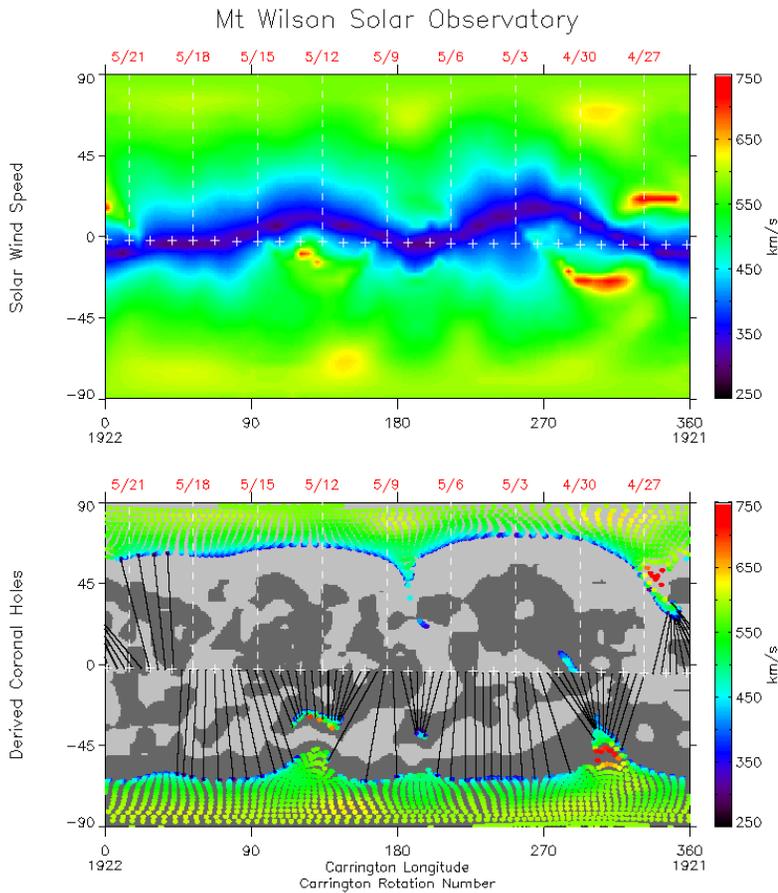


## 3D visualizer-helio Br

05/22/1997 Time = 00:53:55  $r = 0.144AU$



# Particularly Useful WSA Model Site Plots



Created 2005 Jun 30 033 UTC

NOAA/SEC, BOULDER, CO, USA

Key helio model goal is to map solar wind sources and velocities to the ecliptic

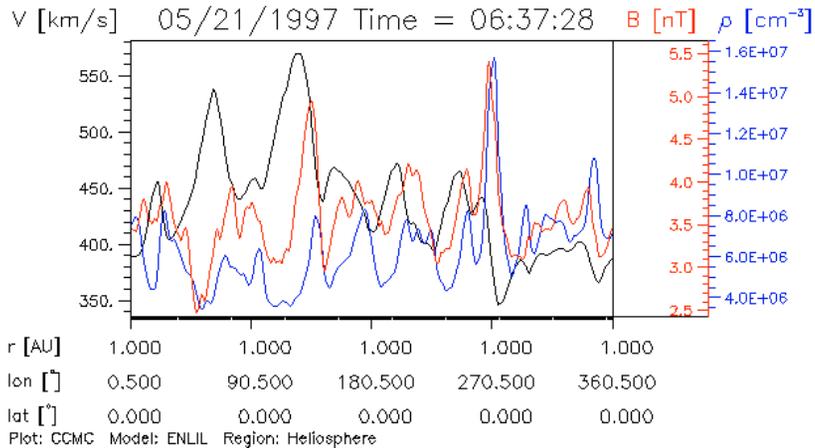
Synoptic plots from SEC WSA model website (*N. Arge*)

# Suggestions for Synoptic Plots:

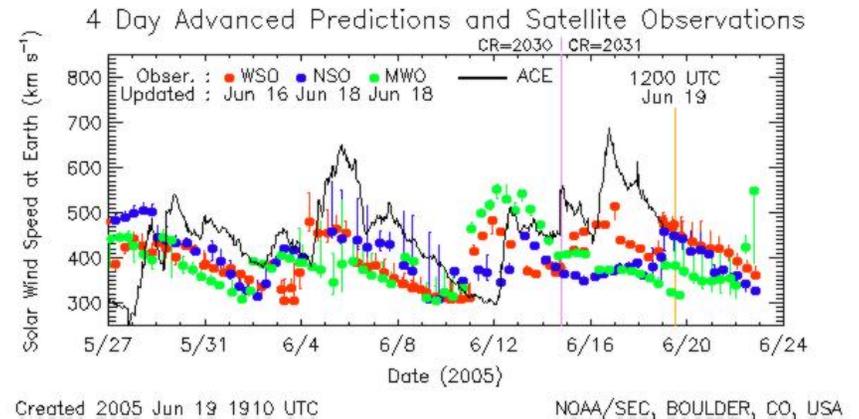
- A common set of synoptic plot content options and plot styles for all coronal models
- Choice of radius for showing synoptic results
- Coronal hole open field footpoints toggle on/off (color coded by sign of radial B)
- Helmet streamer belt field lines on/off toggle
- User-selected field line start points options (e.g. equator traced back to photosphere)
- Neutral line at specified radius -on/off toggle
- B field map (or contours) on/off toggle
- Velocity contours on/off toggle
- Model name and CR # on quality downloadable plot!

# Available CCMC Line Plots vs. SEC WSA Website Timeline Plots

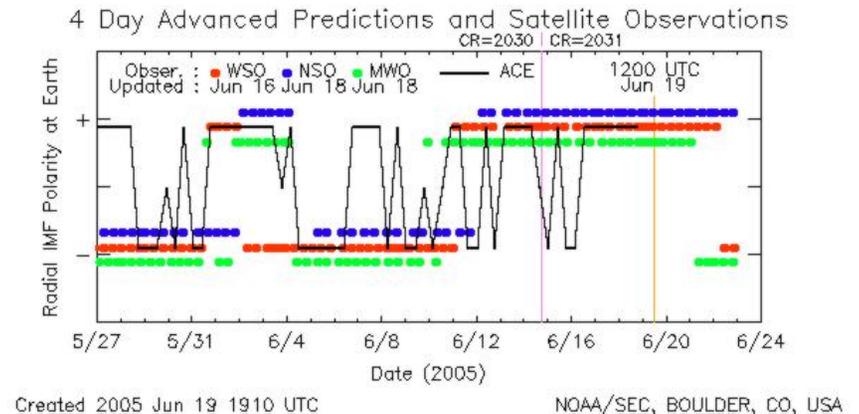
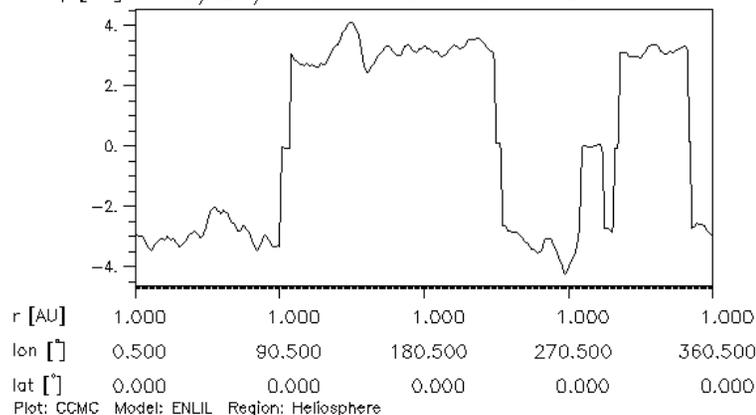
“reverse” time series (vs. long.)



SEC WSA site plots-vs time

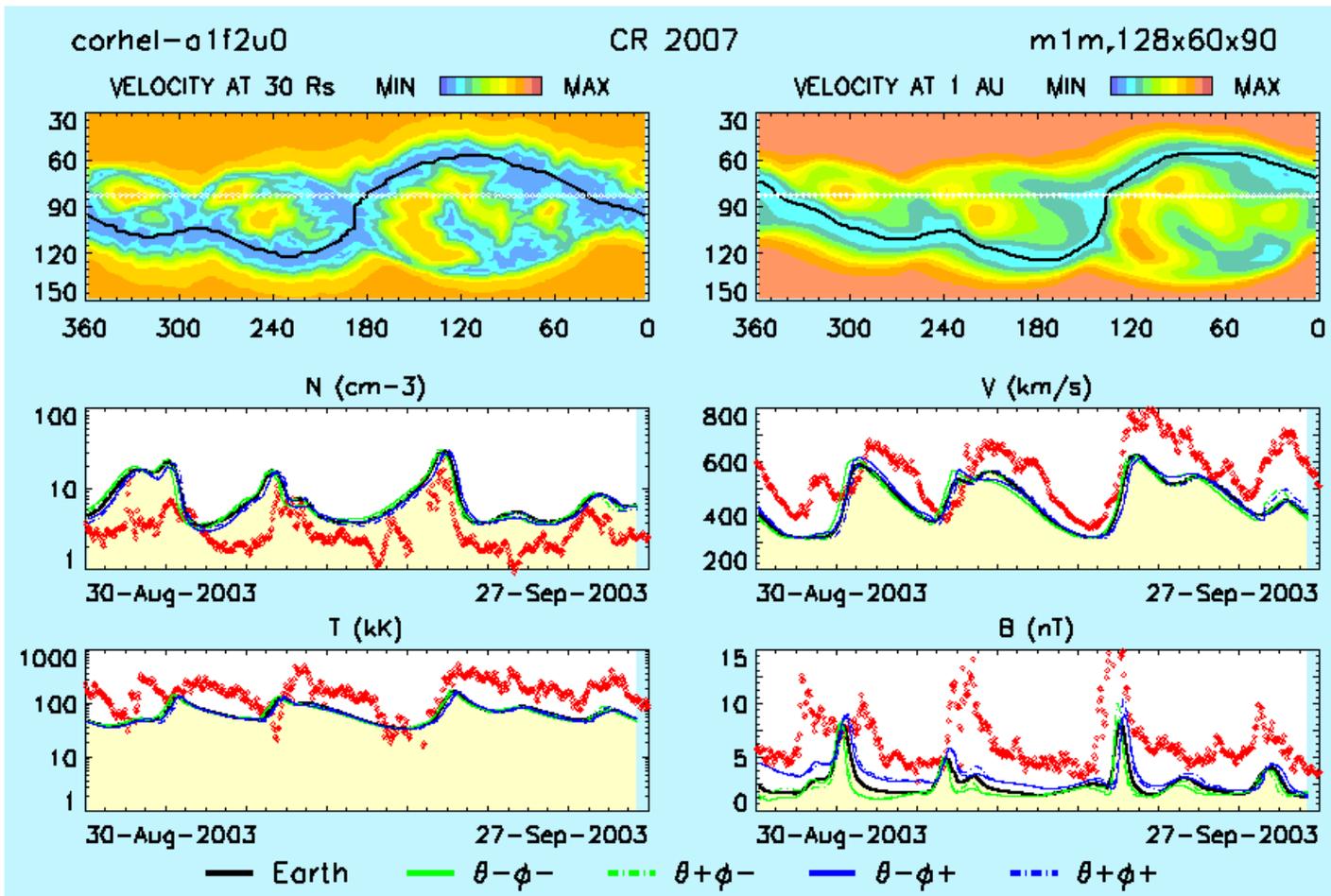


B<sub>r</sub> [nT] 05/21/1997 Time = 06:37:28



Add option for axis reversal and/or max/min axis ranges?

# Also extremely useful: Odstrcil-style plots combining synoptic and timeline content



## Suggestions for time series options:

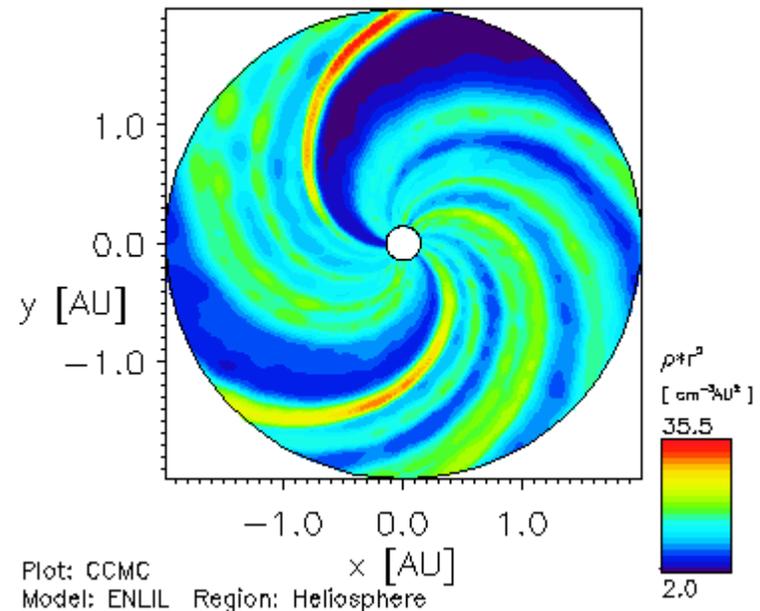
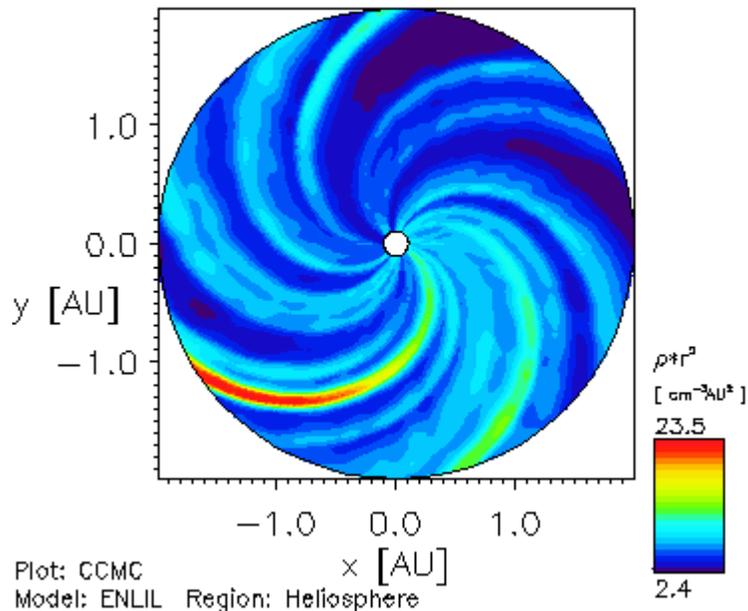
- Allow for default selection of “reverse Carrington Longitude” plot to mimic time series.
- Add option for magnetic polarity (only) plot
- Add option for vector quantity stack plots (components plus magnitude)
- Combine synoptic map plots and line plots (Odstrcil-style)
- Model name and CR # on downloadable plot!

# User experience 1: User wanted to compare 3D WSA/ENLIL (left) and MAS/ENLIL (right) runs for CR 1922

Density\* $r^{**2}$  contours

05/21/1997 Time = 08:37:28 lat= 0.00°

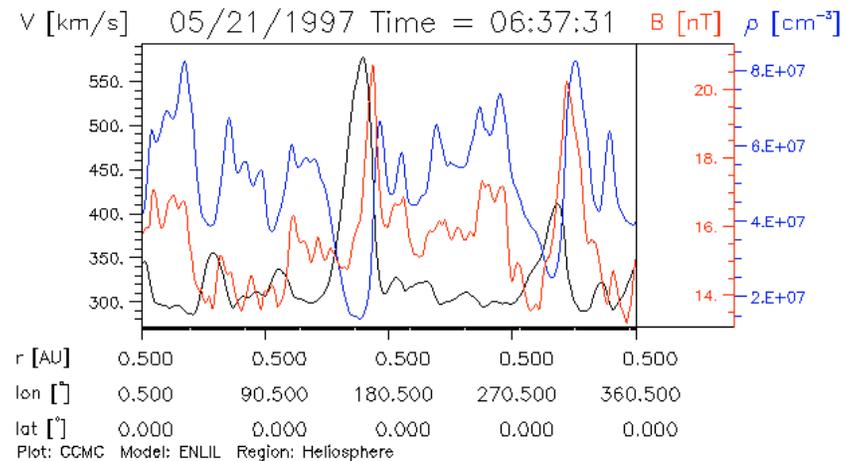
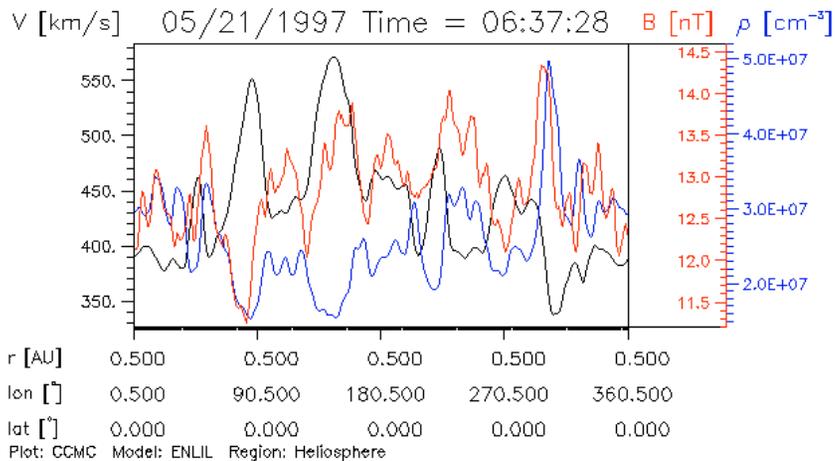
05/21/1997 Time = 08:37:31 lat= 0.00°



Started with 3D visualizer pinwheel contour plots. Different color bar of contour plots makes comparisons difficult – (user controlled contour max/min option would help!?)

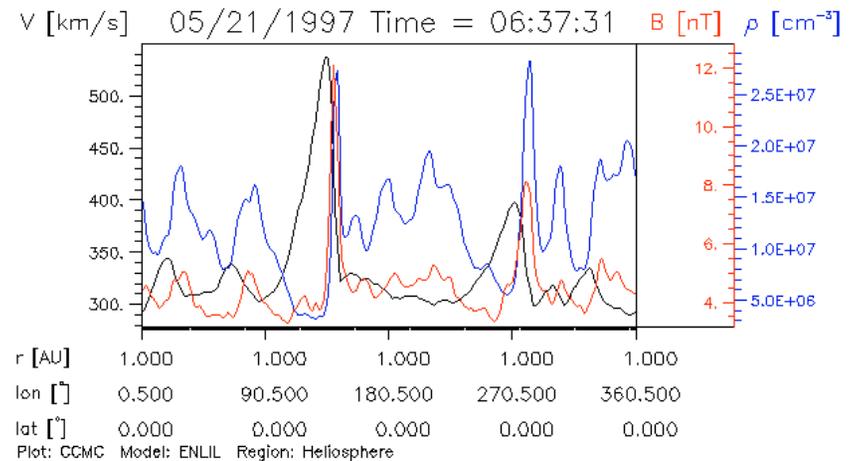
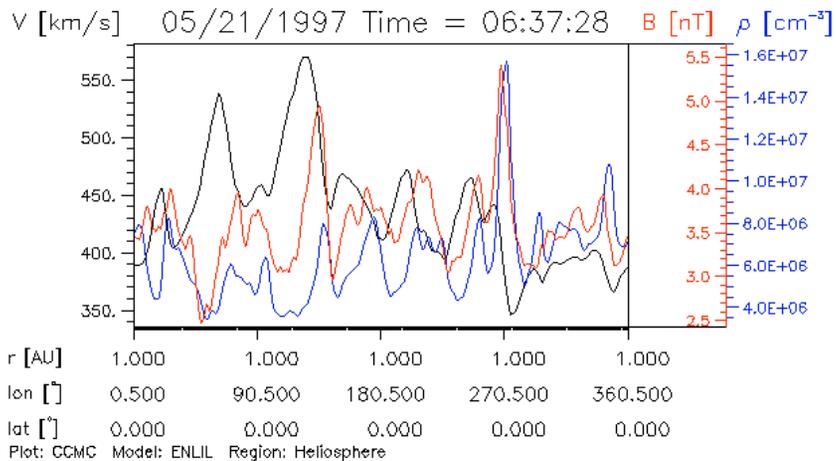
# WSA/ENLIL (left) and MAS/ENLIL (right)

## V,N,B at 0.5 AU: look different-wanted to know why



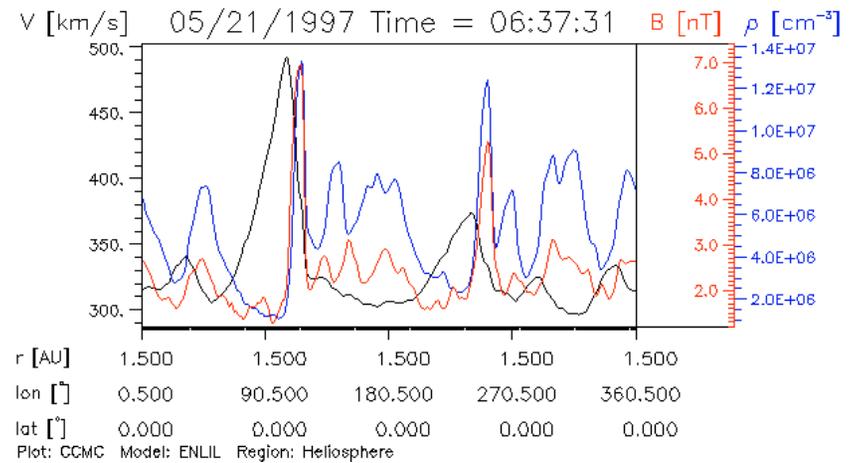
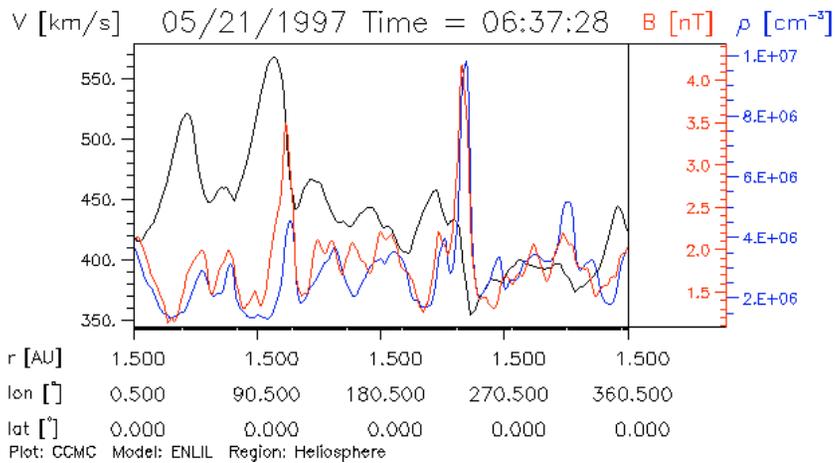
# WSA/ENLIL (left) and MAS/ENLIL (right)

## V, N, B at 1.0 AU: look different- wanted to know why



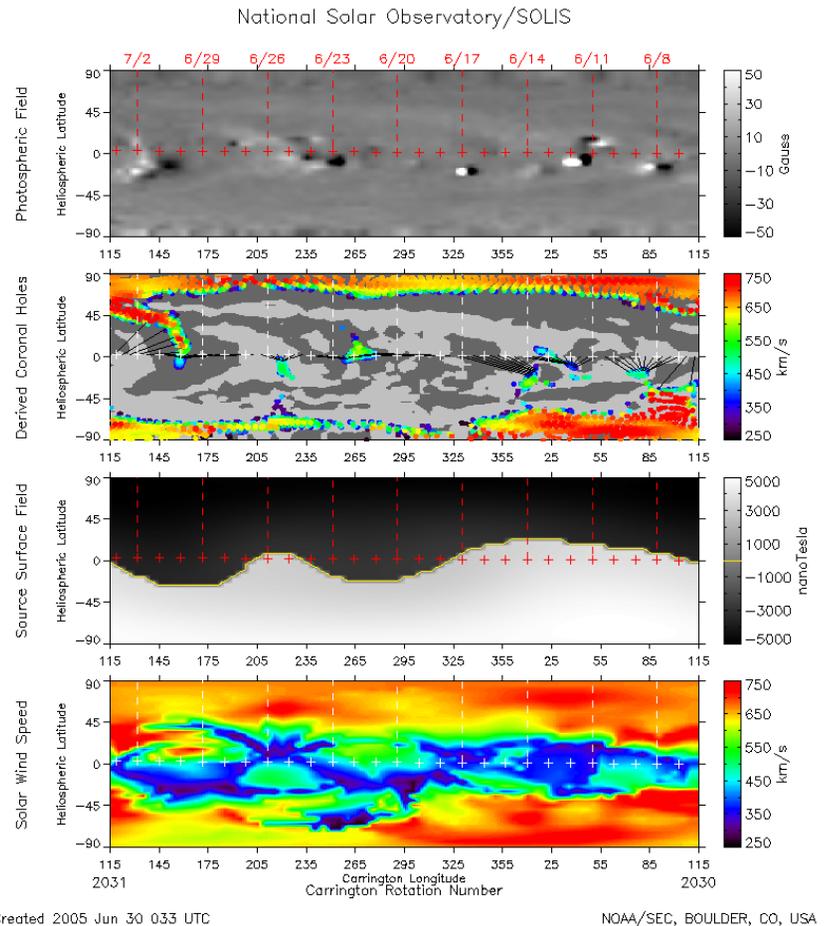
# WSA/ENLIL (left) and MAS/ENLIL (right)

## V, N, B at 1.5 AU: look different- wanted to know why



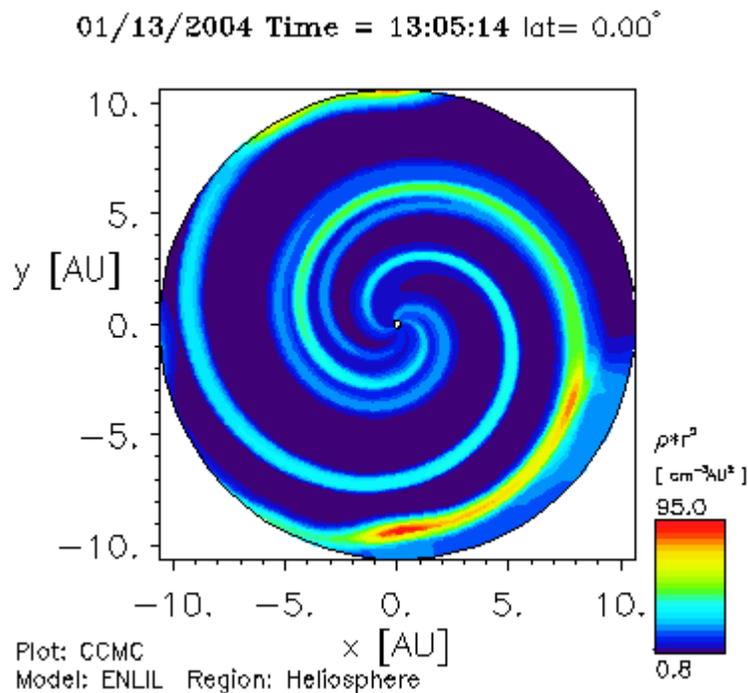
# Diagnosis of differences in these two model runs would have been greatly helped by this plot!

Suggestion- CCMC could routinely solicit coder submission of especially useful graphical display styles together with the models – these can often provide immediate model results diagnostics for users!

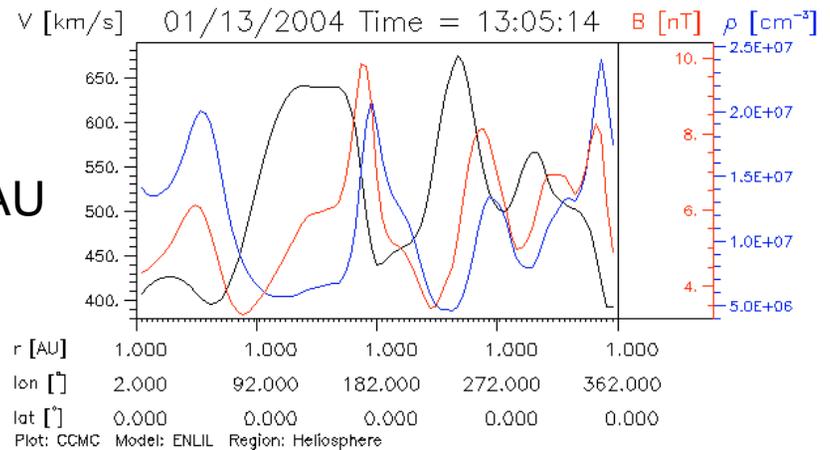


Synoptic plots from SEC WSA  
model website (N. Arge)

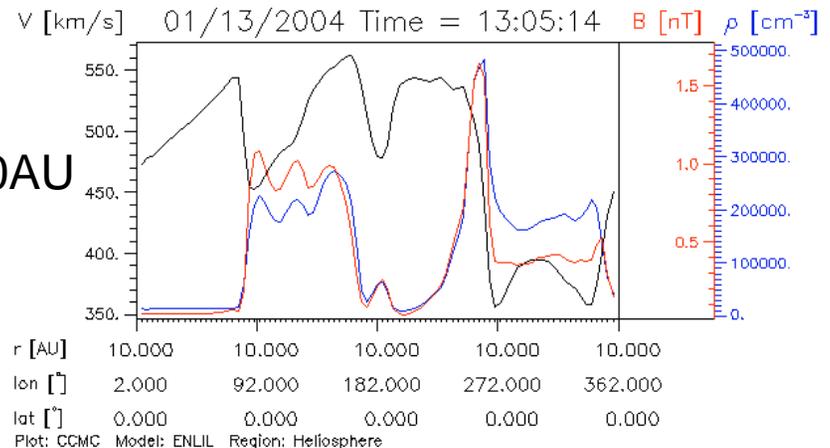
# User experience 2: Test of Extended WSA/ENLIL to “Cassini” (10 AU)



@1 AU

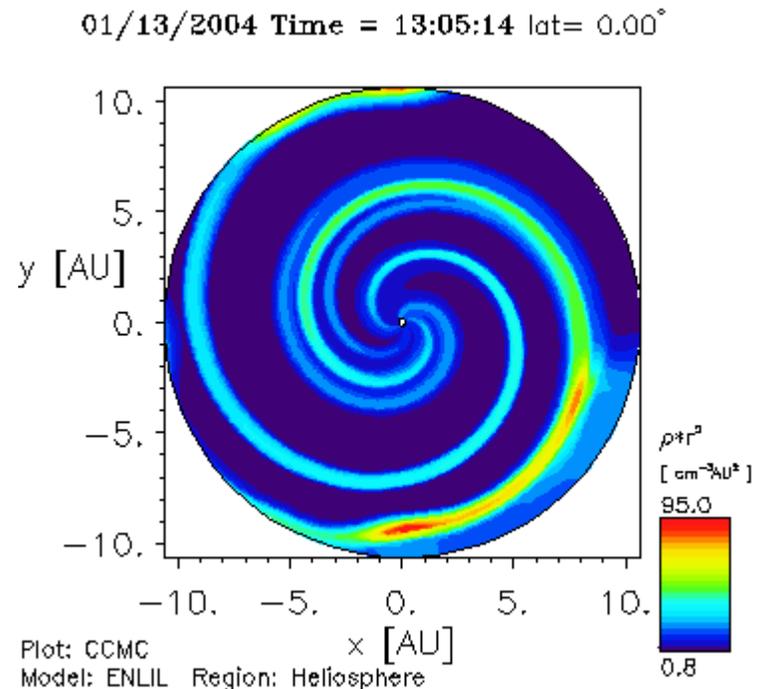
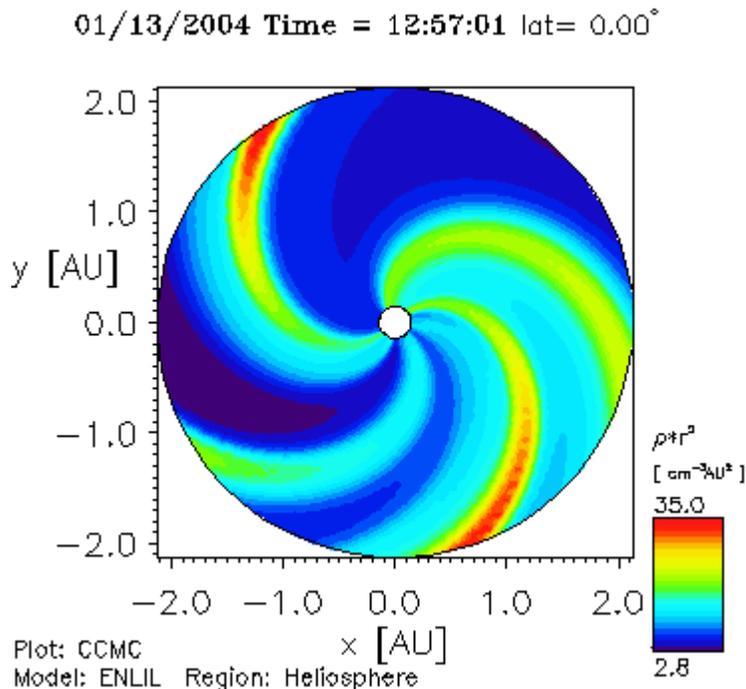


@10AU



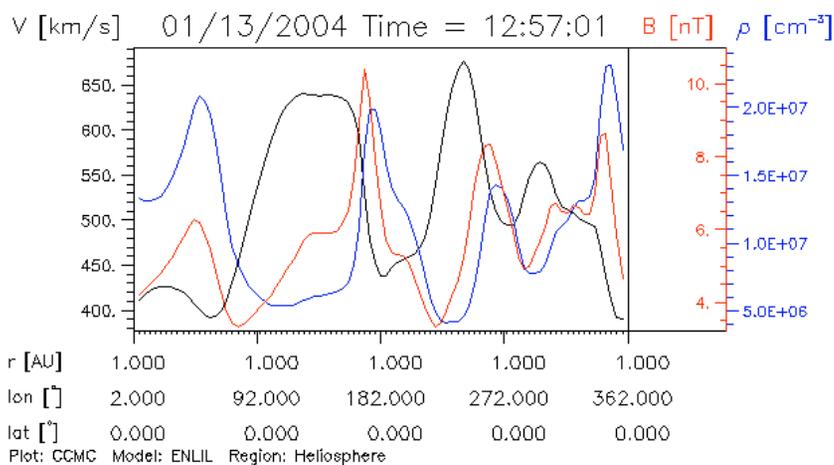
User wanted to see if the inner portion of this extended run gave the same result as inner heliosphere run

# WSA/ENLIL “Mars” vs “Cassini” runs (runs to 2AU (left) and 10 AU(right)) for CR2011

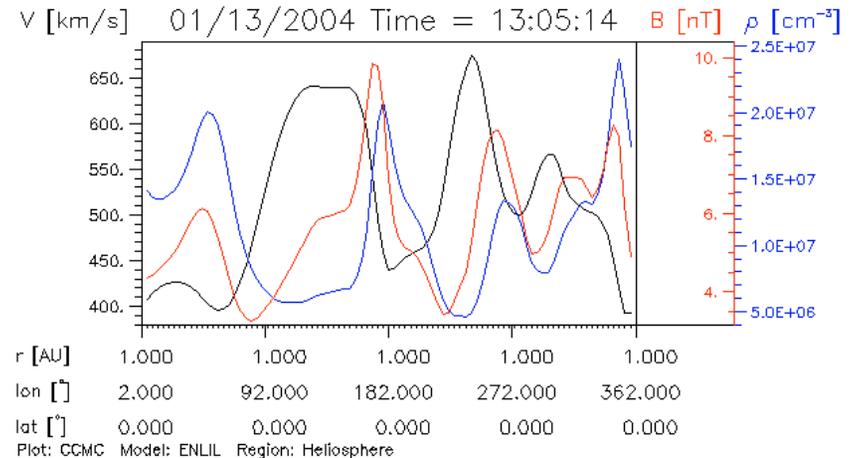


Not clear how to change axis range on 3D visualizer  
contour plots to compare inner portions

Found essentially same results for at 1 AU for “Cassini” and “Mars” limit runs. Wondered if nested grids are used? Need brief but clear on-line text descriptions of nature and assumptions of each model



1 AU results from  
2 AU run (to “Mars”)



1 AU results from  
10 AU run (to “Cassini”)

# Example of Student Research Project: Comparisons of ENLIL Model with Solar Wind Stream Structure Observations Near the Earth

Lan Jian (IGPP UCLA)-with help from  
Dusan Odstrcil, Peter MacNeice

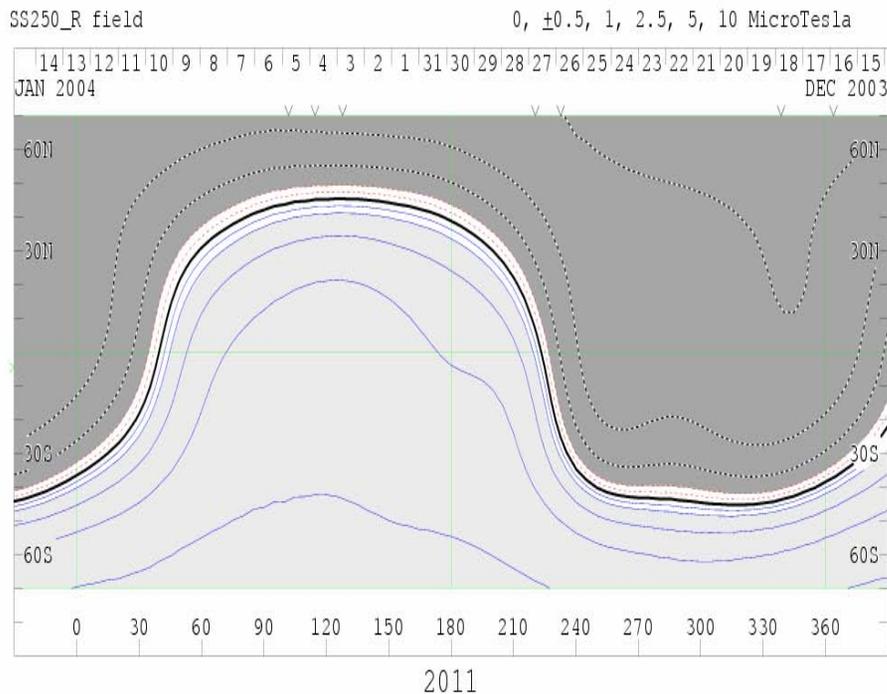
10/07/2005

# Coordinate System Comment

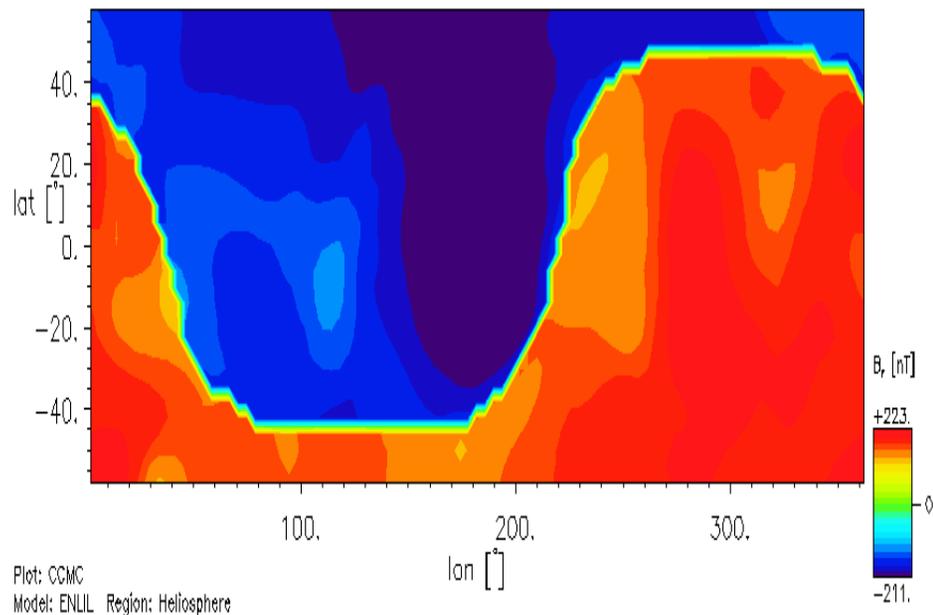
Computed Source Surface Field at 2.5 Rs  
for CR2011- from WSO website

WILCOX SOLAR OBSERVATORY

Boundary Br at 0.160 AU  
Input from the WSA model



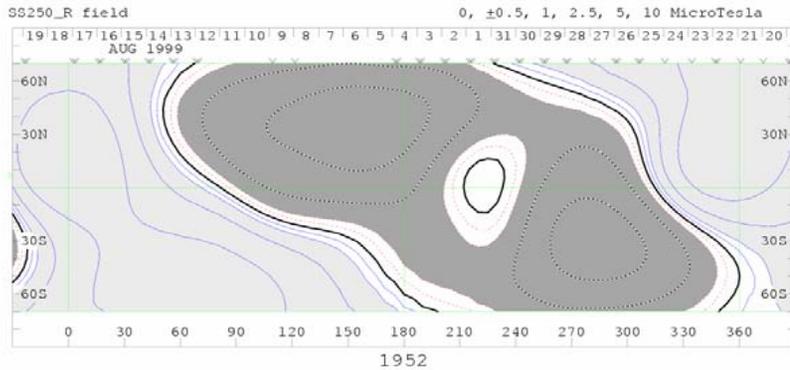
12/17/2003 Time = 08:28:11 r = 0.160AU



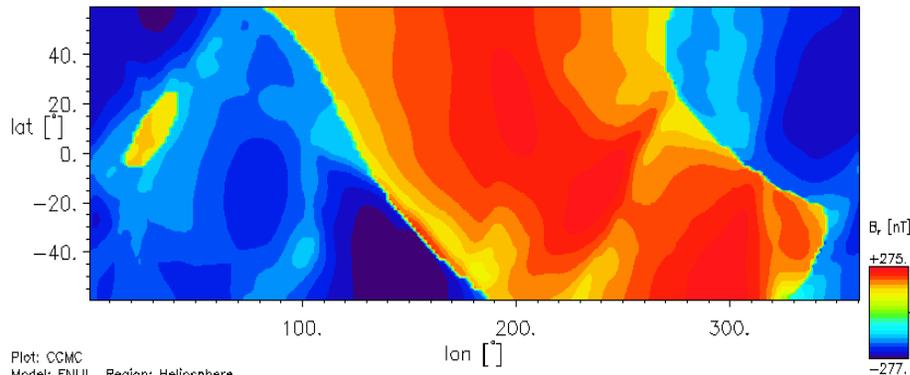
Magnetic Field: tilted dipole field. The distribution of Br in the two figures are different; the right one needs to be drawn along longitude (180-360 and then 0-180 degree). I think the coordinate systems of the two models are not the same.

# CR 1952 (7/22/1999 ~ 8/17/1999) { around solar maximum }

WILCOX SOLAR OBSERVATORY

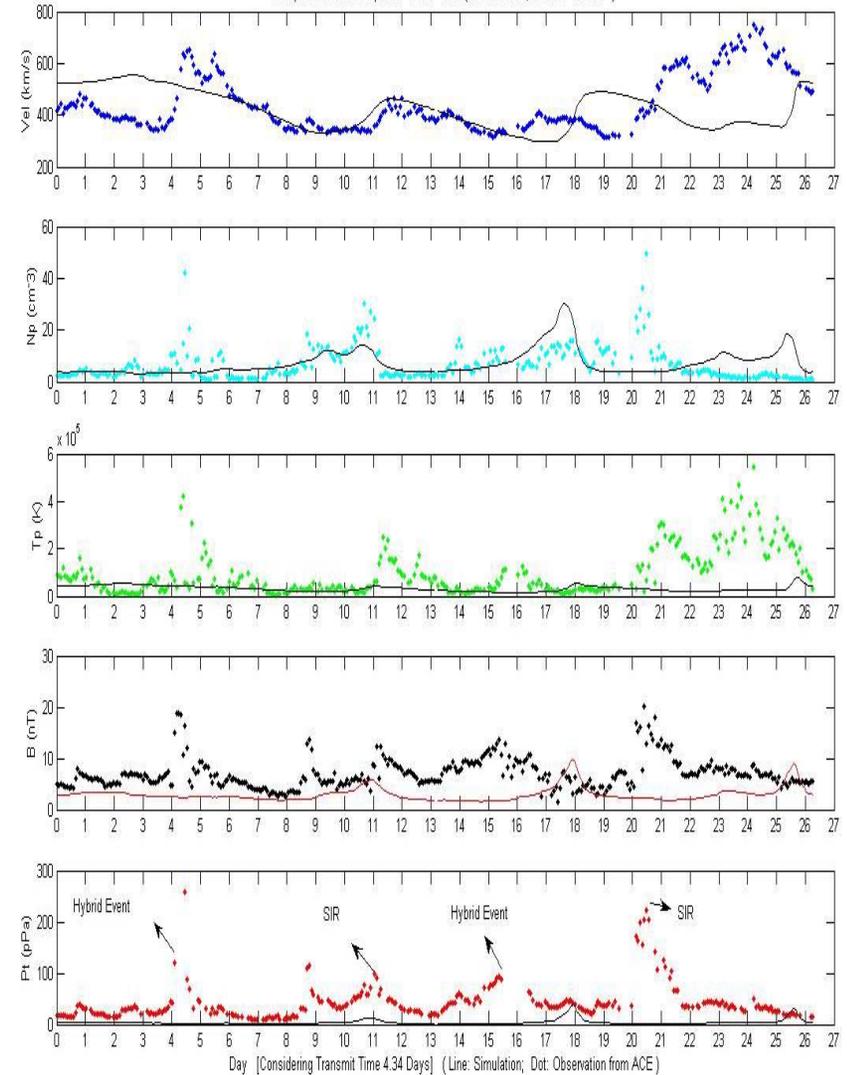


07/22/1999 Time = 00:16:32  $r = 0.105\text{AU}$



Magnetic Field: complicated, during the reverse of photospheric magnetic field

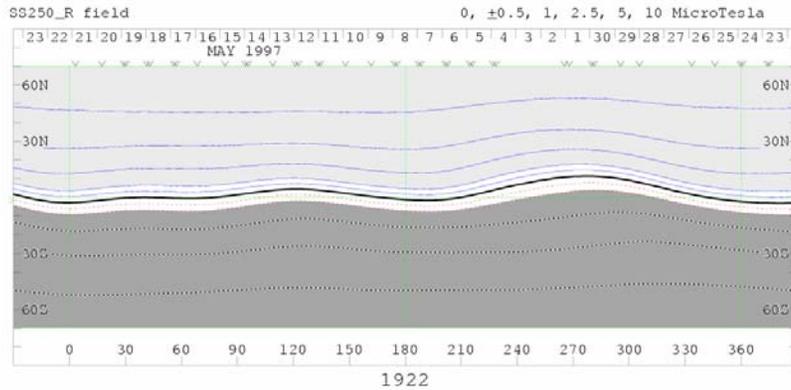
Comparison of the Properties of CR=1952 ( $R=0.9895\text{AU}$ , Latitude= $0.0365^\circ$ )



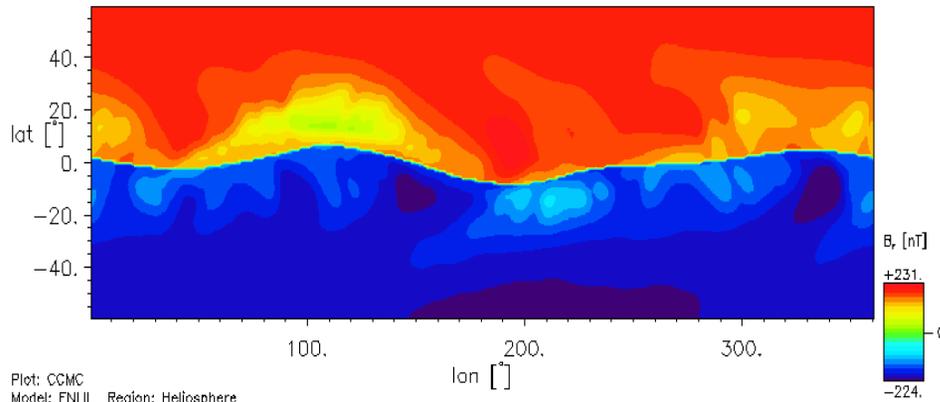
# CR 1922 (4/25/1997 ~ 5/21/1997)

## { Rising phase of solar cycle }

WILCOX SOLAR OBSERVATORY



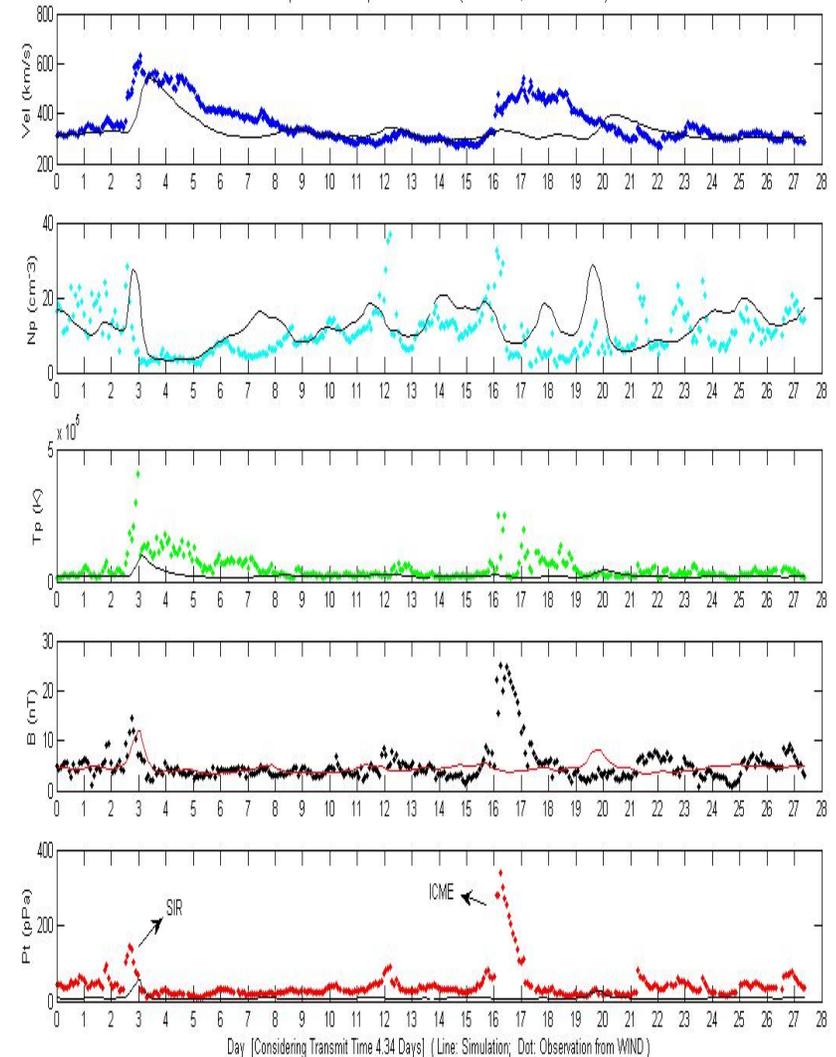
04/25/1997 Time = 00:15:14  $r = 0.145\text{AU}$



Plot: CCMC  
Model: ENLIL Region: Heliosphere

Input from MSA model, better agreement with observation than other CRs

Comparison of the Properties of CR-1922 ( $R=0.9915\text{AU}$ , Latitude= $0.0625^\circ$ )



# Discussion

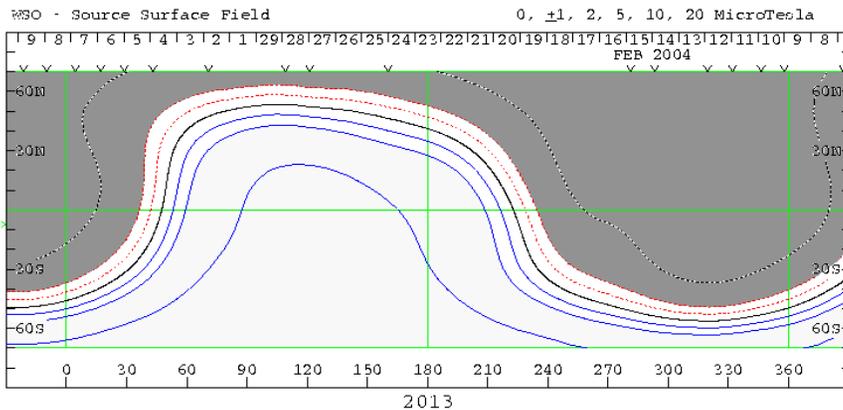
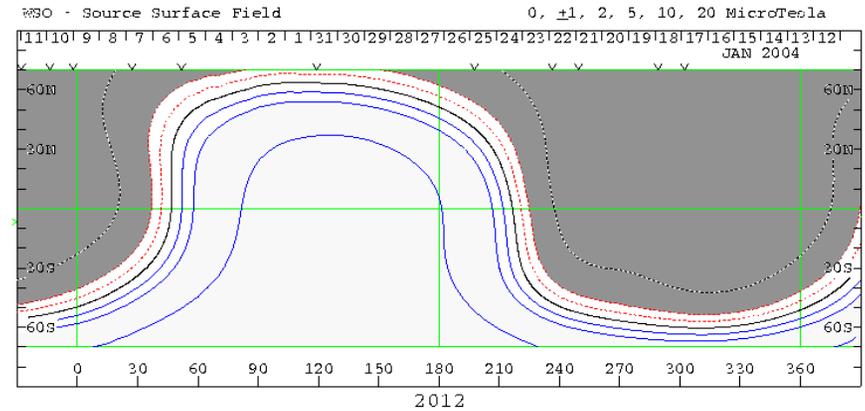
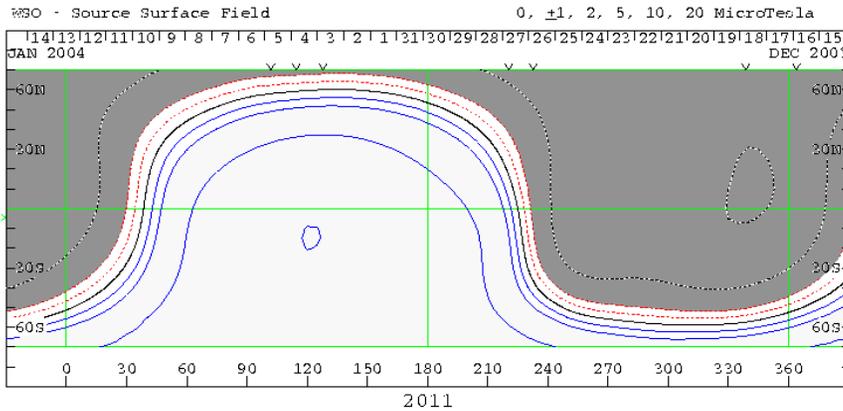
- The model works better for simple input coronal field, like CR 1922
- It is better to automatically change the order of the longitude so that people can easily compare it with the WSO model coronal fields and the observation at the Earth
- The model underestimates the  $T_p$  and  $B$  so that the total pressure  $P$  is also smaller than the observation. For the simulated  $P$ , I already assume constant 4% by alpha ( $\text{He}^{++}$ ) number fraction, and constant solar wind electron temperature 130,000 K.
- The times of some big changes of  $V$ ,  $P$ , etc., do not overlap with the observation very well.

# Example of a Student Research Project: Comparison of (pre- CCMC) extended ENLIL Model with Observations Near Saturn

Christina Lee (UCB), with Dusan Odstroil  
(NOAA/SEC and CIRES), Pete Riley (SAIC),  
Frank Crary (SWRI), Michele Dougherty  
(Imperial College) et al.

12/2004 AGU

# Source Surface Field Synoptic Maps for CR 2011-2013 (Cassini Approach Period)

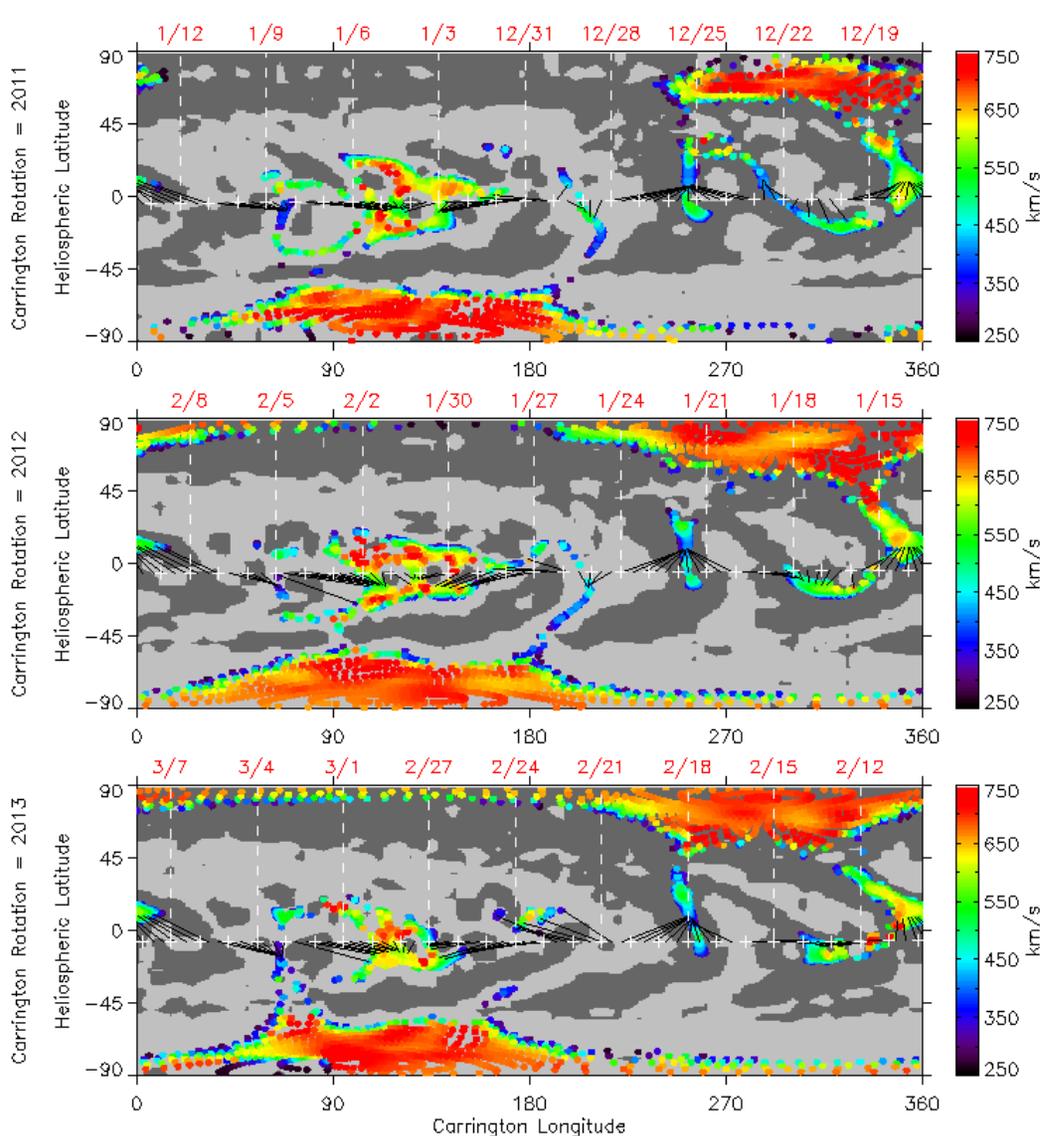


For illustration, coronal magnetic field is calculated from daily photospheric magnetic field observations by the Wilcox Solar Observatory (WSO) with a potential field model, where the source surface is located at 2.5 solar radii. Contour plots of the magnetic field at the source surface for the whole Sun is shown for CR 2011 (upper left), 2012 (upper right), and 2013 (bottom left).

It can be seen that the 2-sector magnetic structure w/steep heliospheric current interfaces observed at 1 AU is long-lived. We expect the steadiness of the structure to repeat over several CRs at 10 AU.

# Derived coronal holes from WSA model

Derived Coronal Holes from National Solar Observatory at Kitt Peak



Photospheric maps with derived coronal holes are shown on the left for CR 2011 (top), 2012 (middle) and 2013 (bottom). Colored points represent photospheric footpoints of open field lines, with different colors used to indicate the solar wind speed as predicted by the Wang-Sheeley-Argge (WSA) model.

Light grey areas represent closed field lines footpoints with  $B_r > 0$ ; dark grey areas represent closed field lines with  $B_r < 0$ .

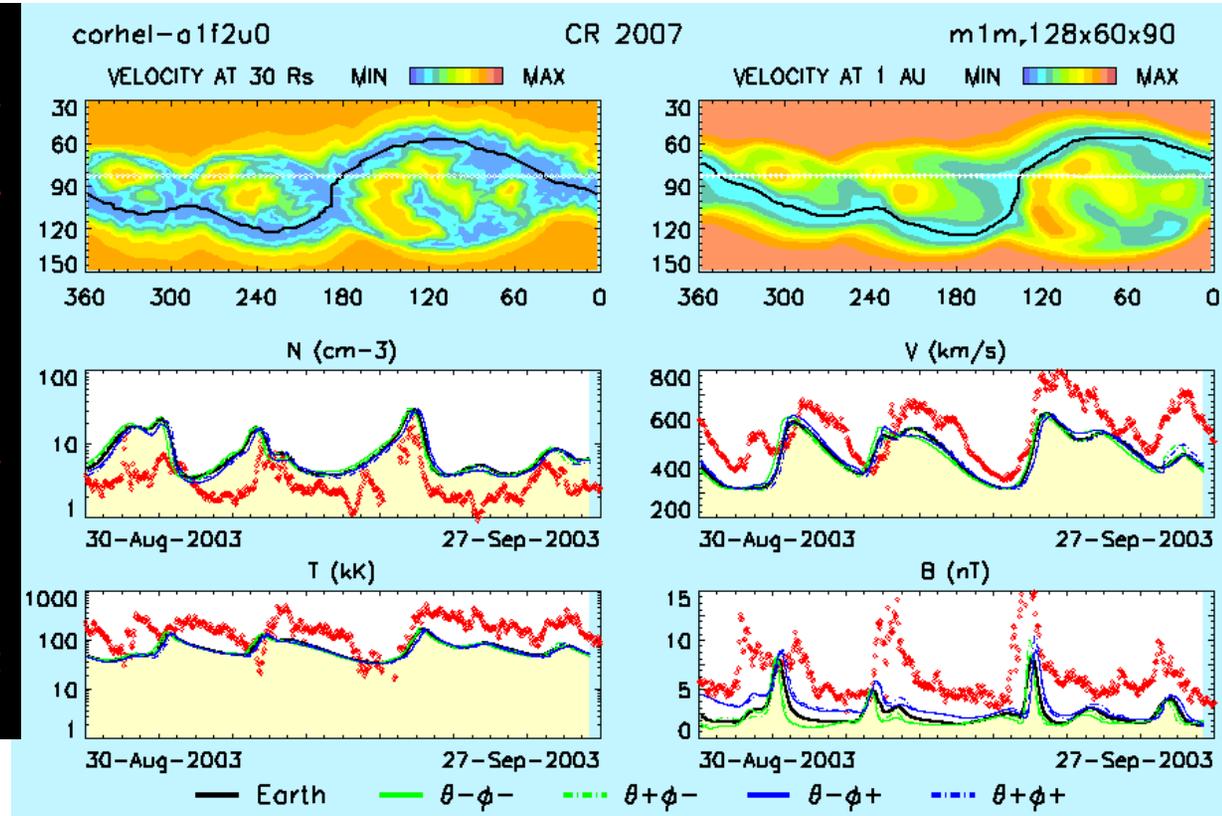
Tracings of the 2.5 solar radii source surface equator to the source regions of the solar wind at the photosphere are given by the black arrows.

The WSA model results for CR 2011-2013 demonstrate that the fast solar wind on the ecliptic plane is not from polar holes, but from coronal holes distributed along the low solar latitudes.

# Sample CISM-CORHEL Results for 1 AU

The results derived from the MAS coronal model at 30  $R_s$  (upper left figure) are the initial conditions for the ENLIL heliospheric solar wind model at 1 AU (upper right figure). The top two panels show the model velocity values for Carrington Rotation (CR) 2007.

The bottom four figures show a comparison of the solar wind parameters for CR 2007 derived from the model (solid lines) and observed from the ACE spacecraft at Earth's L1 point.

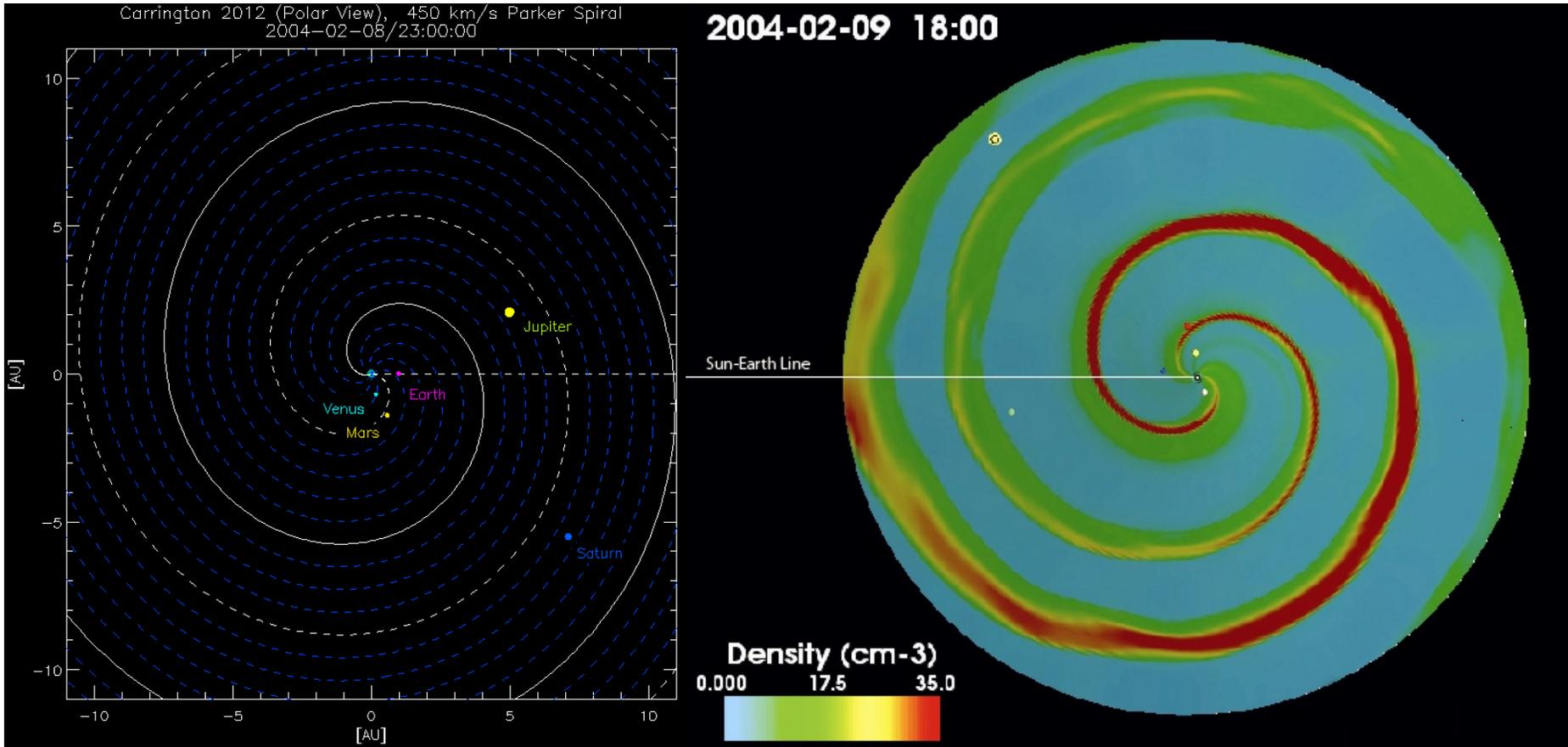


- Steady 2-sector magnetic structure w/steep current sheet interfaces
- Peaked density structures observed at 1 AU are likely from low-latitude coronal holes distributed along solar equator and traditional stream interactions
- Good agreement of model results w/ACE data (red points) obtained from Earth's L1 point

# Parker Spiral Structure for CR 2012

Carrington 2012 (Polar View), 450 km/s Parker Spiral  
2004-02-08/23:00:00

2004-02-09 18:00



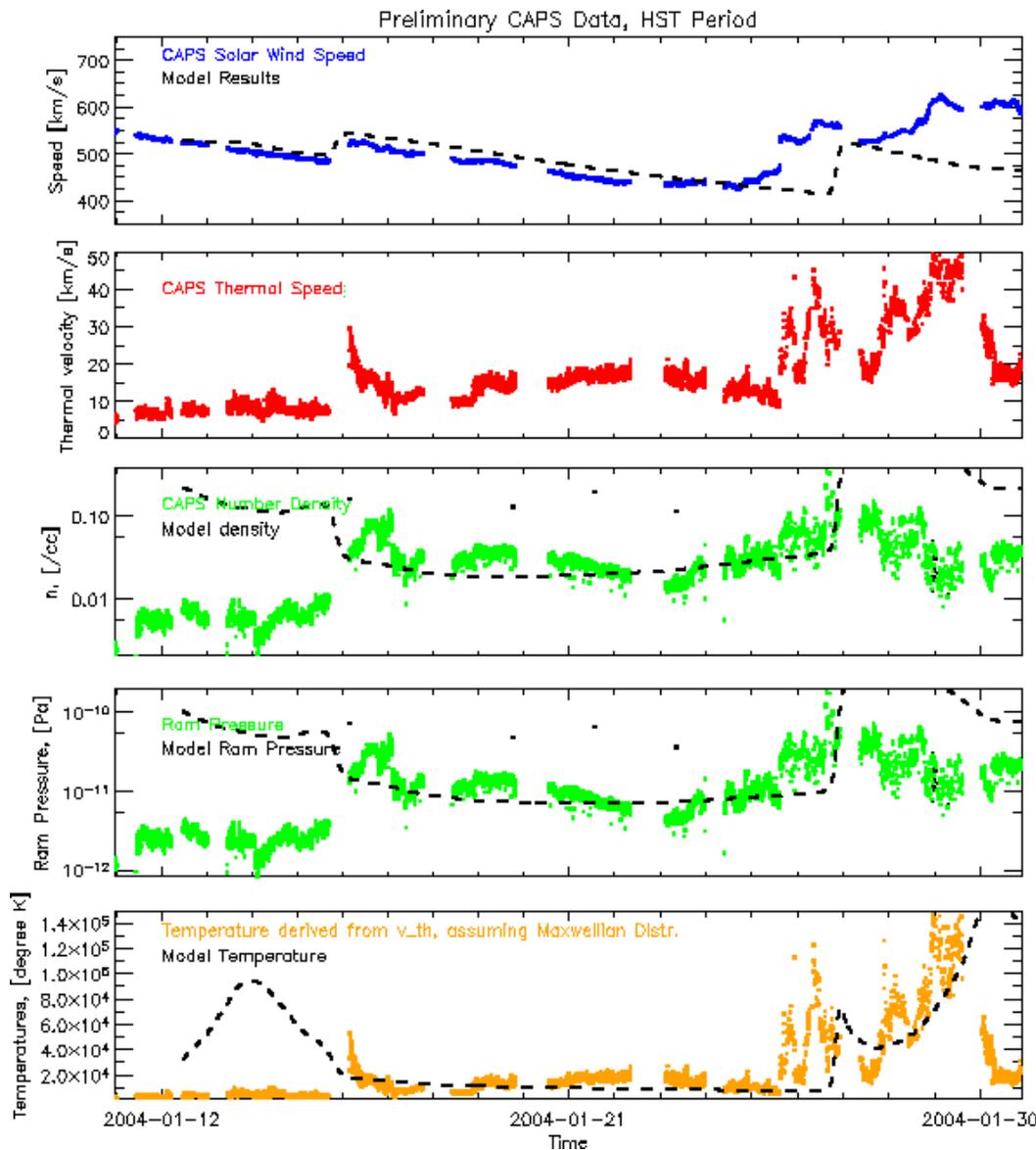
(left) Parker spiral magnetic field structure and planet locations for constant solar wind speed of 450 km/sec with Earth fixed (0 degree CR longitude, straight dashed line)

(right) Derived density distribution out to 10 AU in the ecliptic plane using HELSAT (special Odstroil outer heliosphere model). Note the density ridges, which are associated with solar wind dynamic pressure ridges.

# Validation of HELSAT: model results vs Cassini observations at ~10 AU

The HELSAT model results (black lines) show good agreement in some intervals with the Cassini Plasma Spectrometer Subsystem (CAPS) and the magnetometer (MAG) observations (color points), in part because of low solar activity and a particularly simple and steady interplanetary sector pattern.

The solar wind velocity is best modeled by HELSAT, and disagreements of the model with the observations are not well understood at this time. Overall, the basic characteristics of the velocity and temperature are reproduced by the model (except for temperature at the beginning of the observation period).



# CONCLUSION

- The study demonstrates that MAS-ENLIL models can be extended to 10 AU with some success during quiet solar times
- The modeling is solar magnetogram-based and is thus not restricted to the cases for when Earth and Jupiter/Saturn are co-aligned.
- Future work will include: introduction of transients
- Cassini Project is interested in routine solar wind predictions if they can be provided

# Presenter's Bottom Lines

- CCMC Solar/Heliosphere capabilities have exploded with the arrival of Peter MacNeice- a great opportunity for researchers and students
- Huge effort is needed to make just the basic models useful (includes digestion and documentation of synoptic map boundary conditions- including codes to pre-process if applicable), documentation of basic models assumptions and inputs, useful diagnostic and visualization options
- Concern that undertaking too many internal validation efforts, in-house code coupling, advanced frameworks evaluations, etc. undermines necessary base-level efforts (e.g. first things first ?– identifying and installing codes, identifying and maintaining needed computer resources, running requests, user interfaces, “data” management, visualization and data analysis tools development)
- Congratulations to CCMC for the great strides evident since the original Maui workshop- in technical capability and code provider interactions especially – and thanks for their dedication to serving the community!

# Longer Term Solar/Helio Concerns

- No space-based coronagraph after SOHO (e.g. Odstrcil cone model depends on it)- not even planned?!
- Needed support for ongoing acquisition of full-disk magnetograph data and serious consideration of farside magnetographs (who will pick that up?- all solar models and full-system coupled models hinge on that single measurement. Yet no such measurement is planned - except as far as ESA's Solar Orbiter will do it)
- STEREO support- first mission CCMC has offered to support- how will CCMC be able to help STEREO data analysis and interpretation? (e.g. by running and archiving STEREO related model runs? Detailed plans needed soon!! Launch is spring '06.)