Wang-Sheeley-Arge (WSA) Model – CCMC Collaborations

Nick Arge

Space Vehicles Directorate

Air Force Research Laboratory

WSA-CCMC Interactions

Model Description: The *Wang-Sheeley-Arge* (WSA) model is a combined *empirical* and *physics-based* representation of the quasi-steady global solar wind flow that can be used to predict *ambient* solar wind *speed* and interplanetary magnetic *field polarity* at Earth.

- **Submitted a request in May 2004 asking that the WSA model be considered for inclusion at the CCMC.**

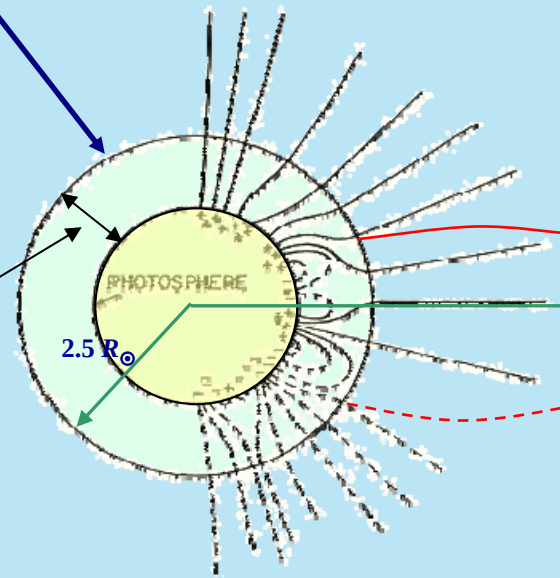
- **Asked by Michael Hesse in Jan. 2005 to begin porting the WSA to the CCMC at my earliest convenience.**

- **Visited the CCMC in March 2005 to finalize installation.**
  - Described the model in detail to the CCMC staff and answered questions.
  - Assisted the CCMC staff with installing and testing the code.
  - Automated the running of the code.
  - Nearly all objectives were accomplished in 2 days.
  - A lot of prep-work was required ahead of time!
  - The CCMC staff followed up with occasional questions.
  - Over all, the CCMC have been very helpful, patient, and courteous!

- **Areas for improvement:**
  - Get updates on what's happening.
  - Notification as to when the model will be available for public use.

Coupled Model: PFSS+SCS

Schatten Current Sheet Model (SCS): 2.5 – 21.5 $R_\odot$



Potential Field Source Surface Model (PFSS): 1.0 – 2.5 $R_\odot$

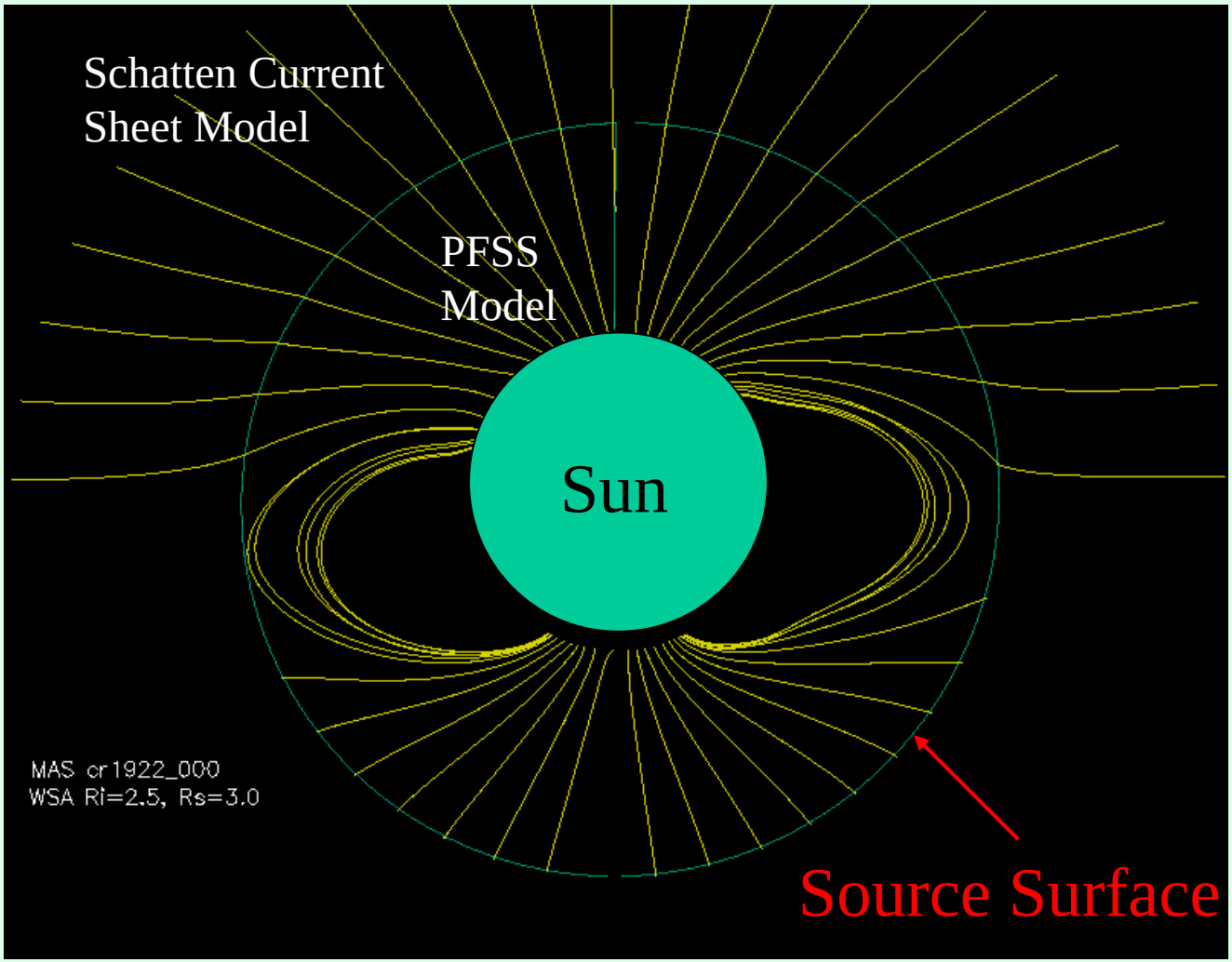
Solar Wind Model

(e.g., 1D Kinematic model, ENLIL, HAF)

http://www.sec.noaa.gov/ws

Schatten, 1971; Wang and Sheeley 1995

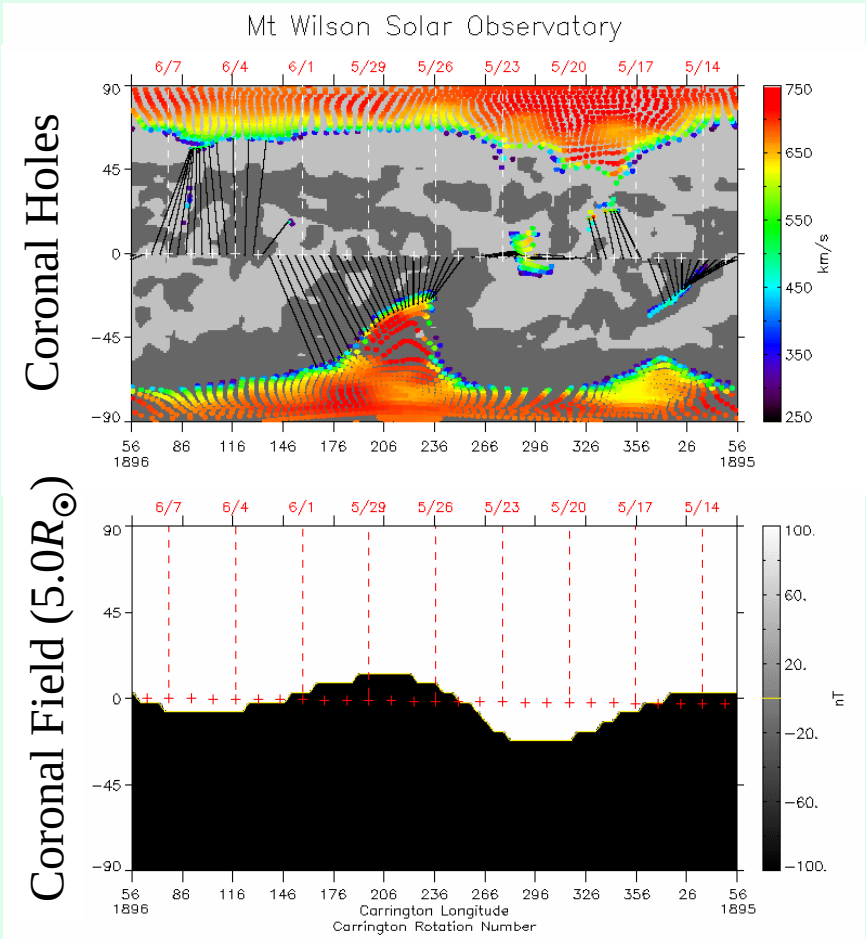
Coupled PFSS+ Schatten Current Model



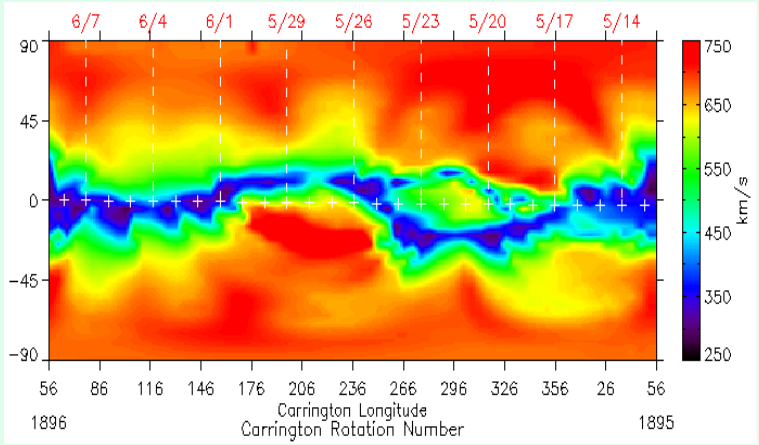
Plot courtesy Sarah McGregor (BU/CISM)

WSA Model Output

PFSS+SCS MODEL (R = 5.0 $R_\odot$)



Predicted Solar Wind Speed at 5.0 $R_\odot$ (New Empirical Relationship)



$$V(f_s,\theta_b) = 265 + \frac{1.5}{(1+f_s)^{1/3}}\left\{5.8 - 1.6e^{\left(1-\left(\theta_b/7.5\right)^3\right)}\right\}^{3.5} \text{ km s}^{-1}$$

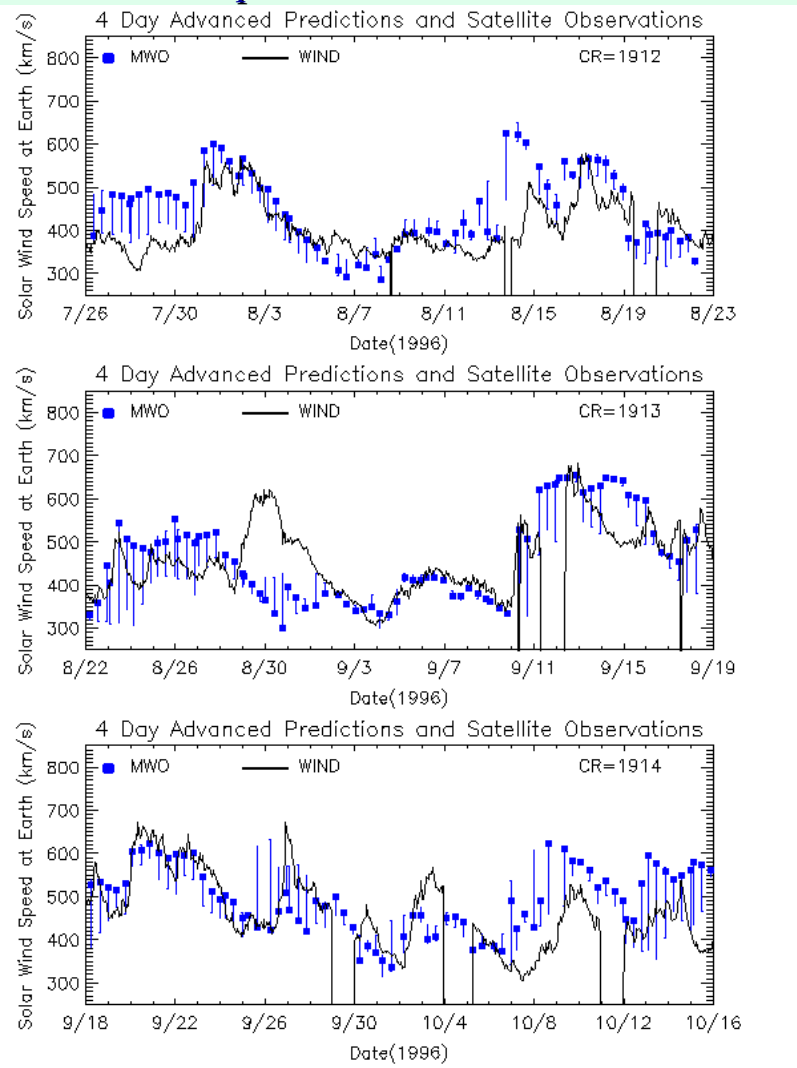
Where:

f_s = Magnetic field expansion factor.

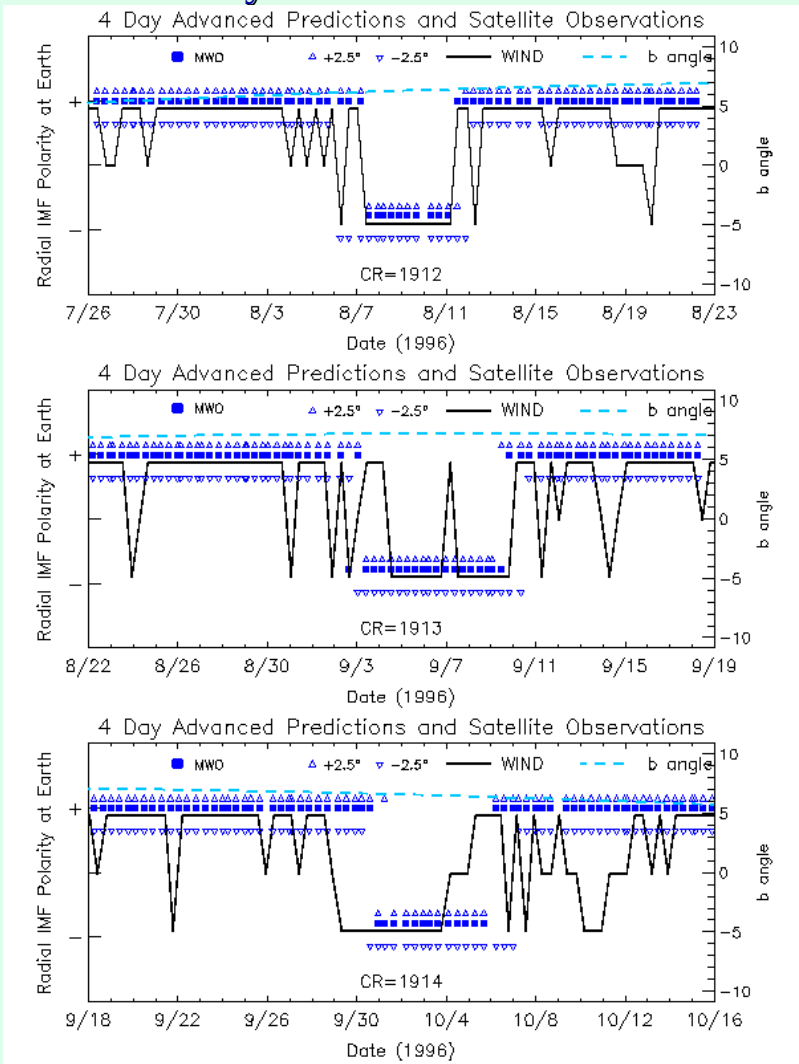
θ_b = Minimum angular distance that an open field footpoint lies from nearest coronal hole boundary (i.e., Angular depth inside a coronal hole)

Predictions & Observations:Near Solar Minimum

Solar Wind Speed Predictions & Observations

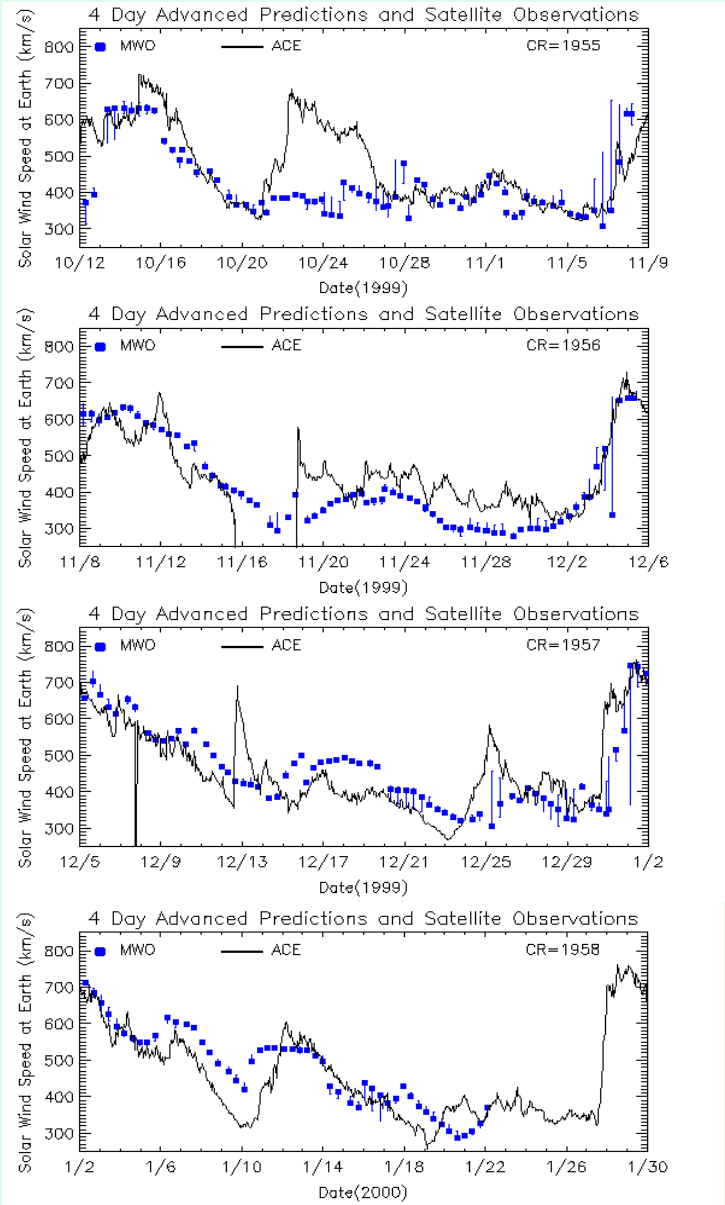


IMF Polarity Predictions & Observations

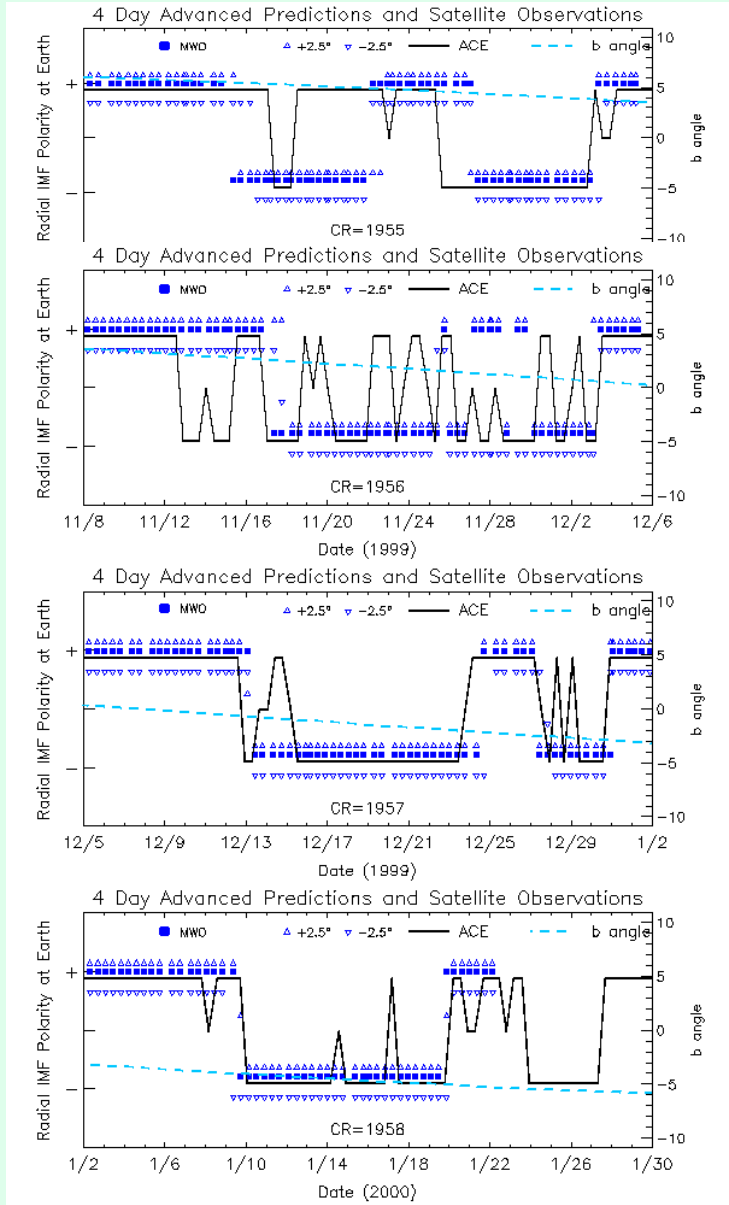


Predictions & Observations:Near Solar Maximum

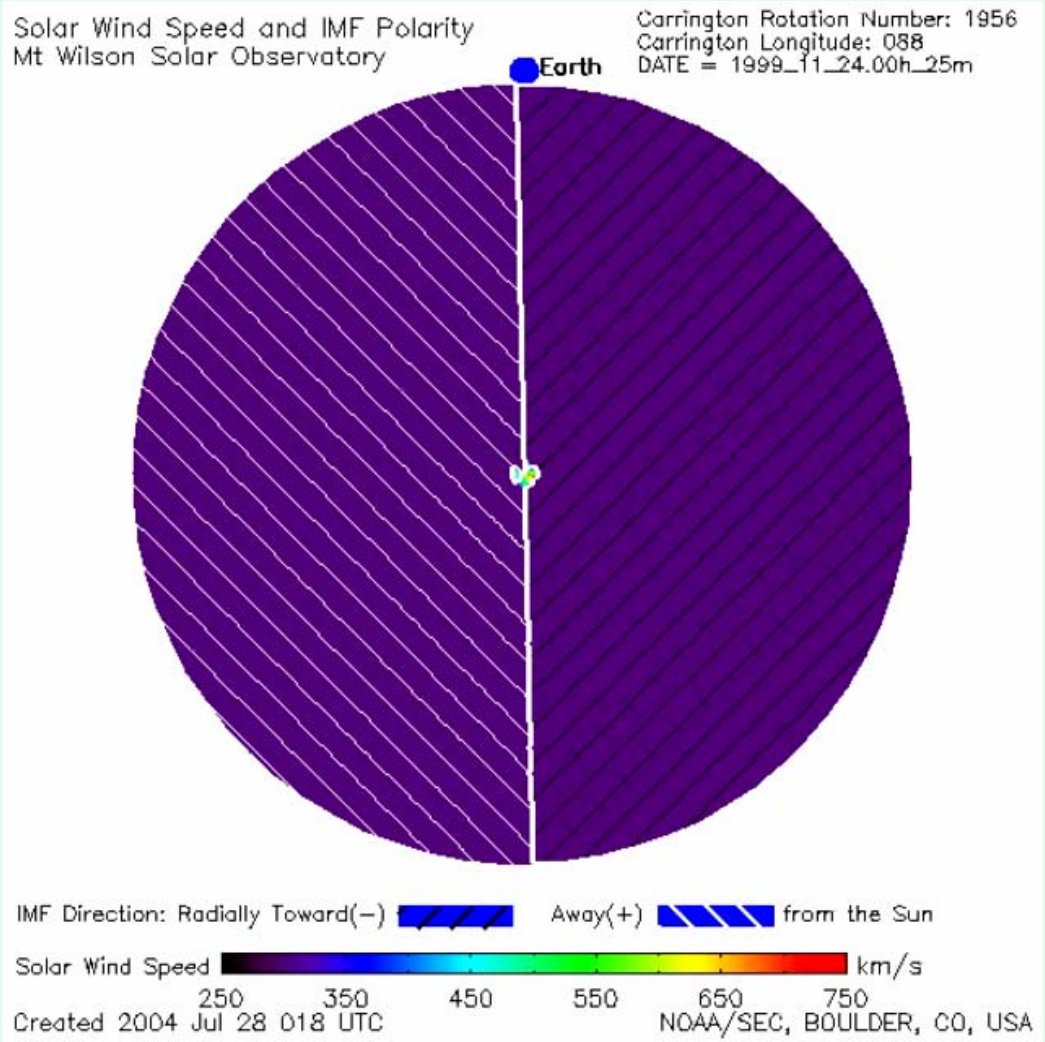
Solar Wind Speed Predictions & Observations



IMF Polarity Predictions & Observations



Solar Wind Speed and IMF Polarity in the Ecliptic Driven by Daily Updated Photospheric Field Maps

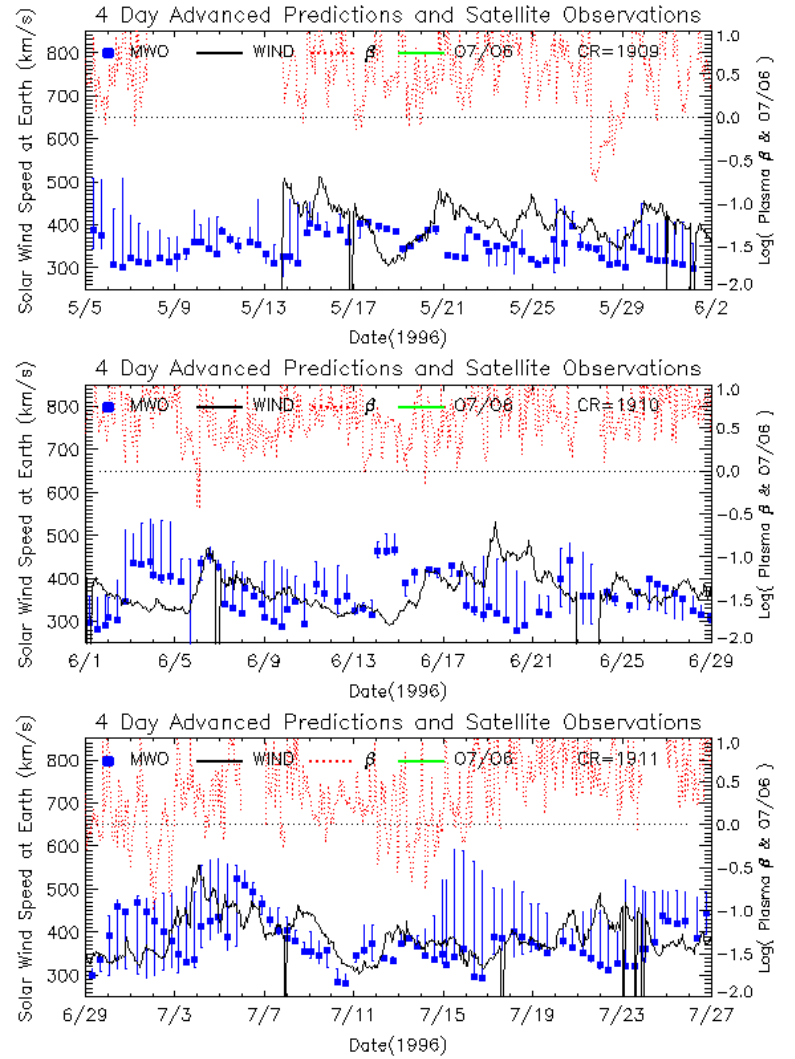


IMF directed radially ***away*** from Sun.

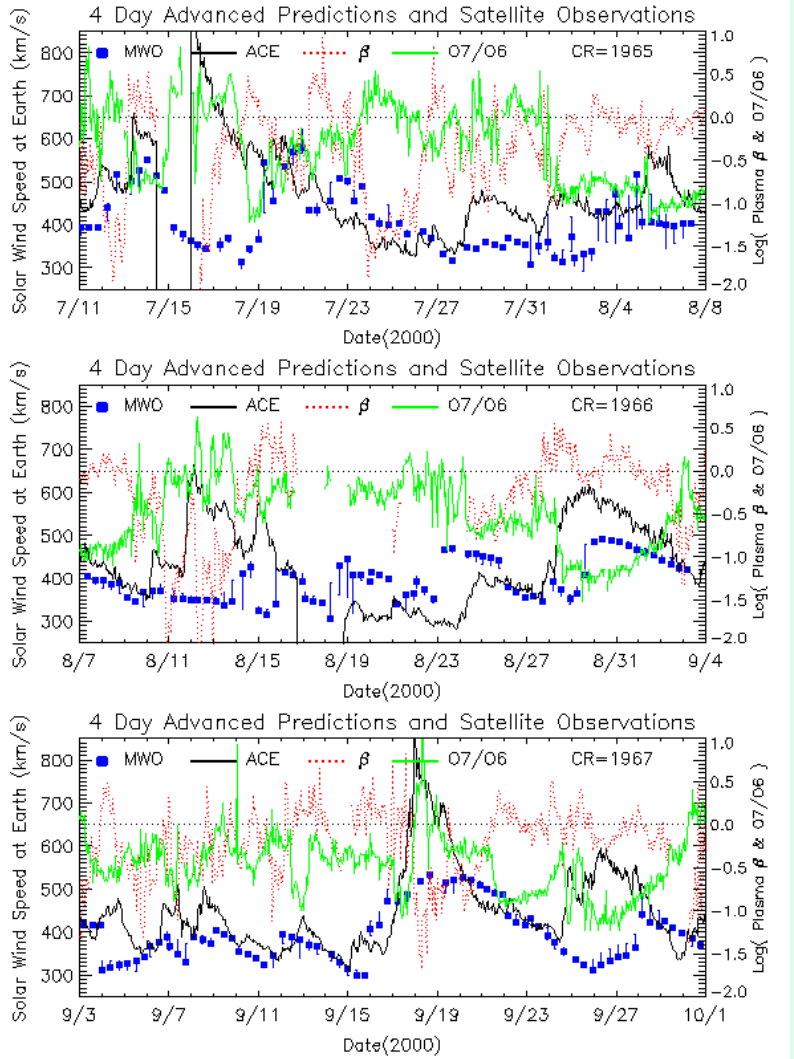
IMF directed radially ***toward*** from Sun.

Predictions & Observations

Solar Wind Speed Predictions & Observations



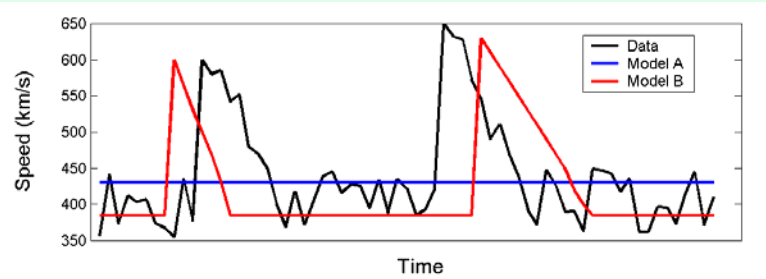
Solar Wind Speed Predictions & Observations



Boston University Validation of WSA (Owens et al., JGR 2005)

- Validated 8 years of WSA predictions
- Mean Squared Error (MSE)
  - 3 day old magnetograms give optimal prediction
  - No systematic time lag
  - Skill scores low on average (<10%)

Hypothetical Example



MSE(A) < MSE(B)
(Same for correlation coefficients)

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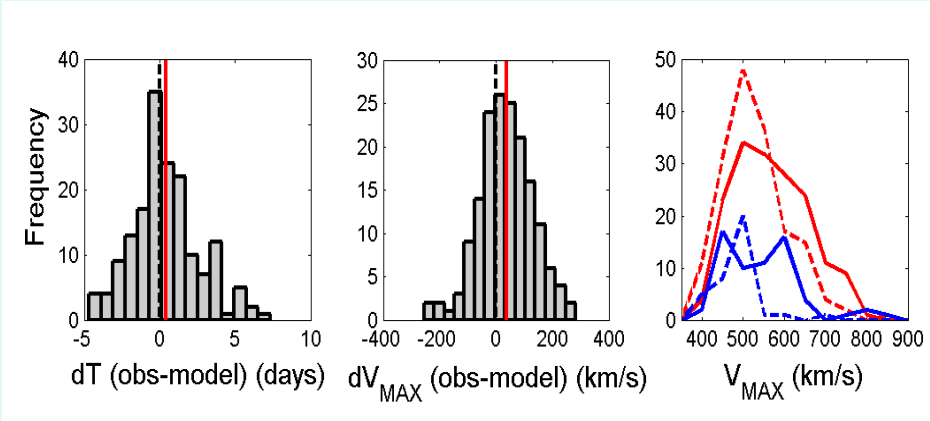
Courtesy Matt Owens (BU/CISM)

Event-Based Approach: (High Speed Events)



Contingency tables

		Observed	
		HSE	**No HSE**
Model	**HSE**	**166**	**36**
	No HSE	**64**	**-**

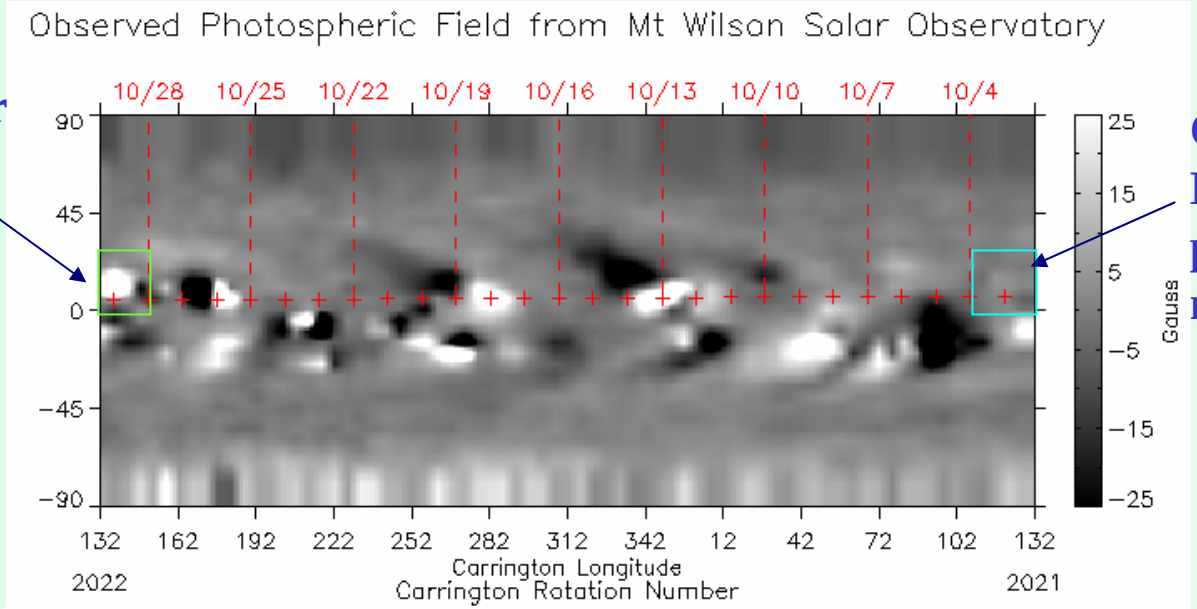
- Event-based approach: high speed enhancements (HSE):
  - Captures more than 72% of the observed HSE events
  - Most of the false HSEs are small
  - Missed HSEs: are small events or transients
  - Timing of HSEs shows no offset. Slight underestimation of magnitude of fastest events – probably due to transients

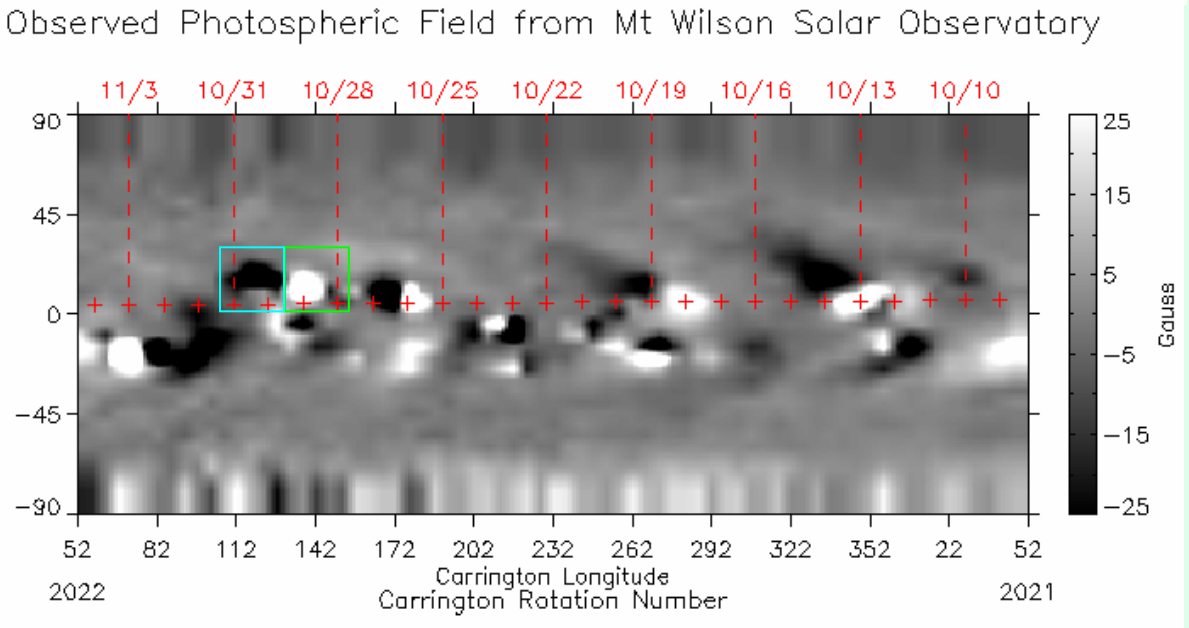
Courtesy Matt Owens (BU/CISM)

Monopole Moments in Synoptic Maps

Split bi-polar Region

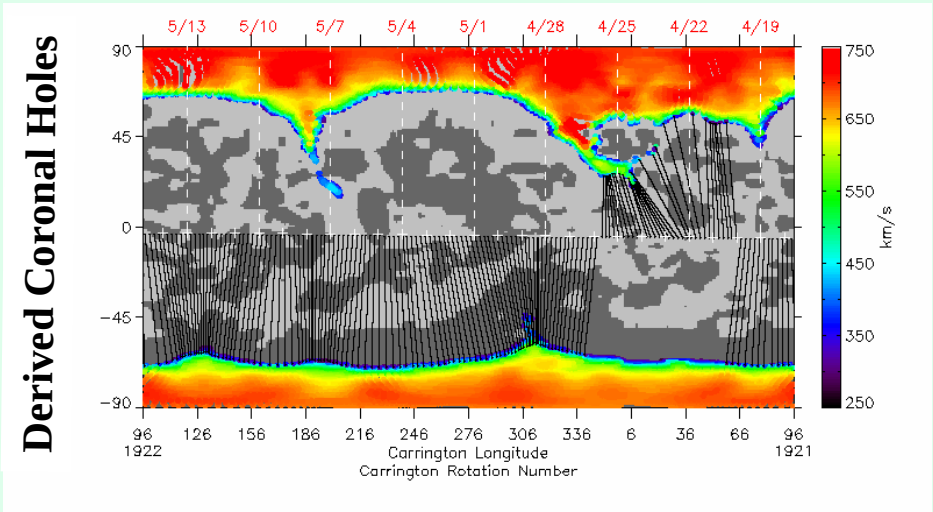
Corresponding Negative polarity missing



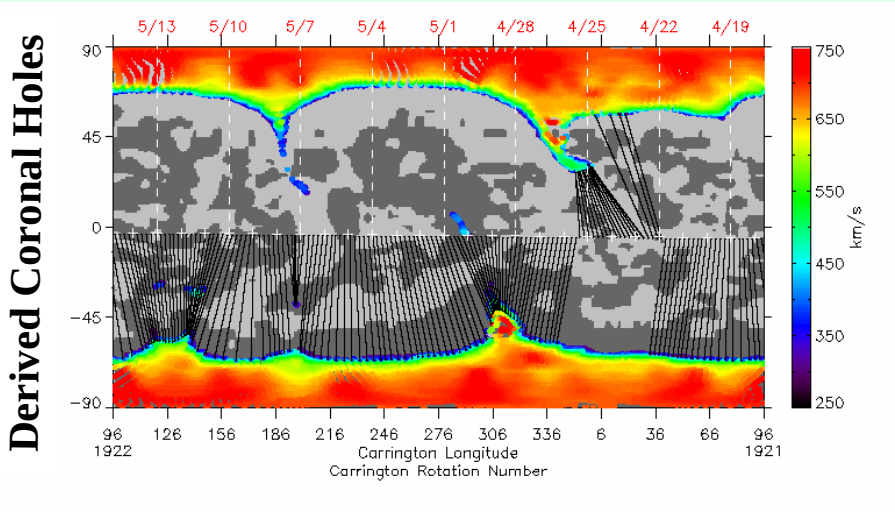


Modeling Results With & Without Polar Field Corrections Applied

Polar Fields Not Corrected



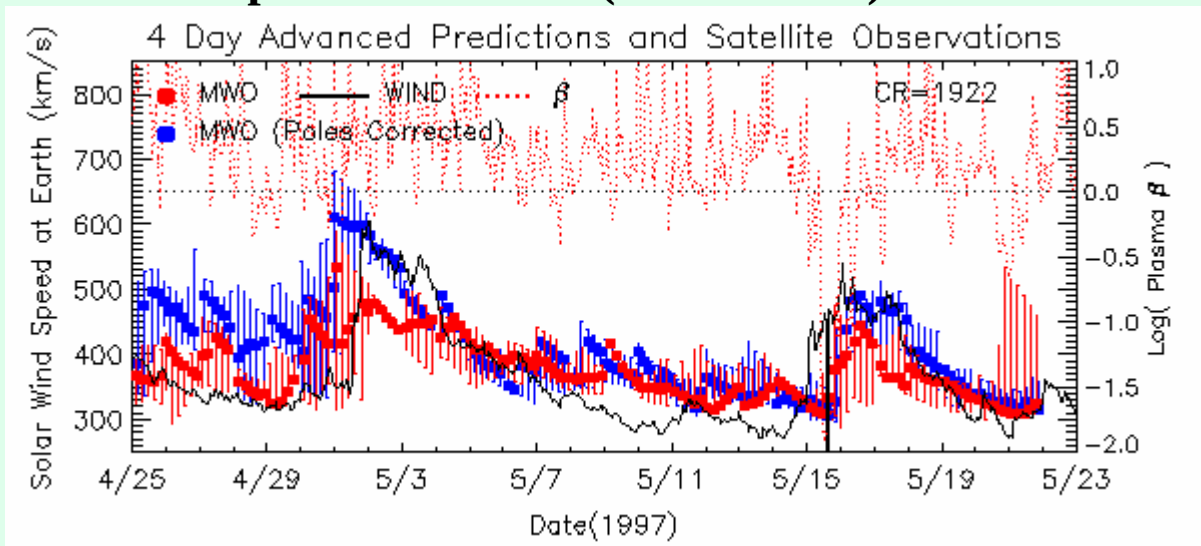
Polar Fields Corrected



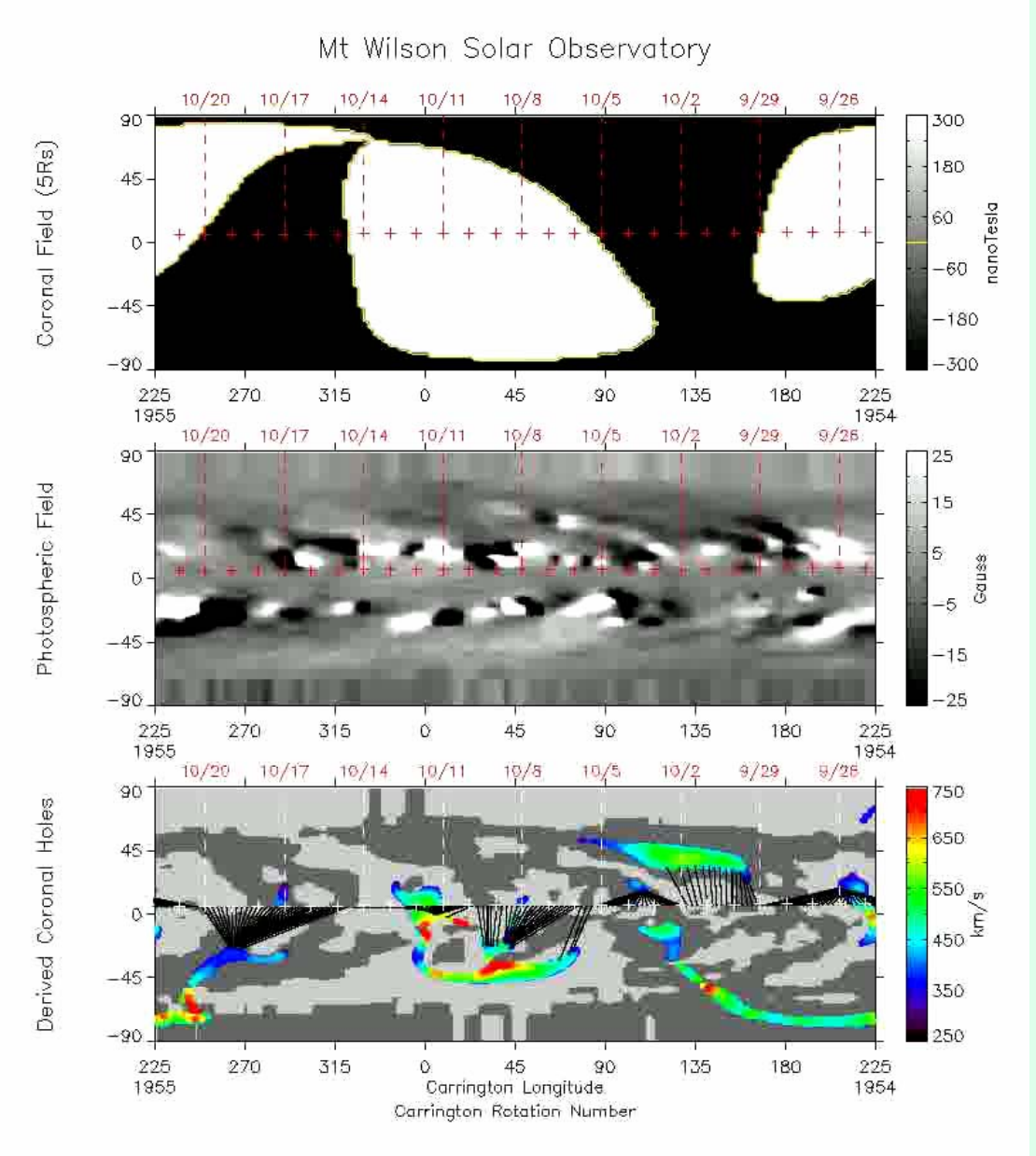
Poles NOT Corrected

Poles Corrected

Solar Wind Speed Predictions (WSA Model) and Observations



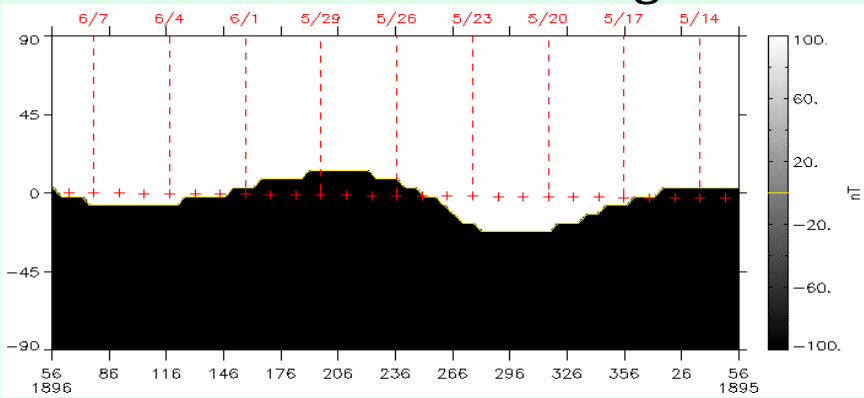
Time Evolution of Photospheric & Coronal Features



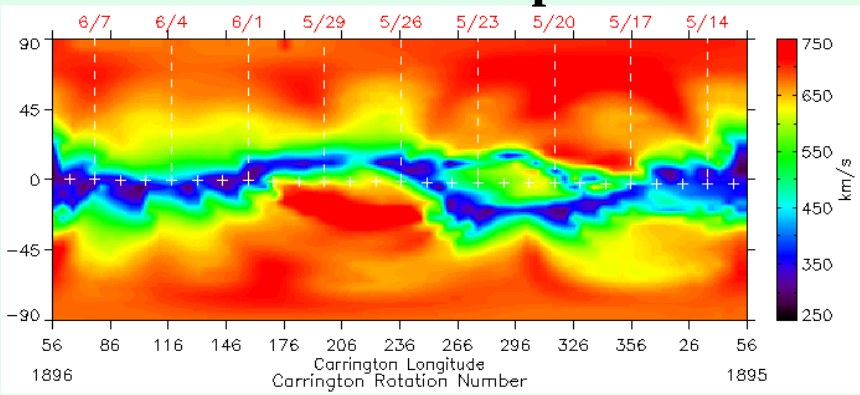
WSA Coronal - ENLIL MHD Solar Wind Model Coupling

PFSS+SCS MODEL (R = 21.5 $R_\odot$)

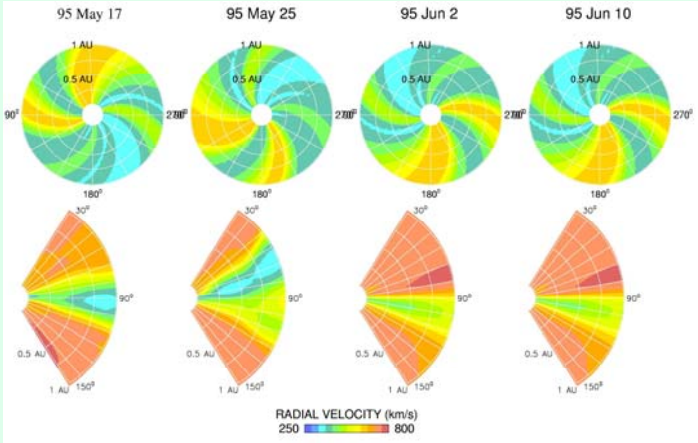
Coronal Field Strength



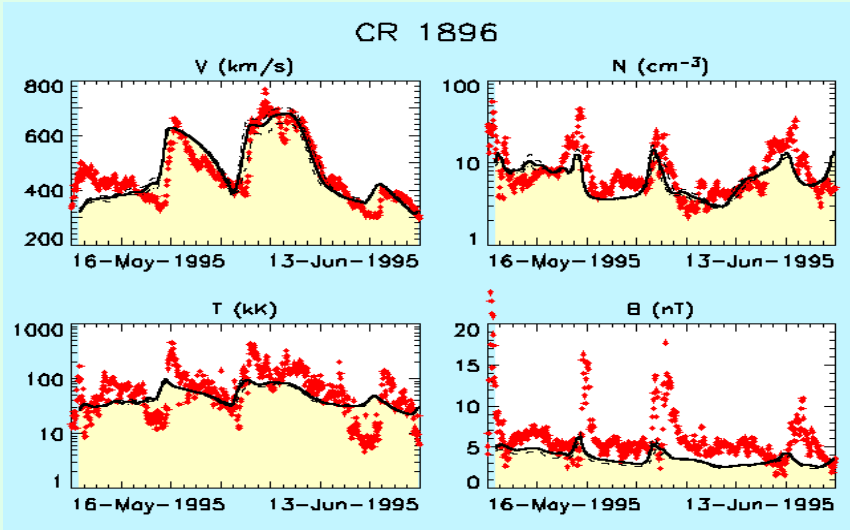
Solar Wind Speed



ENLIL MHD Solar Wind Model



Ecliptic (top) & meridional (bottom) slices through 3D MHD numerical simulation volume for CR1896.



Simulated (gray) and observed (dots) solar wind speed at Earth. Simulated speed for 5° above (dashed) and below (dash-dot) ecliptic plane.

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Summary

1) WSA model provided to the CCMC in March 2005.

2) Ambient solar wind speed and IMF polarity can be predicted at L1 with the use of a coupled PFSS+SCS model and an empirical velocity relationship that is a function of

   - Magnetic field expansion factor (f_s) and the
   - Angular distance between an open field footpoint and its nearest coronal hole boundary (θ_b).

3) Quality control of the input magnetic data is essential for improving the predictive success of the model.

4) Model validated using 8 years (~1 solar cycle) of predictions & the results are VERY encouraging.

   - It is important to have a good understanding of the physical system being modeled.

     What are you trying to predict? How do you validate?

   - How does the quality of the input data affect model predictions?
   - BIG JOB!

5) CISM is using the WSA model as it's baseline solar/solar wind model.

6) Joint AFRL-CISM effort to couple the WSA+ENLIL model.

   - Relatively quick running, coupled hybrid code.

   - Useful as both a forecasting tool and a basic research model.