WSA Model Update

Community Coordinated Modeling Center Workshop

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College Park, Maryland

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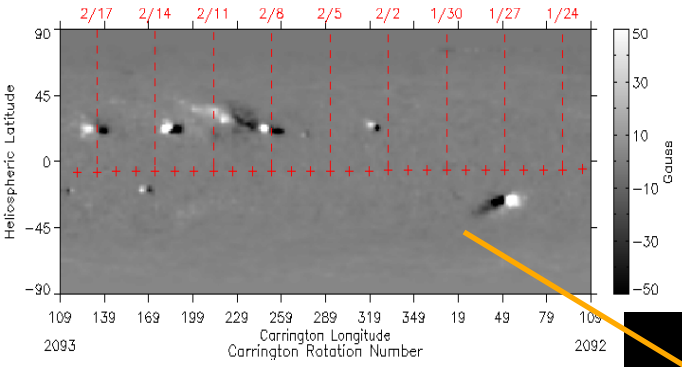
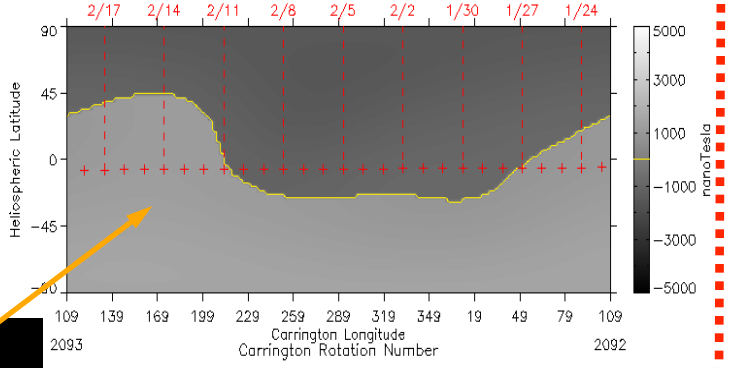
WSA

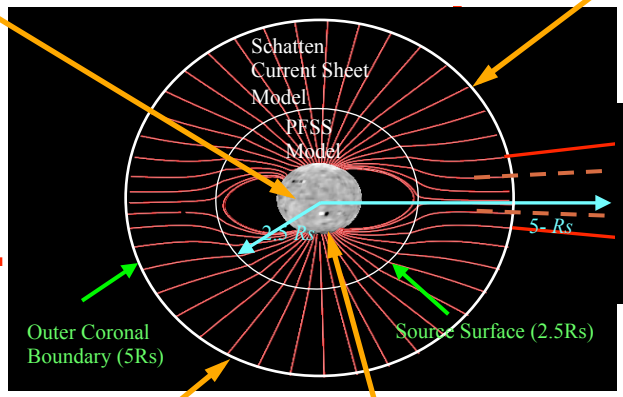
MODEL INPUT: Observed Photospheric Field



MODEL OUTPUT

Field at Outer Coronal Boundary (5.0 R_s)

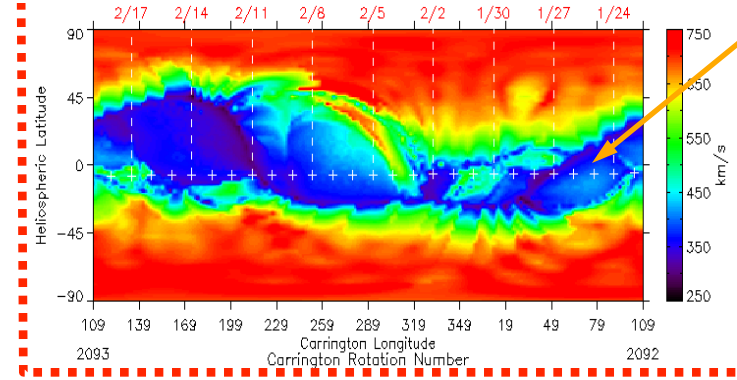




Solar Wind Model (e.g., WSA 1D Kinematic model, Enlil, LFM-Helio, & HAF) (5-30*Rs* to 1AU)

MODEL OUTPUT

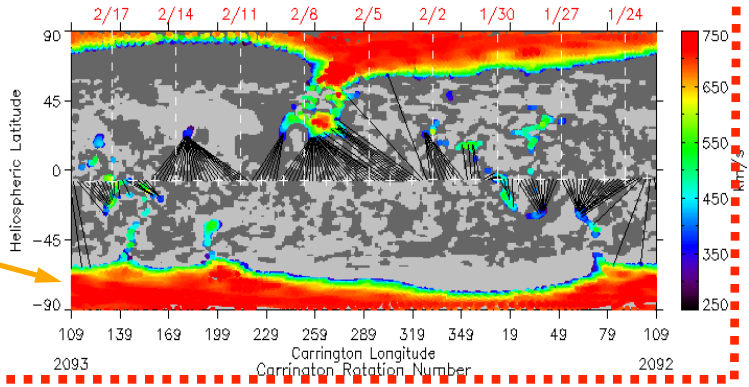
Predicted Solar Wind Speed (5.0 R_s)



Open Field Footpoints (coronal holes)

MODEL OUTPUT

Derived Coronal Holes (1.0 R_s)



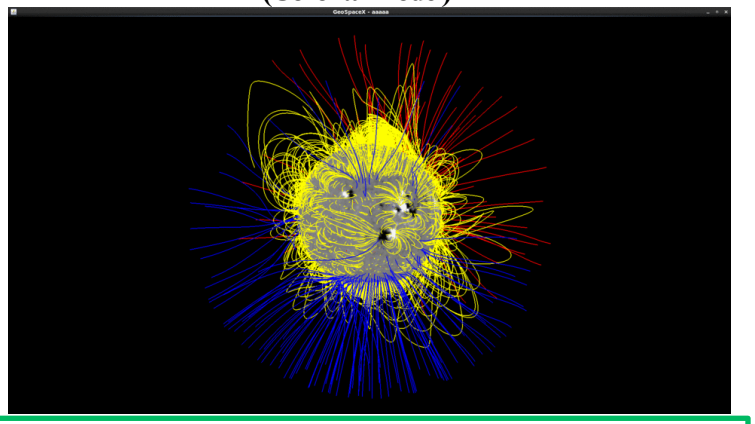
WSA 4.4

Key Features:

1. Can be run in the following modes:
   - PFSS
   - Coupled PFSS+Schatten Current Sheet (SCS)
   - Traditional or Improved interface between PFSS & SCS models.
     - Improved: minimizes "kinking" at interface.
2. FORTRAN 95, Python, and some XML
3. Compatible with
   - NSO (VSM, GONG, KPVT)
   - ADAPT (KPVT, VSM, GONG, HMI)
     - Understands multi-realization input files
4. Field line tracing parallelized & improved
   - Faster
   - Runge-Kutta-Fehlberg method (RKF45)
5. Empirical solar wind speed relationship retuned
   - Need to use data optimization methods to improve beyond this.
6. Field line visualization tool.
7. WSA-Coronal Analysis Tool (CAT)

Wang-Sheeley-Arge (WSA)

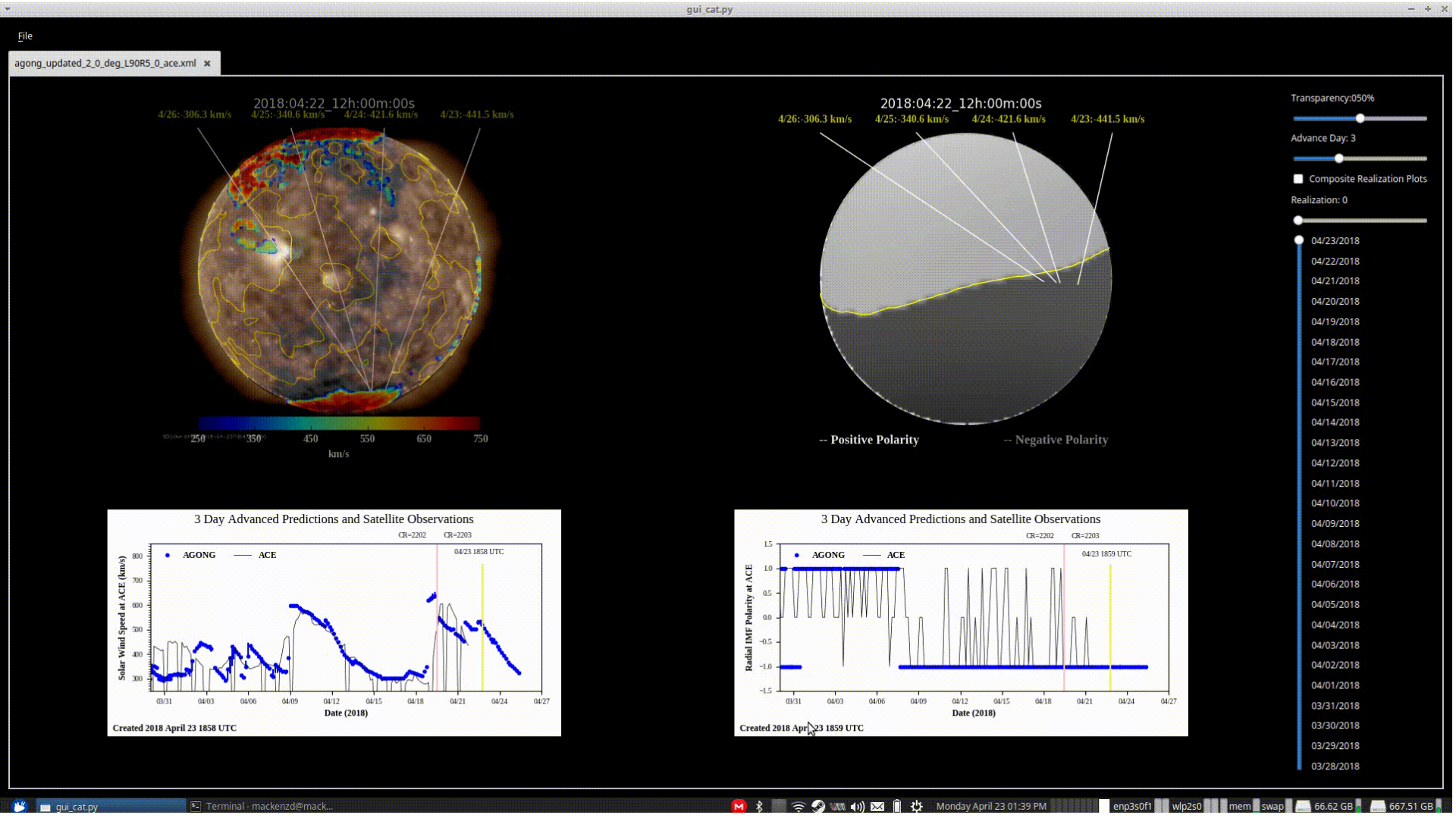
(Coronal Model)



Input: Global maps of photospheric magnetic field (e.g., ADAPT)

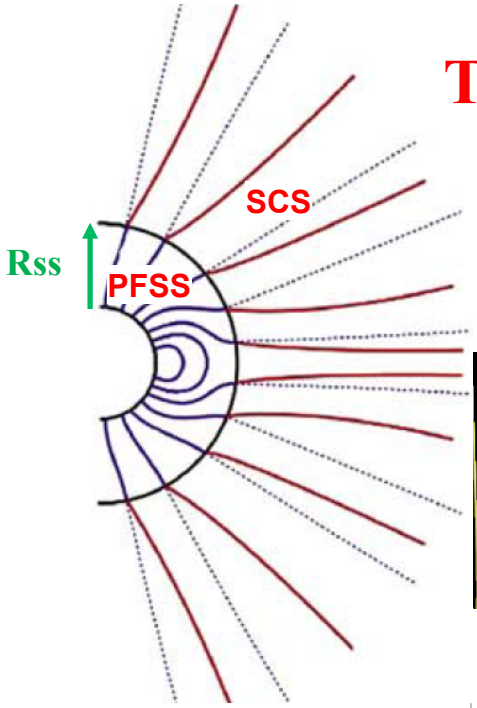
8. Forecasts solar wind speed & IMF polarity at spacecraft positions
   - Near Earth spacecraft (e.g., ACE, DSCVR, WIND, etc.)
   - STEREO A & B, & Ulysses
   - Easy to add other positions (e.g., PSP, SO)
9. Provides 3D data cubes of
   - vector B at each grid cell in computational domain (1Rs to outer boundary)
   - field line tracings (open & closed)

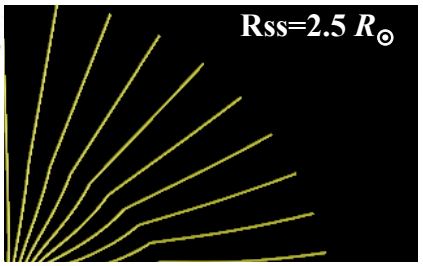
WSA-Coronal Analysis Tool (CAT)



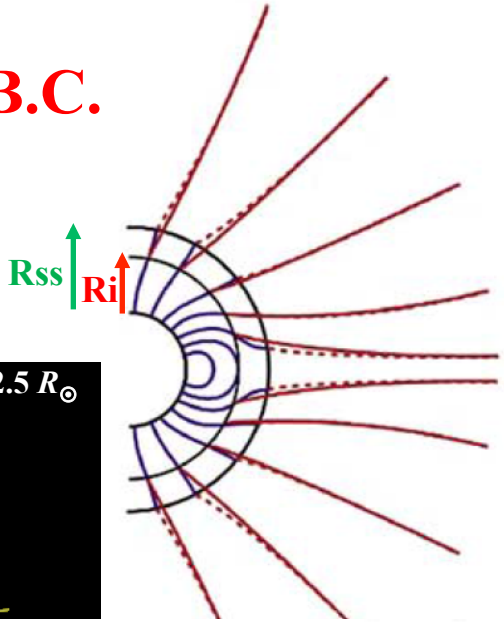
Improved Interface B.C. Between PFSS & SCS Models

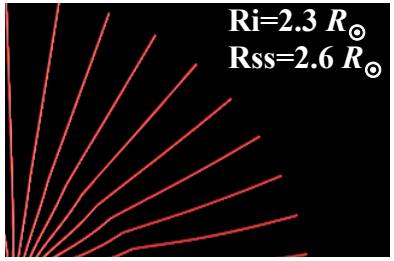
Traditional B.C.



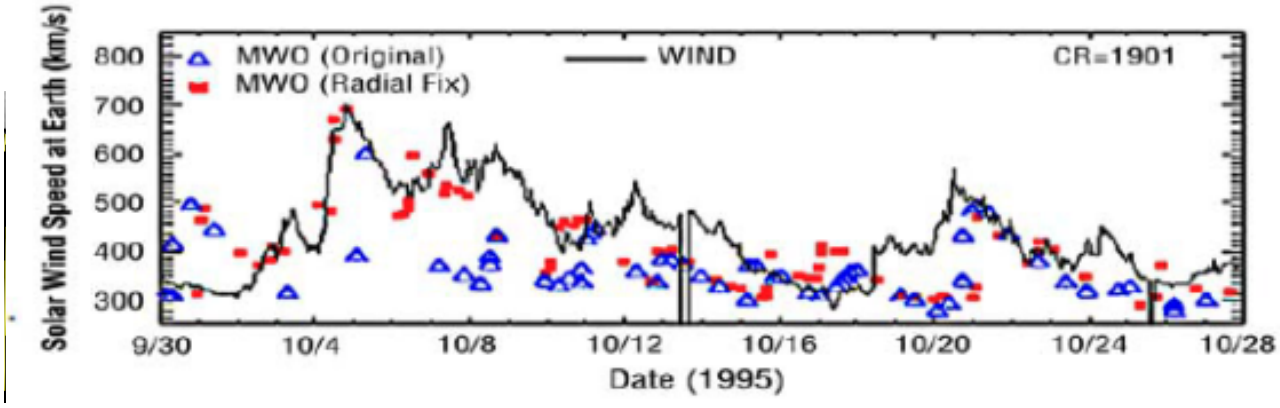


Improved B.C.





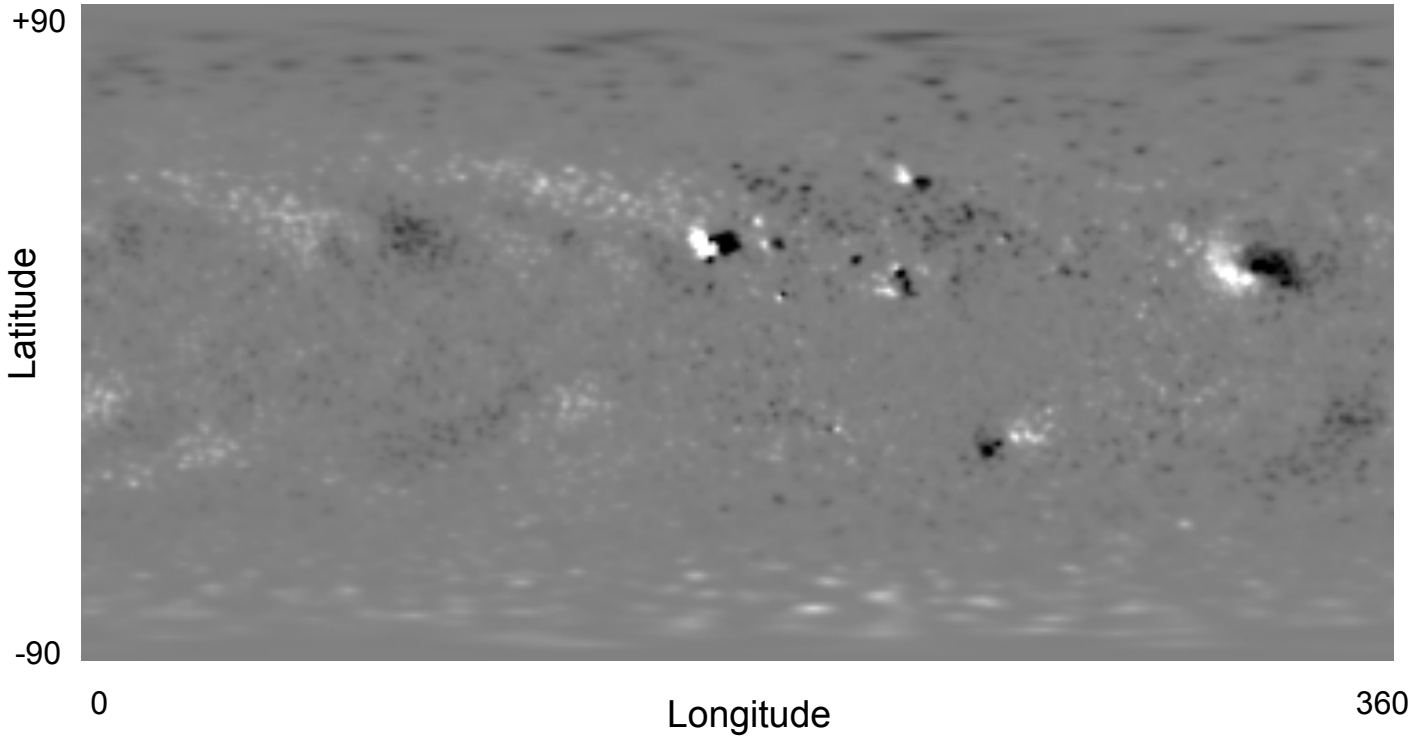
WSA 4.0 allows user to choose between standard interface B.C. (left) and improved one (right)



McGregor et al., JGR, 2008

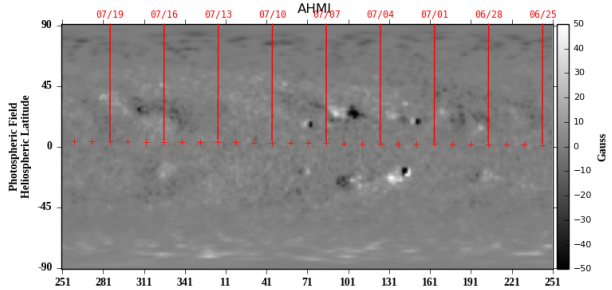
ADAPT HMI Vector with RARs:
the movie (May 1, 2010 to Sep 15, 2010)

ADAPT global map movie (realization 1 @ 24 hour cadence)

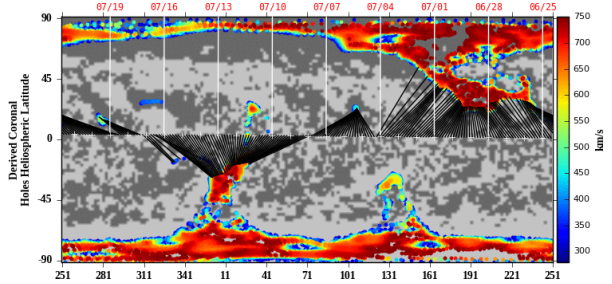


WSA ADAPT HMI-LOS

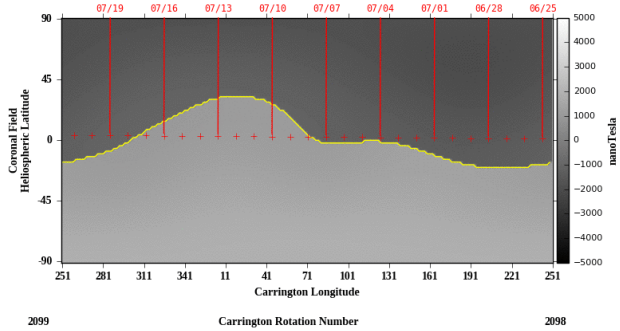
Photospheric Field Map



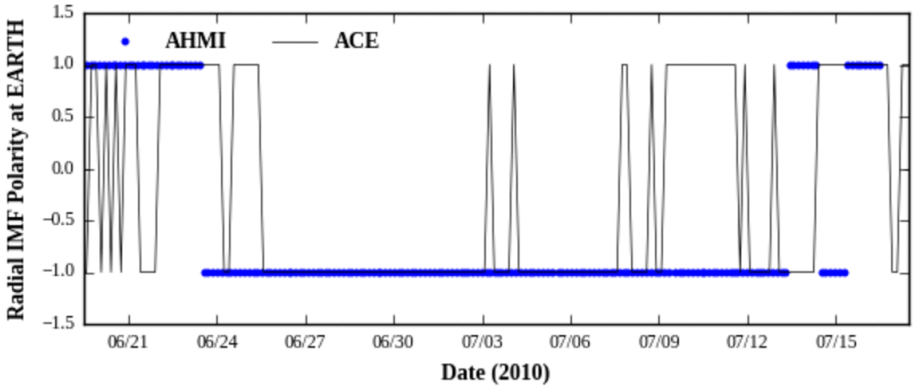
Derived Coronal Holes



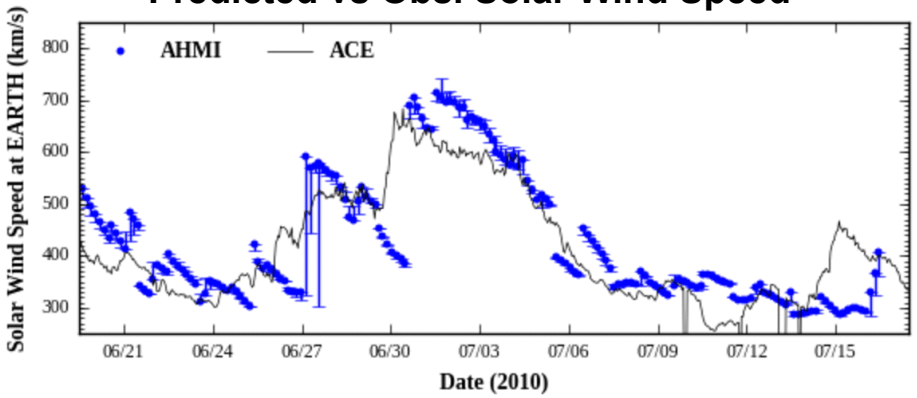
Coronal Field Map (5.0Rs)



Predicted vs Obs. IMF Polarity

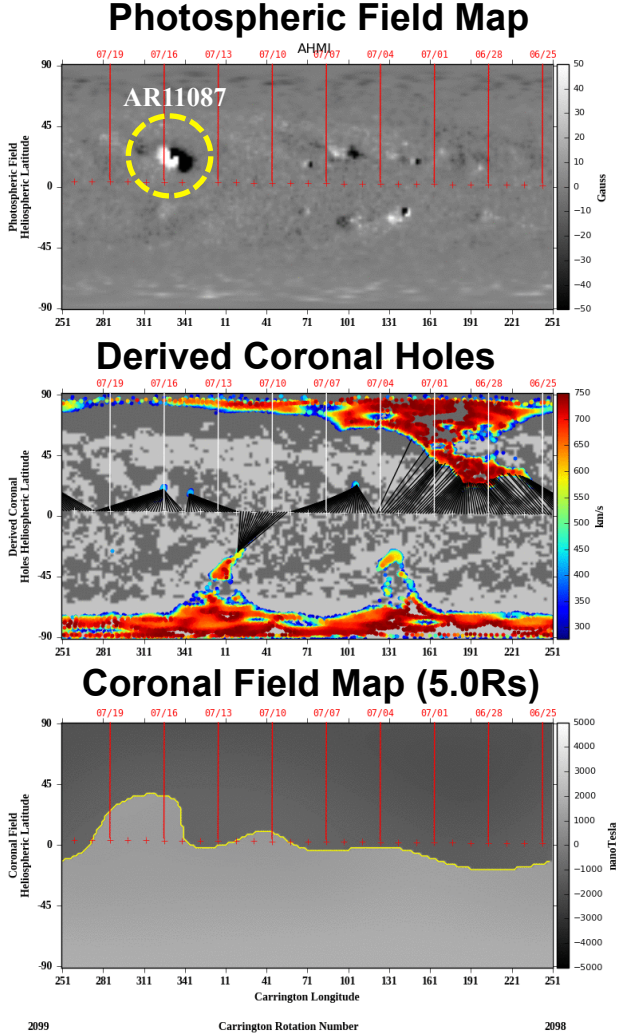


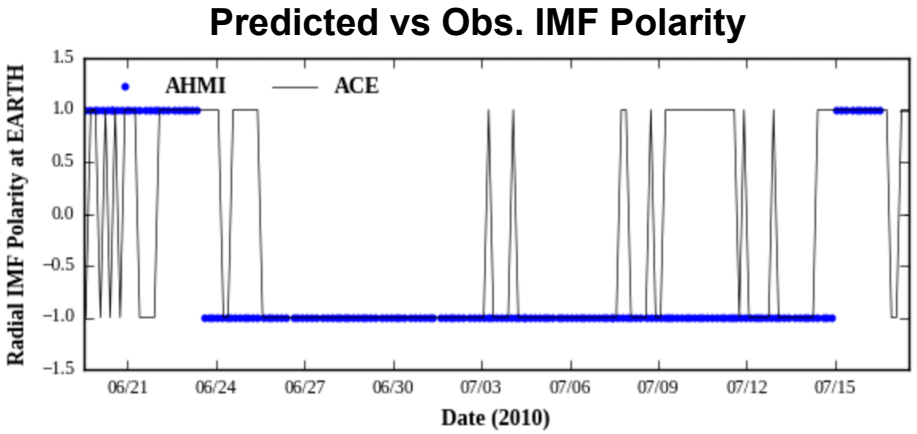
Predicted vs Obs. Solar Wind Speed

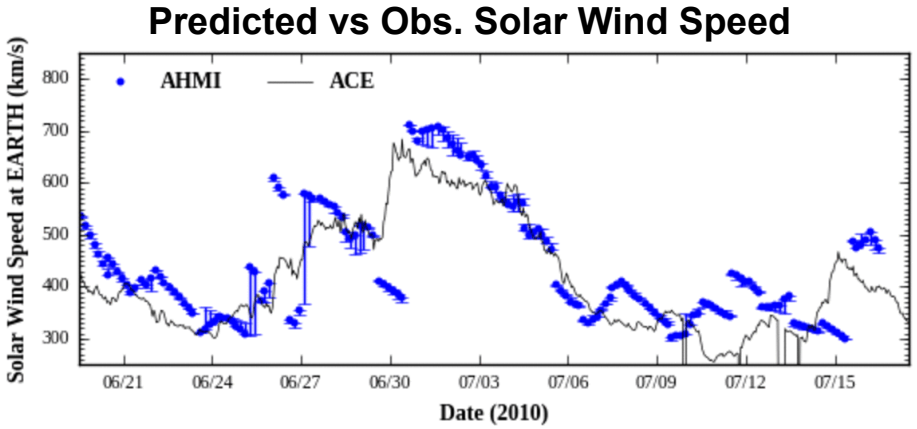


July 8, 2010

WSA ADAPT HMI-LOS *with Far-Side*



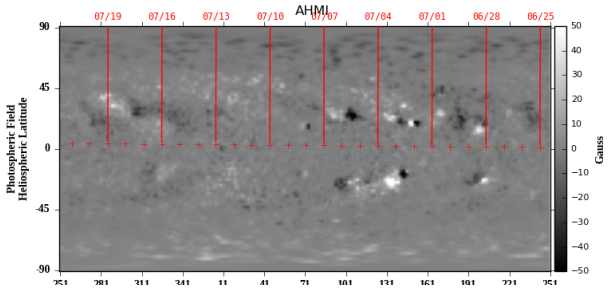




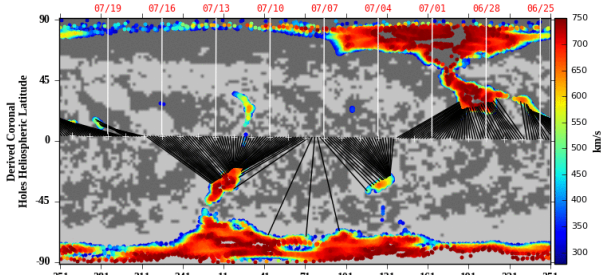
July 8, 2010

WSA ADAPT HMI-Vector

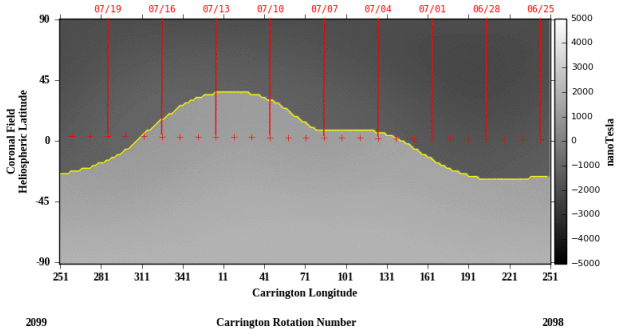
Photospheric Field Map



Derived Coronal Holes

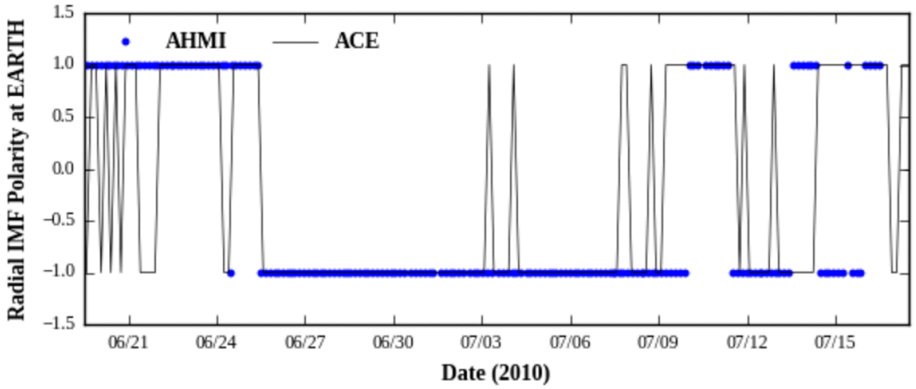


Coronal Field Map (5.0Rs)

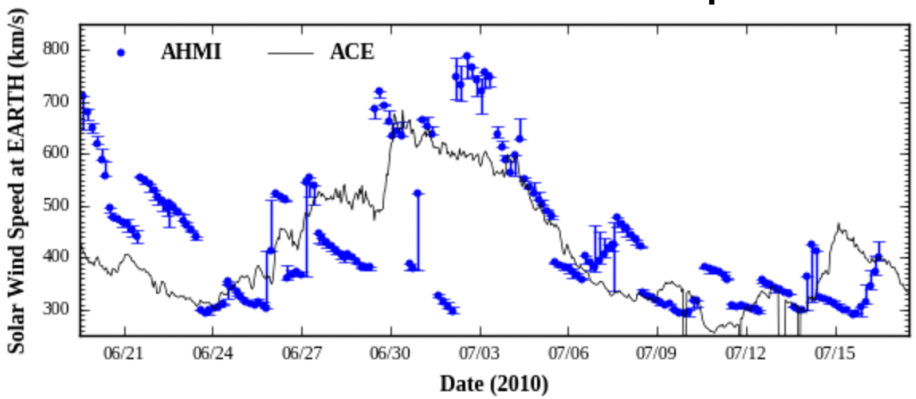


July 8, 2010

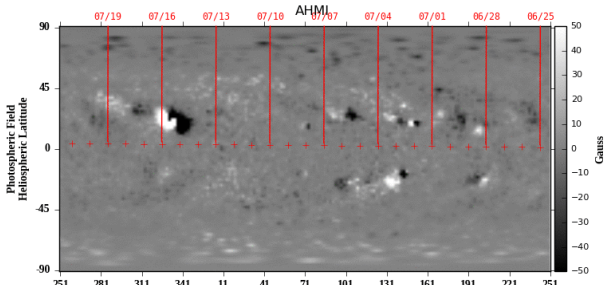
Predicted vs Obs. IMF Polarity

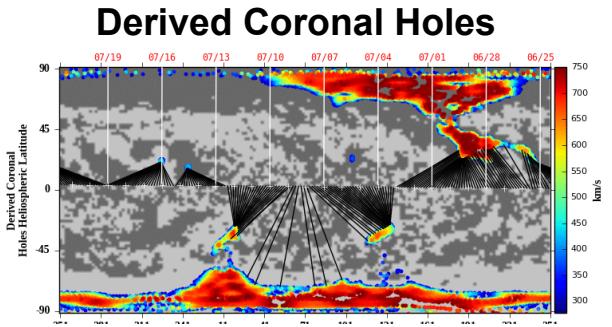


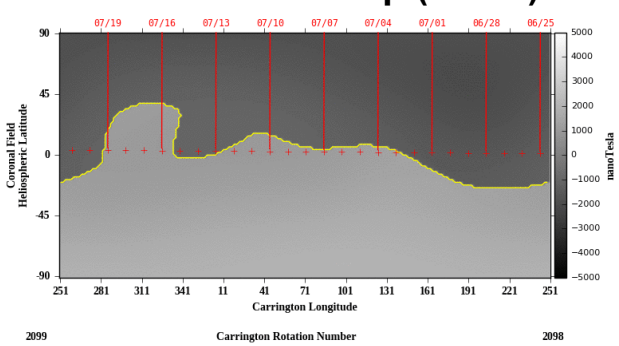
Predicted vs Obs. Solar Wind Speed



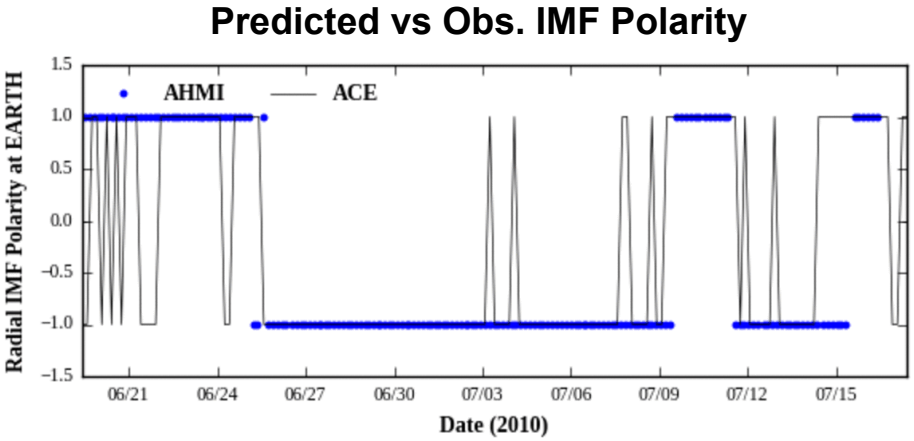
WSA ADAPT HMI-Vector *with Far-Side*

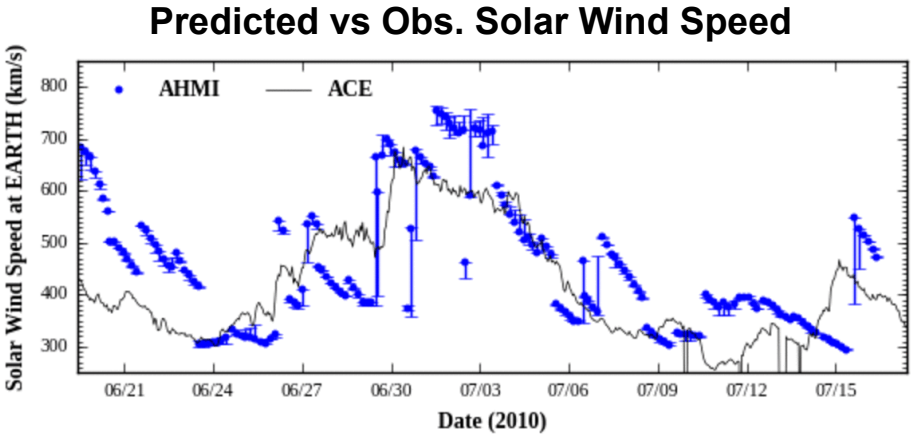






July 8, 2010

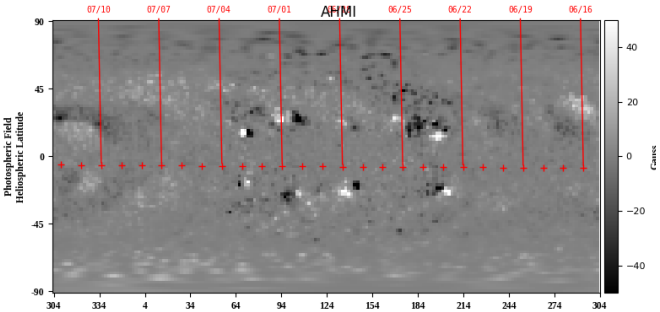




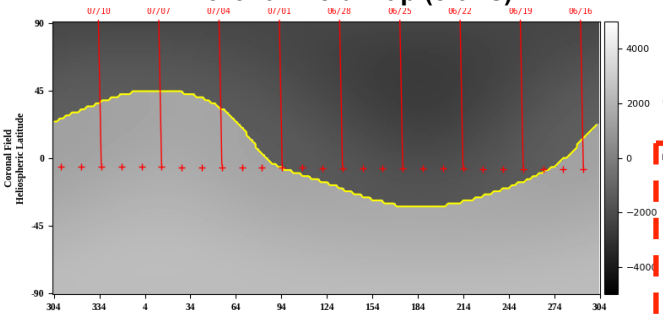
WSA ADAPT HMI-Vector: STEREO B

STEREO B Coronal & Solar Wind Predictions *without* Active Region

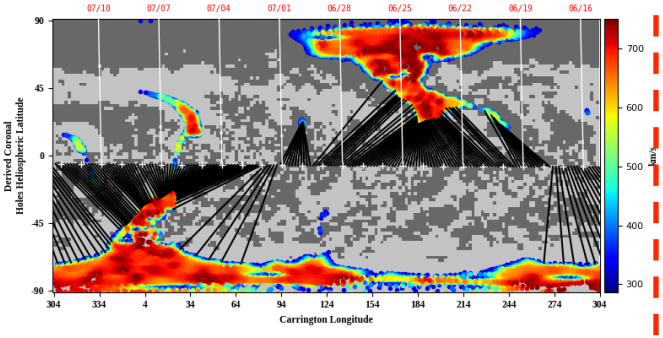
Photospheric Field Map



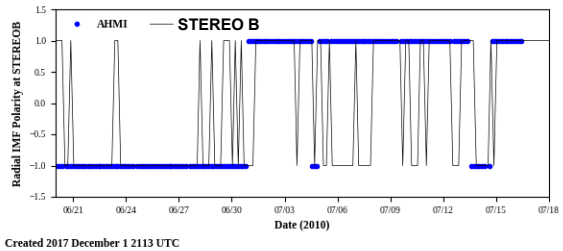
Coronal Field Map (5.0Rs)



Derived Coronal Holes

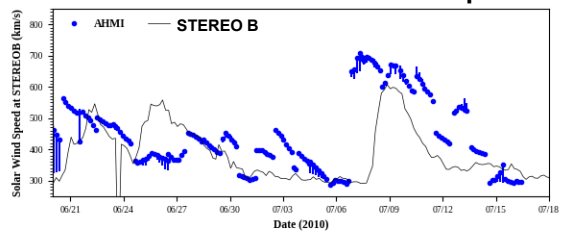


Predicted vs Obs. IMF Polarity



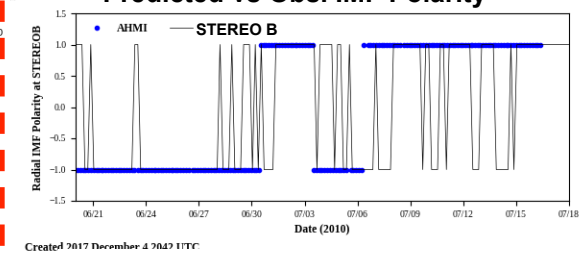
Created 2017 December 1 2113 UTC

Predicted vs Obs. Solar Wind Speed



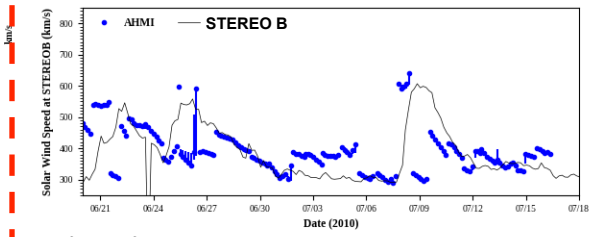
Created 2017 December 1 2113 UTC

Predicted vs Obs. IMF Polarity



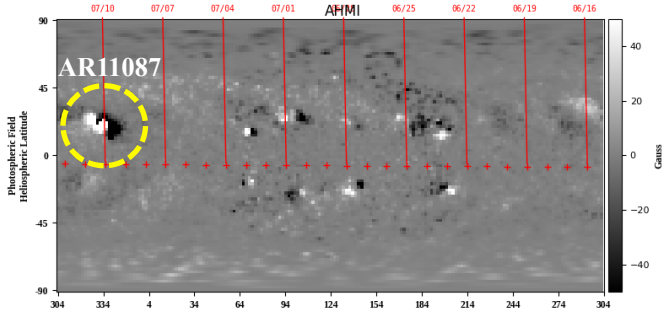
Created 2017 December 4 2042 UTC

Predicted vs Obs. Solar Wind Speed

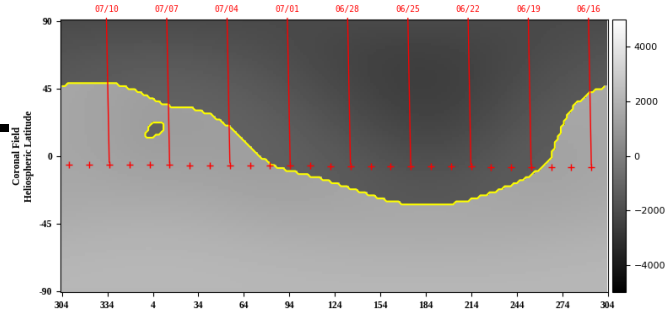


STEREO B Coronal & Solar Wind Predictions *with* Active Region

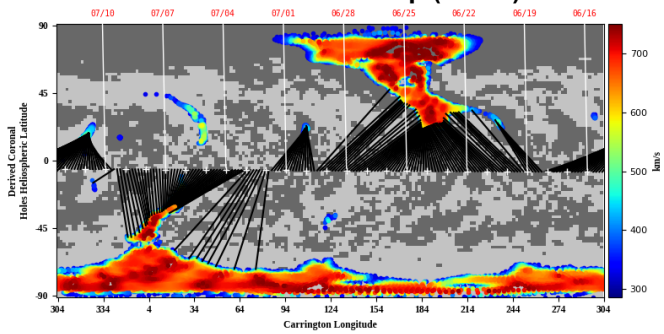
Photospheric Field Map



Derived Coronal Holes



Coronal Field Map (5.0Rs)



Ranking ADAPT Realizations

Developed a methodology for objectively ranking WSA predictions derived from different ADAPT realizations

Score ranking metric:

$$\frac{\text{\% Correct IMF Polarity}}{\text{RMS Velocity Residual}}$$

(over a given time period)

Highest Scoring Realization over Time in 2009

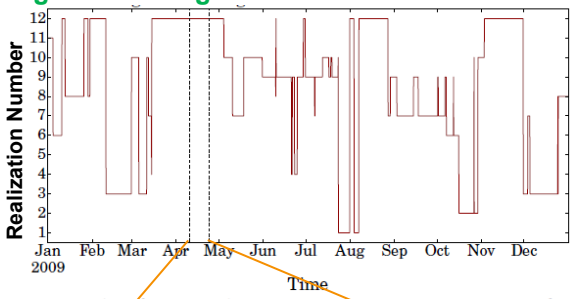


Figure 1: Plot of which realization has the highest score over time for the year of 2009. The figure highlights individual realizations performing better for extended periods.

Comparing Predicted Velocities to Observations

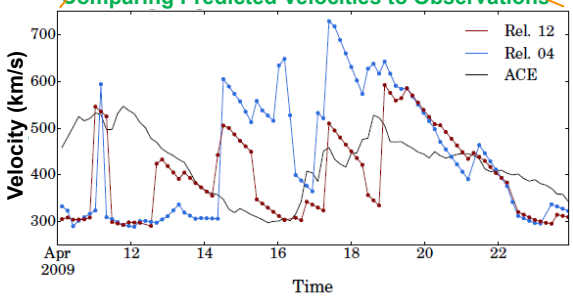


Figure 2: Plot comparing predicted velocities from the highest and lowest scoring realizations to ACE measurements from the marked area in Fig. 1. Realization 12 shows superior performance.

Comparing Predicted Polarities to Observations

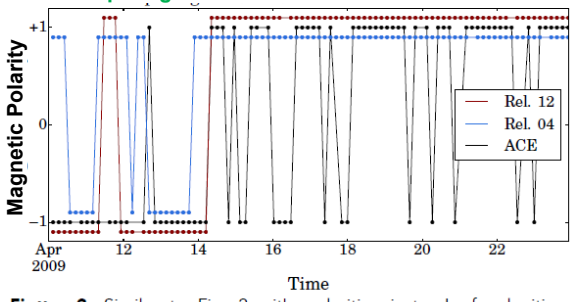


Figure 3: Similar to Fig. 2 with polarities instead of velocities. Realization 12 shows increased ability to predict the polarity, especially around April 12th and 14th.

Preliminary Results:

- **Provides a quick & quantitative way to determined which ADAPT realizations are best.**
- **Combines model IMF & velocity predictive performance into *one metric*.**
- **Sustained periods (weeks/ months) where one ADAPT realization consistently outperforms the others.**
  - **Truer during solar min**
  - **Less true during solar max**

Summary

Wang-Sheeley-Arge (WSA) model - combined empirical and physics based model of the corona and solar wind.

- **Improved version of the original Wang and Sheeley model.**
- **Operational at NOAA/NCEP, NASA/CCMC, & (soon) UK Met Office**

Key Features:

- **Field line tracing parallelized and improved**
- **Compatible with most input photospheric field maps including ADAPT.**
- **Can be run in PFSS or coupled PFSS+Schatten Current Sheet (SCS) modes.**
- **Optional improved interface between PFSS & SCS models can be employed**
  - **minimizes "kinking" at interface.**
- **FORTRAN 95, Python, and XML**
- **WSA - Coronal Analysis Tool (CAT)**
- **Forecast solar wind speed and IMF polarity at large number of spacecraft**
  - **Easy to add other satellites.**
- **Empirical solar wind velocity relationship retuned.**
  - **Need to use data optimization methods to improve beyond this.**

Using Vector Br along with far side-updates appears to *significantly improve* solar wind model predictions.

Developed a quantitative and objective method for selecting ADAPT map realizations that provide the best agreement between WSA predictions and observations.