On the solar wind source surface radius for cycle 23

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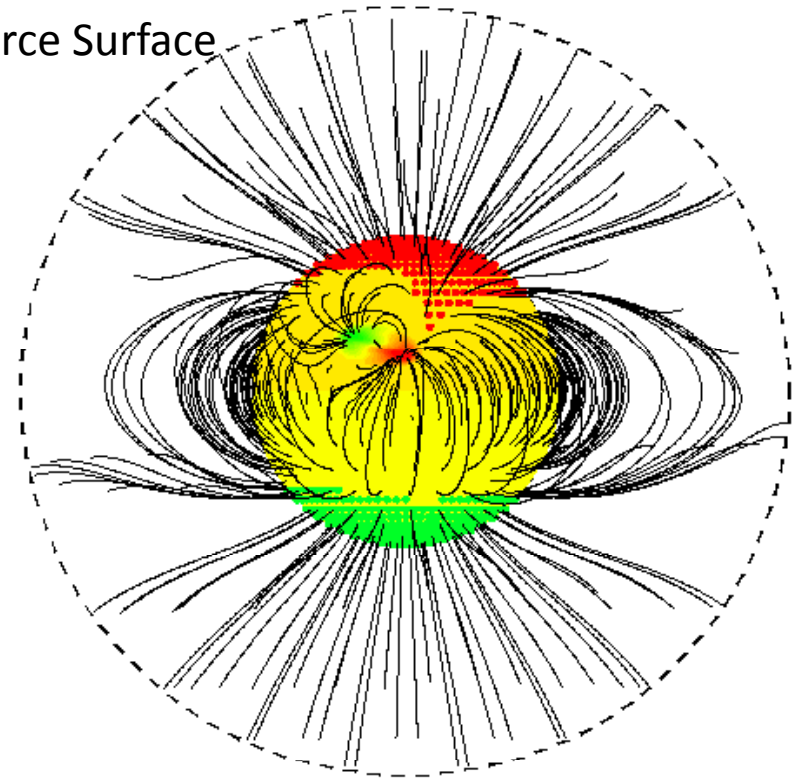
The potential field source surface model with a source surface radius of 2.5 Rs was shown by Hoeksema, Wilcox, and Scherrer (1983) to routinely provide a good description of the interplanetary field polarity at 1 AU, and thus presumably a good description of coronal streamer belt geometry and the location of coronal holes as well. We find that for the cycle 23 declining phase a smaller source surface radius is required to produce the observed coronal structure inferred from solar EUV and coronagraph images. We speculate on the implications.

A brief history of PFSS model use:

- 1969 First papers on the model by Altschuler and Newkirk and Schatten et al., showing some comparisons with eclipse images.
- 1970s Many applications to Skylab soft x-ray image interpretation by Altschuler et al., and Levine among others
- 1980s WSO scientists regularly model the source surface neutral line for use in IMF polarity prediction and analysis, including PhD thesis work of Hoeksema
- 1990s PFSS models are extensively used by Sheeley and Wang to analyze aspects of coronal fields throughout the solar cycle, including coronal holes, and to develop an empirical model for solar wind stream velocities based on coronal flux tube divergence. Wang, and also Zhao and Hoeksema use it to calculate interplanetary field strength. Bravo et al., and Luhmann et al. investigate its use for learning more about the global context of coronal transients.
- 2000s Arge et al. use a version of the Wang/Sheeley empirical model to post solar wind speed and IMF polarity predictions versus observations from WIND and ACE on the WWW at the NOAA-SEC Rapid Prototyping Center. Schrijver and DeRosa also post forecasts of coronal hole geometries using temporally evolving synoptic maps. Arge uses his model to analyze the solar wind stream context of ICMEs.

Basics of the PFSS Model

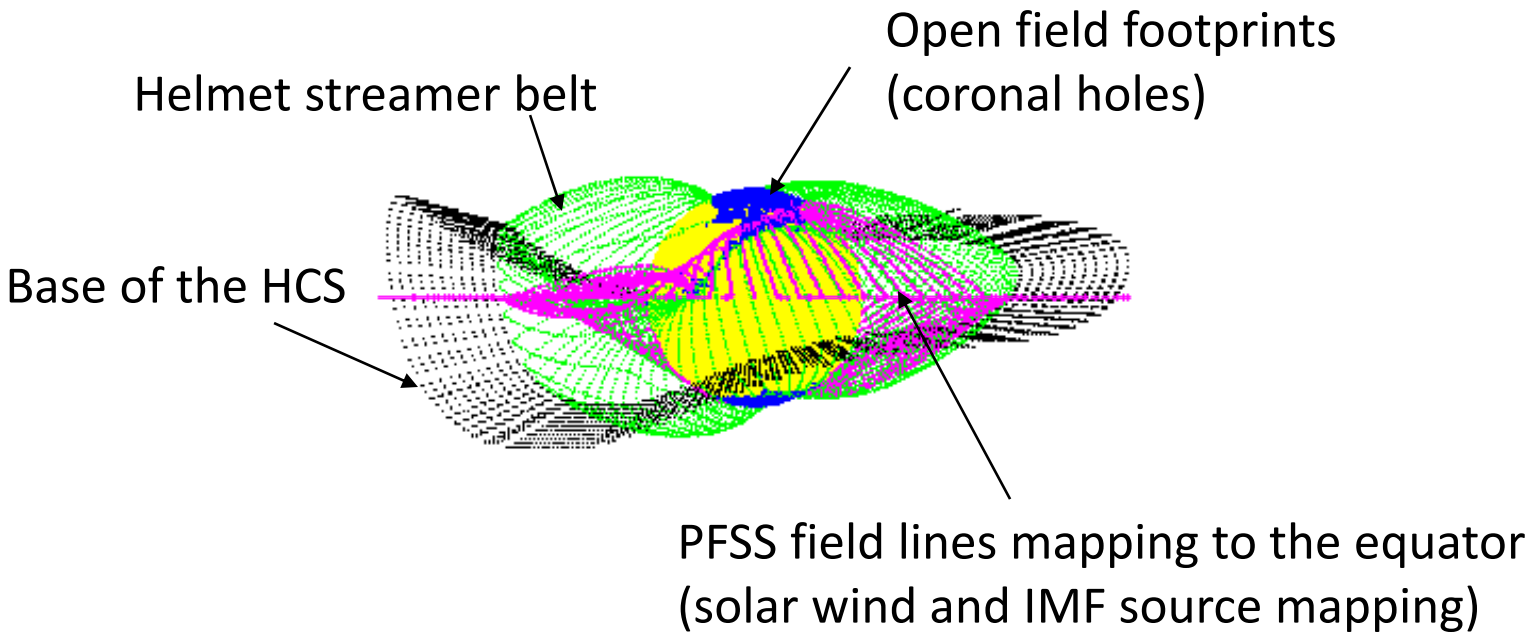
Spherical
Source Surface

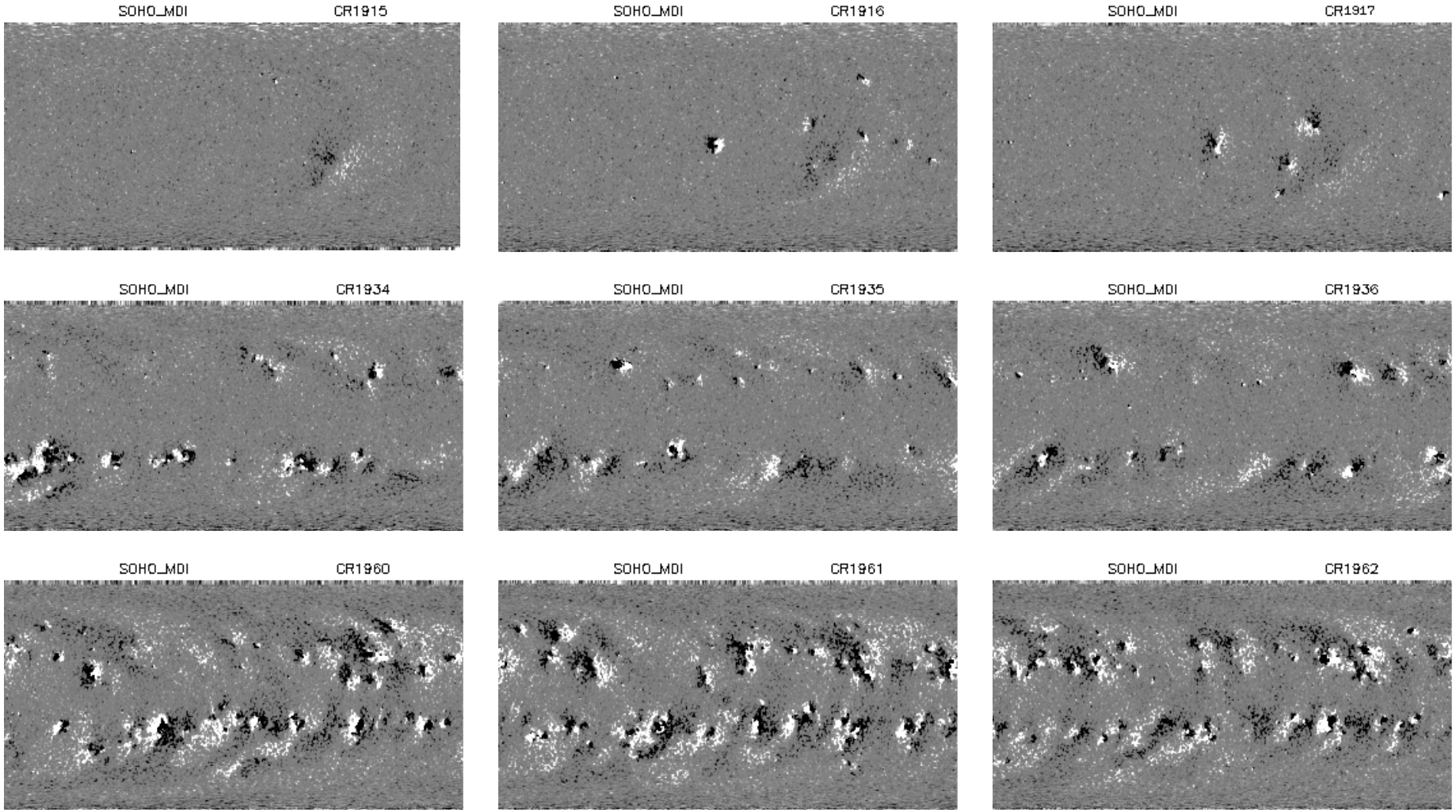


(Image from Yan Li)

- Useful attributes of the model include open/closed field regions (e.g. coronal hole footprints for a specific photospheric field map and source surface radius-usually 2.5 solar radii (Rs)).
- The last closed field lines form the helmet streamer belt whose cusps at the source surface define the base of the heliospheric current sheet.

Information obtained from PFSS models:



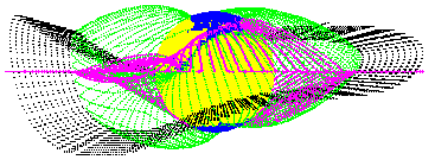


Synoptic maps of the photospheric field provide the inner boundary condition for PFSS models. The details of their construction make important differences in the accuracy of the coronal field configurations. These maps significantly change with solar activity.

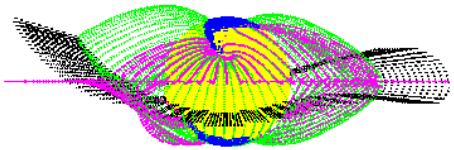
(synoptic maps from SOHOMDI of CR 1915-1917, 1934-1936, and 1960-1962)

The variety of photospheric field conditions produces a variety of coronal field configurations from nearly dipolar to highly complex. Observed coronal holes and ray structures reflect these changes.

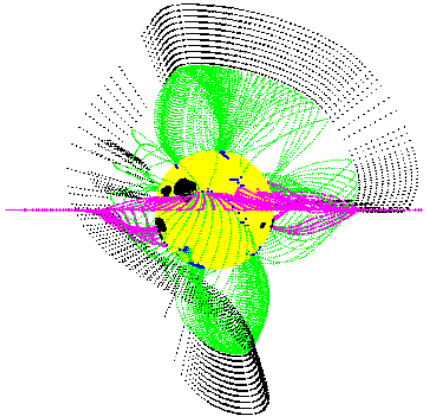
CR1918



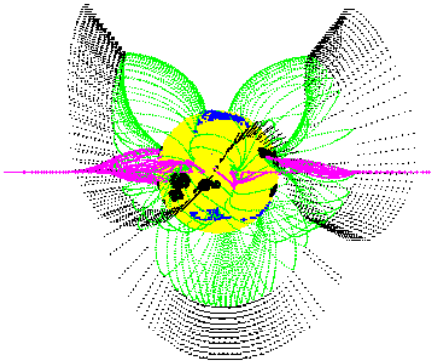
CR1922



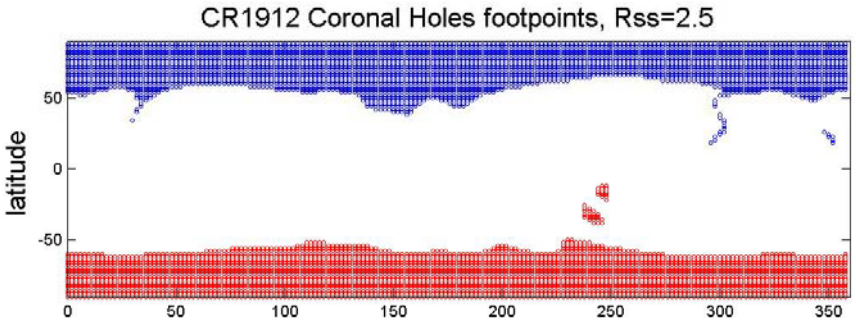
CR1951

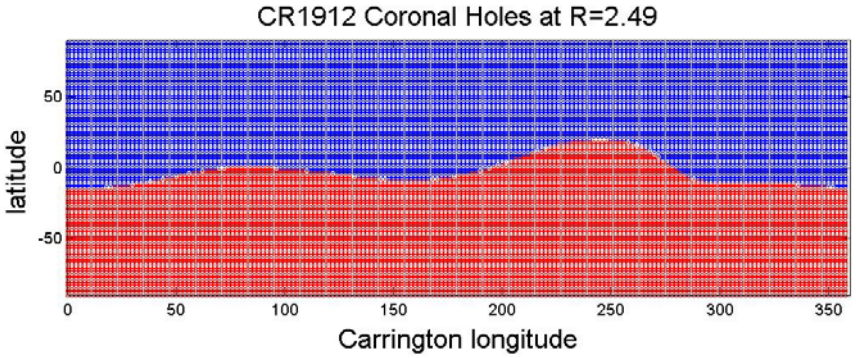


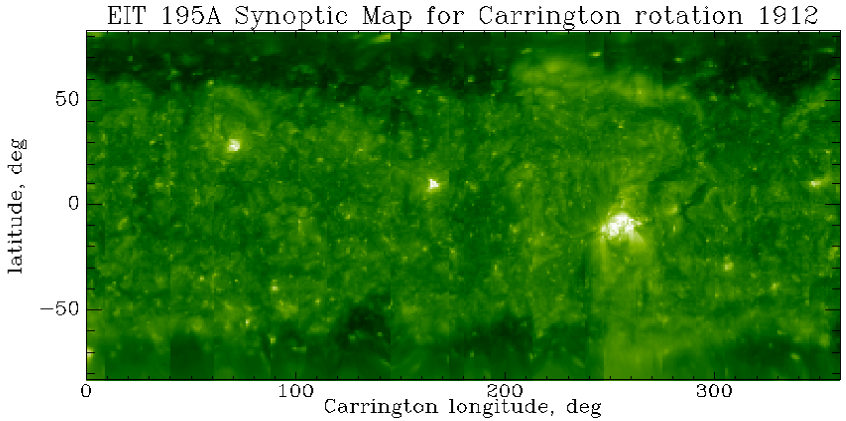
CR1968



The previous cycle declining phase/minimum coronal holes and streamer belt were well-described by the PFSS model with the usual 2.5 Rs source surface radius. The current cycle is different.

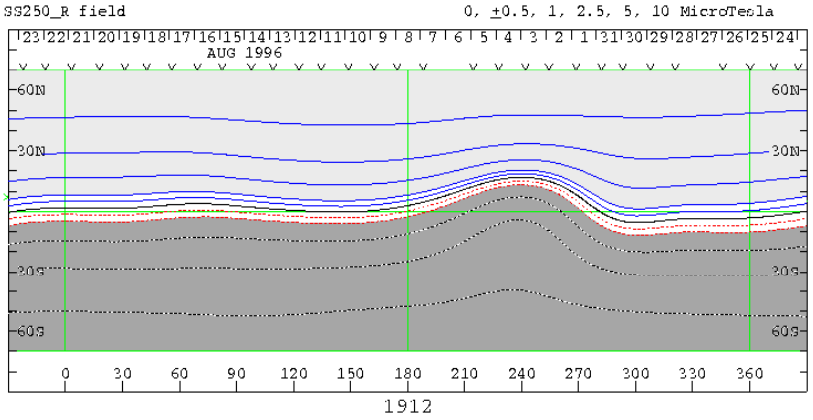


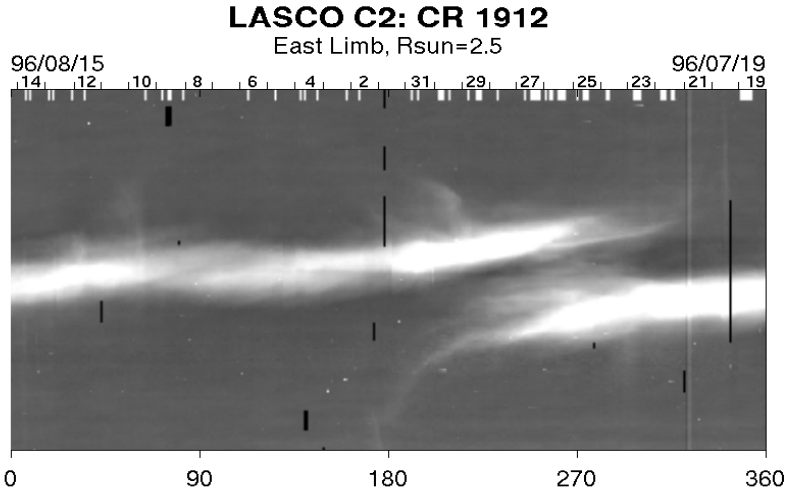


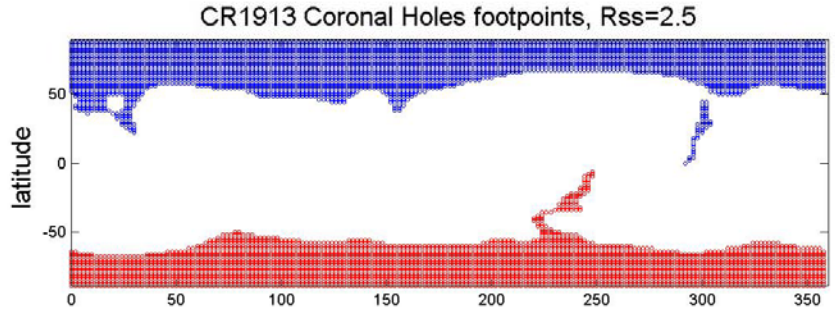


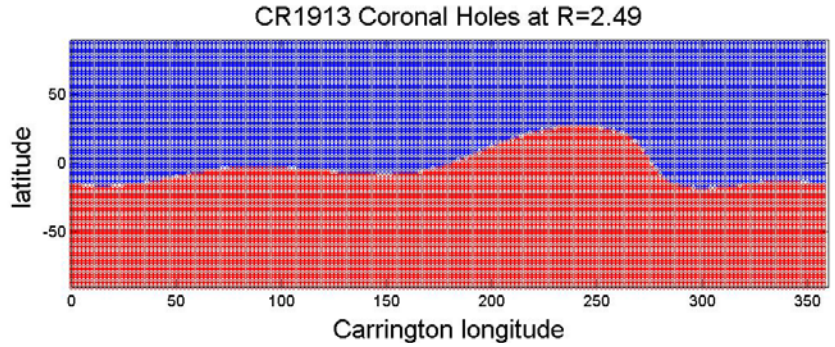
(E. Benevolenskaya website)

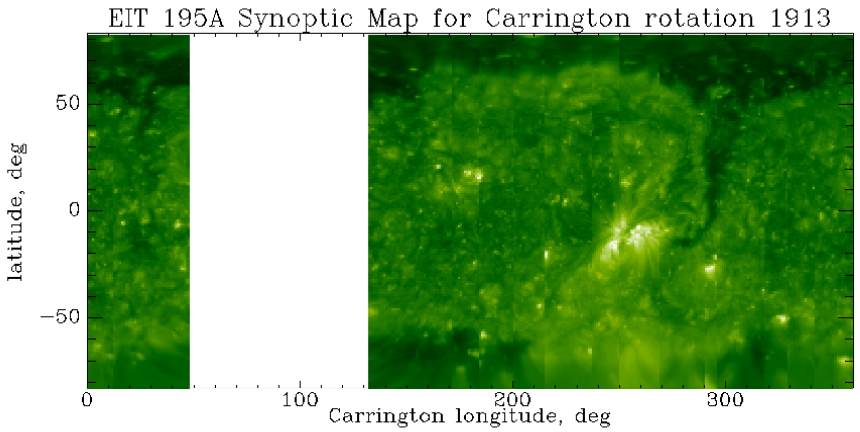
CR1912: images from SOHO EIT, LASCO C2. PFSS models based on WSO (right) and MWO (left) maps



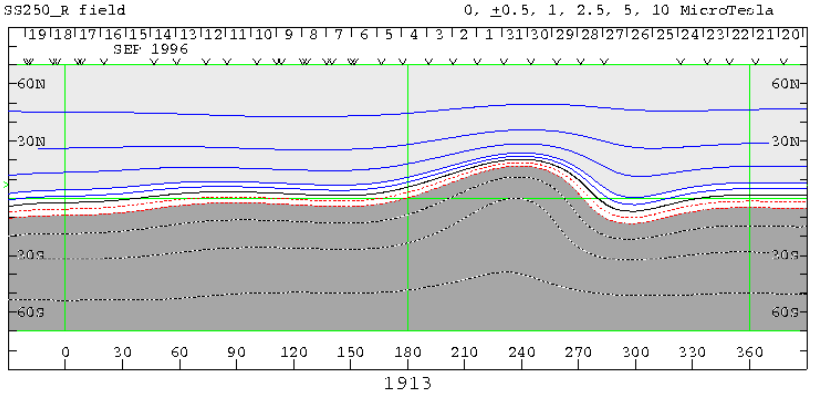


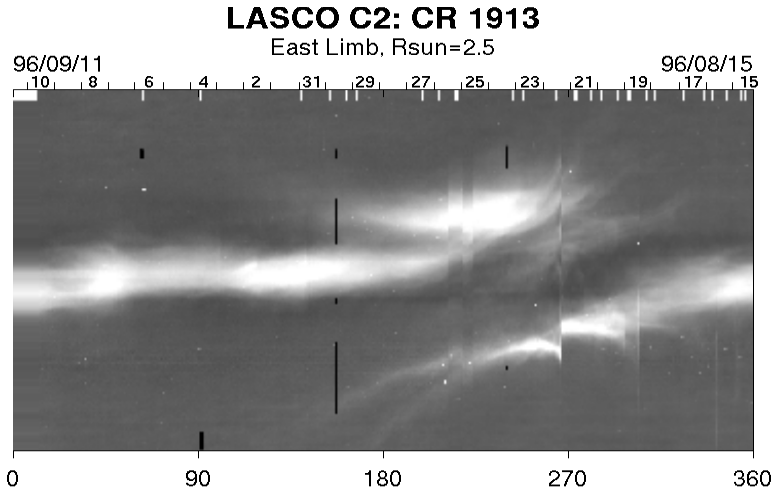




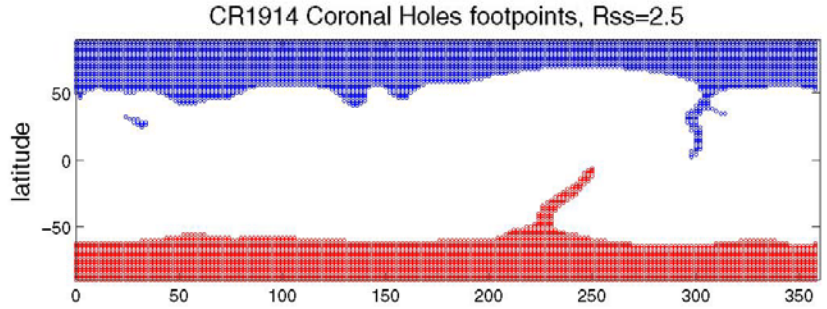


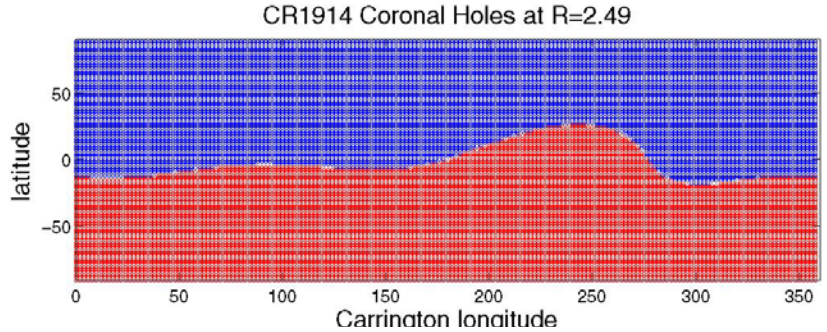
CR1913: images from SOHO EIT, LASCO C2. PFSS models based on WSO (right) and MWO (left) maps

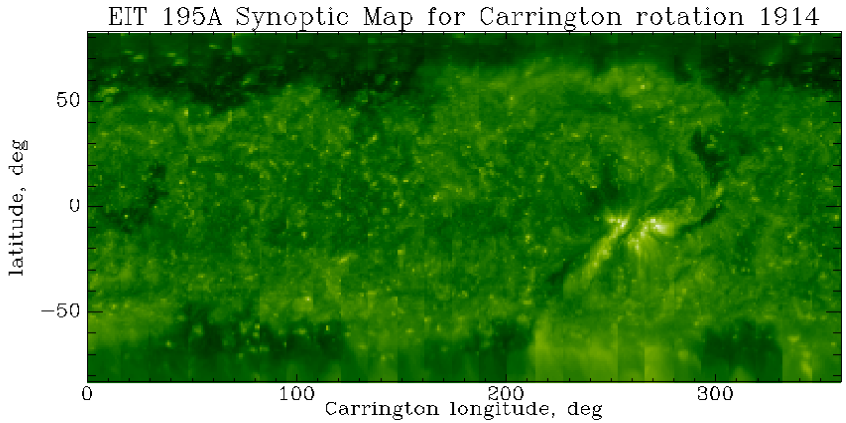




(E. Benevolenskaya website)

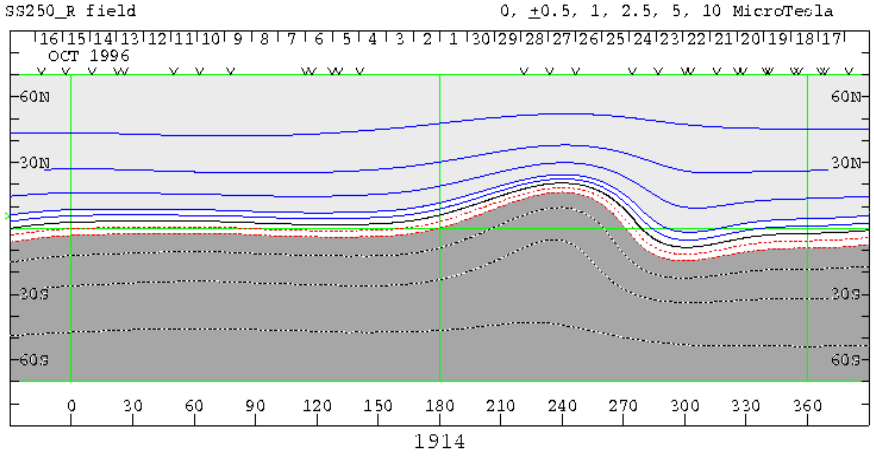


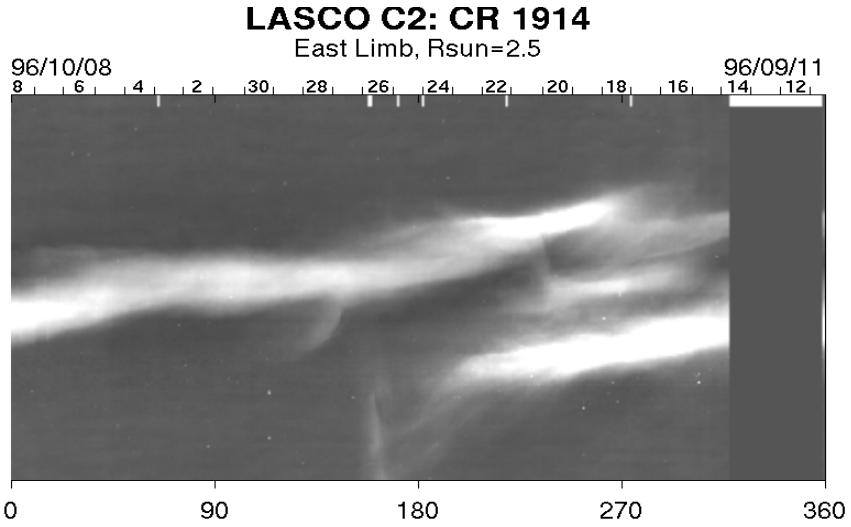


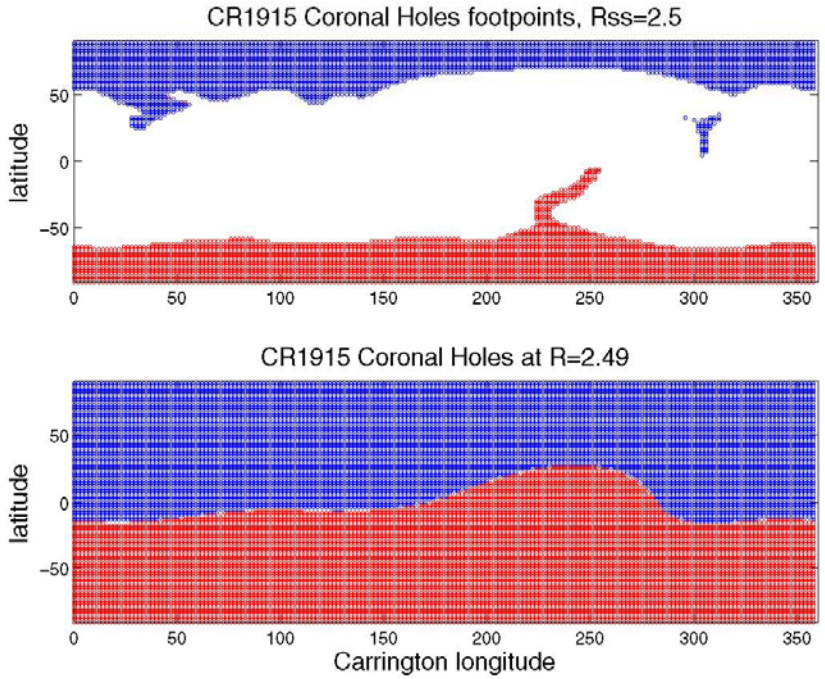


(E. Benevolenskaya website)

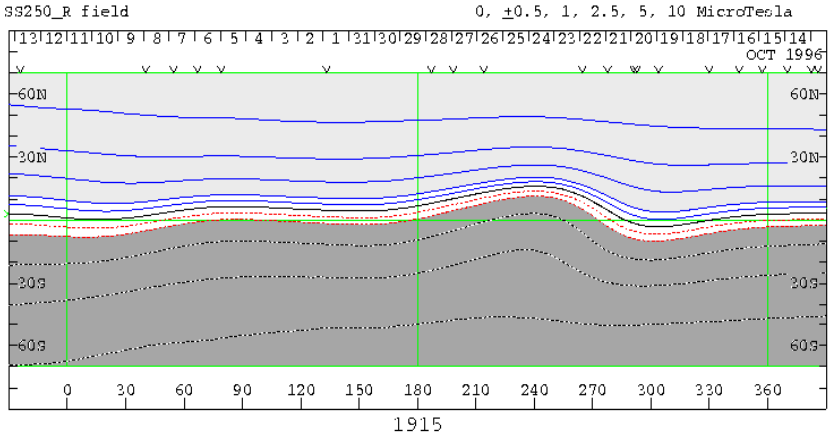
CR1914: images from SOHO EIT, LASCO C2. PFSS models based on WSO (right) and MWO (left) maps

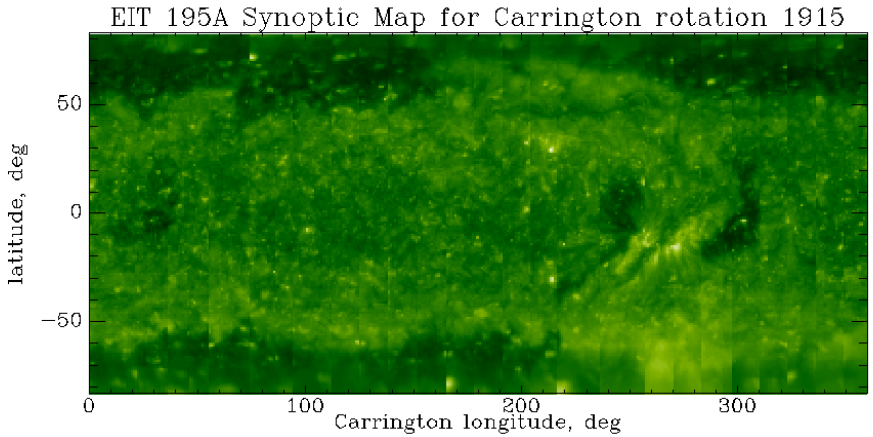




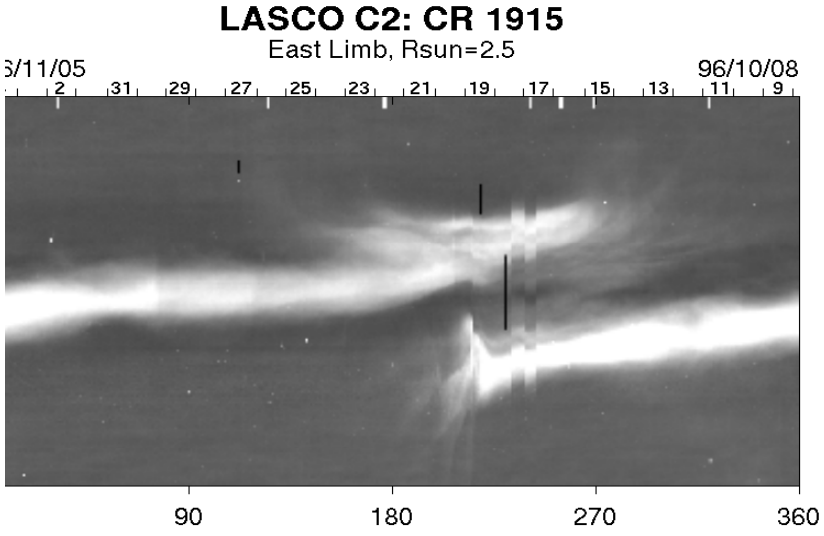


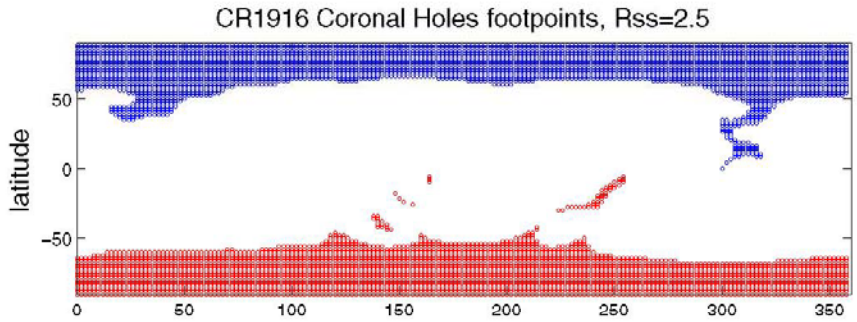
CR1915: images from SOHO EIT, LASCO C2. PFSS models based on WSO (right) and MWO (left) maps

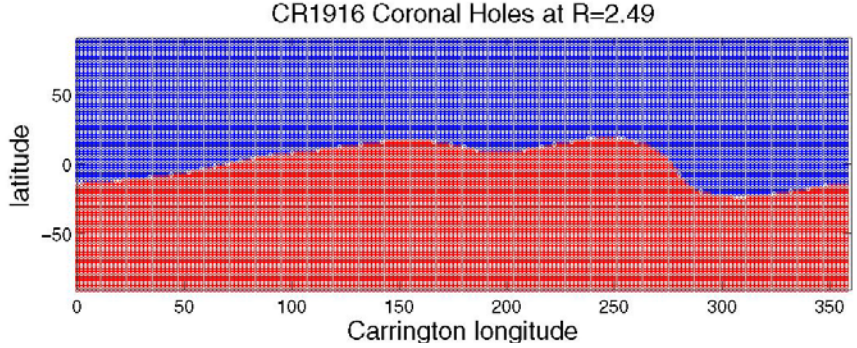


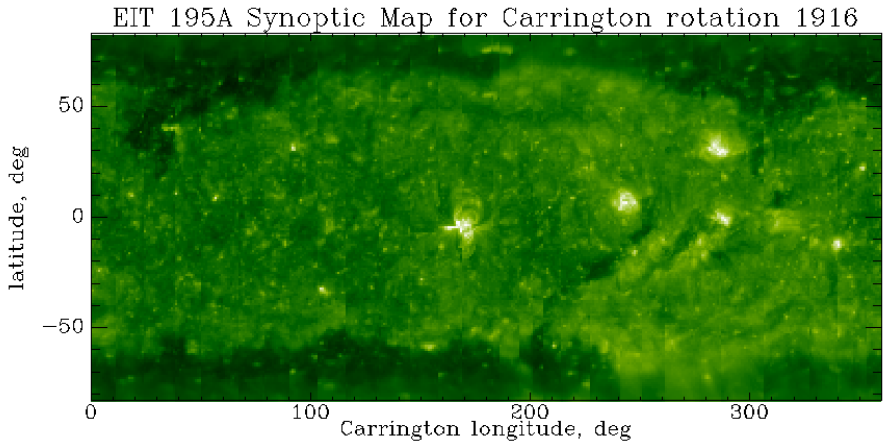


(E. Benevolenskaya website)



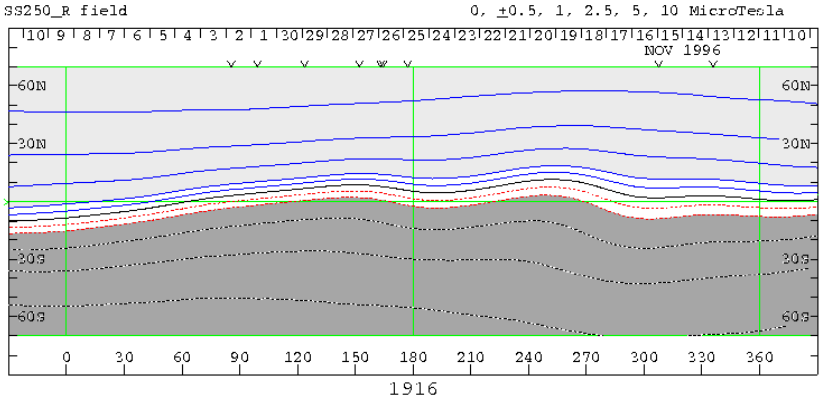


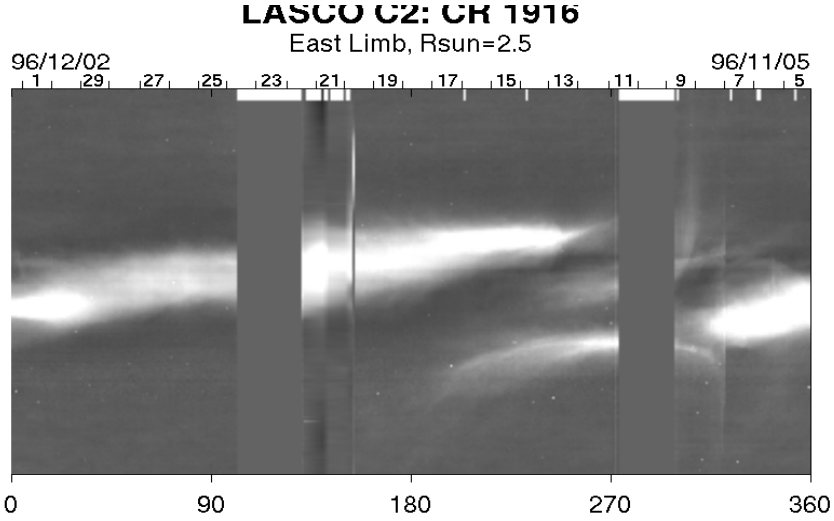




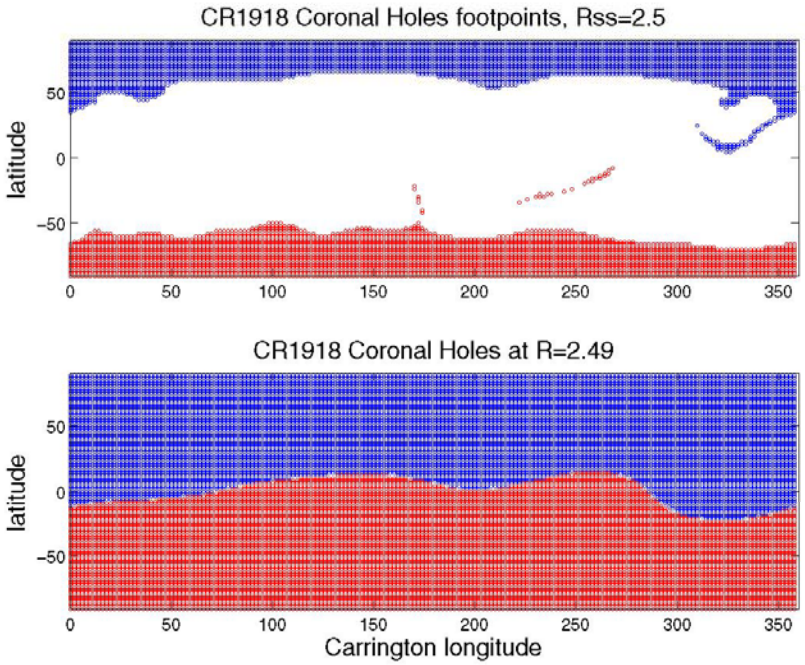
(E. Benevolenskaya website)

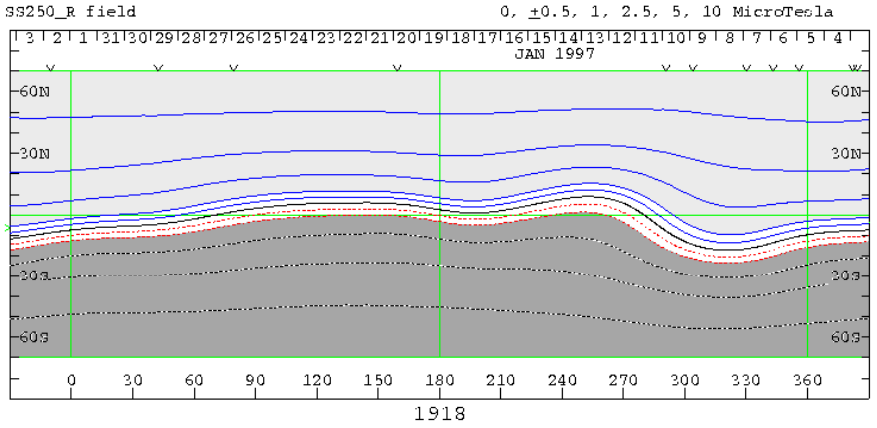
CR1916: images from SOHO EIT, LASCO C2. PFSS models based on WSO (right) and MWO (left) maps

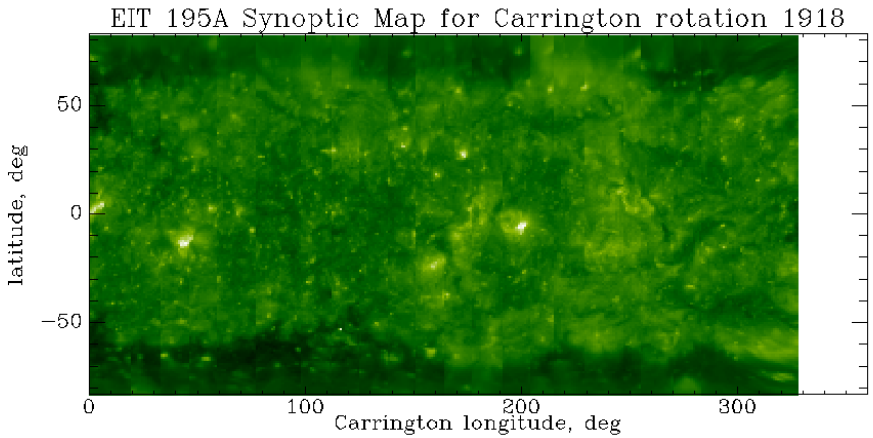


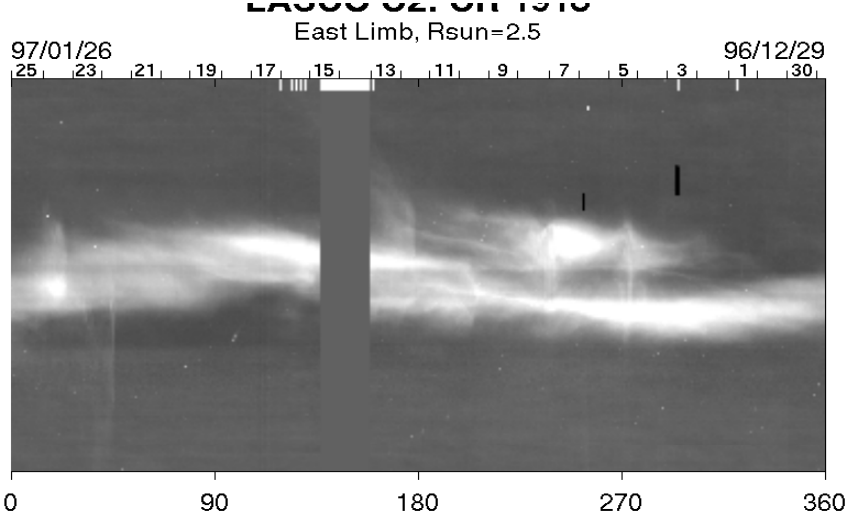


CR1918: images from SOHO EIT, LASCO C2. PFSS models based on WSO (right) and MWO (left) maps



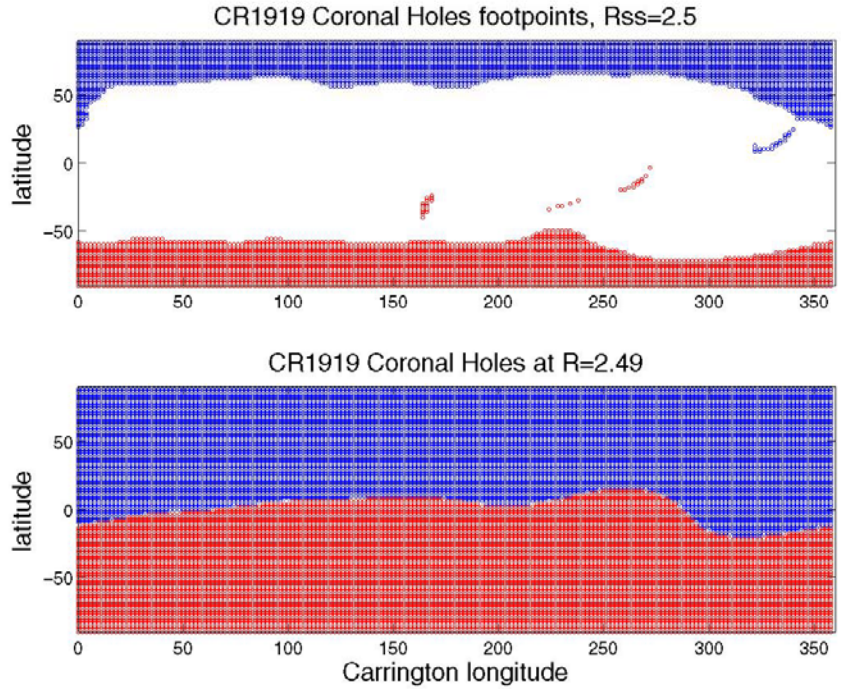


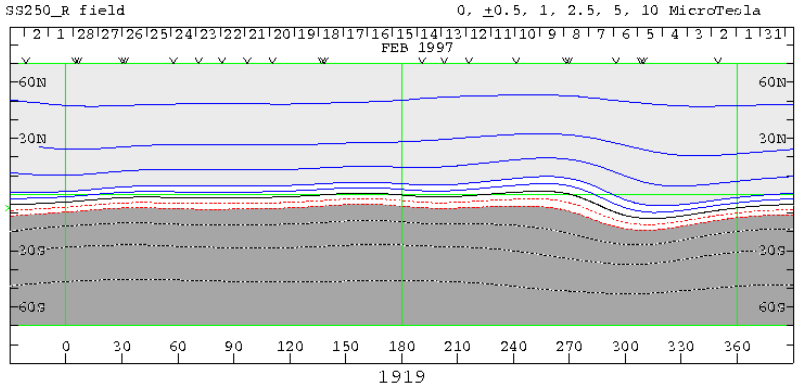


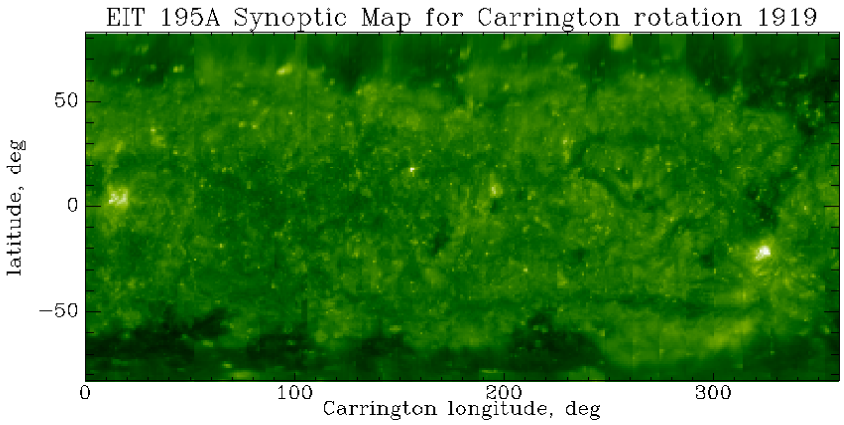


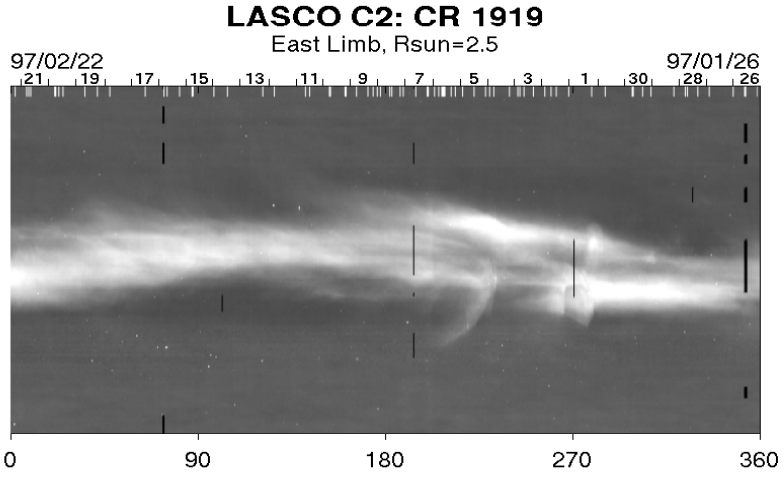
(E. Benevolenskaya website)

CR1919: images from SOHO EIT, LASCO C2. PFSS models based on WSO (right) and MWO (left) maps



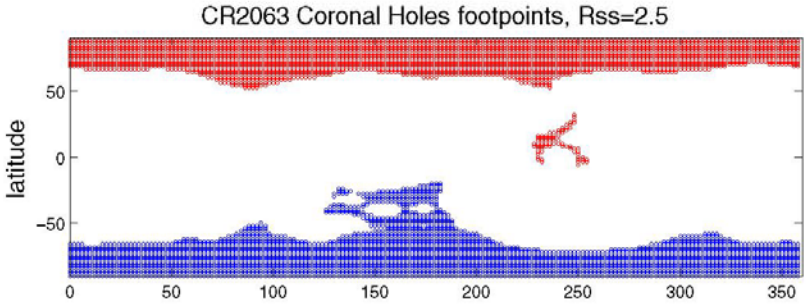


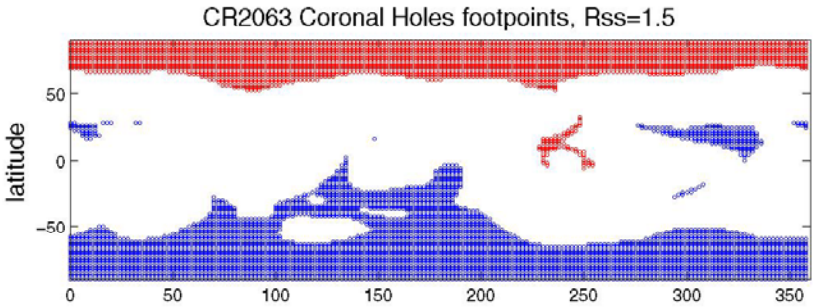


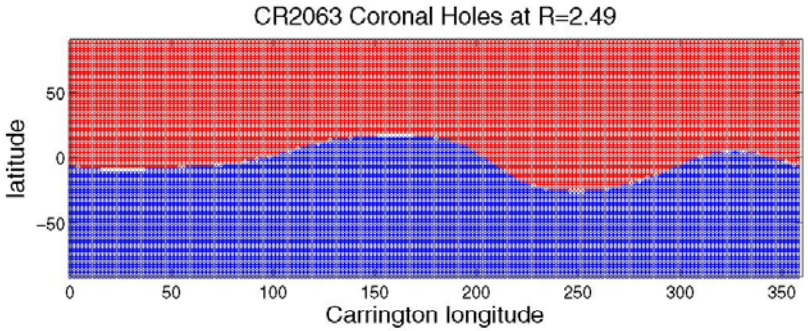


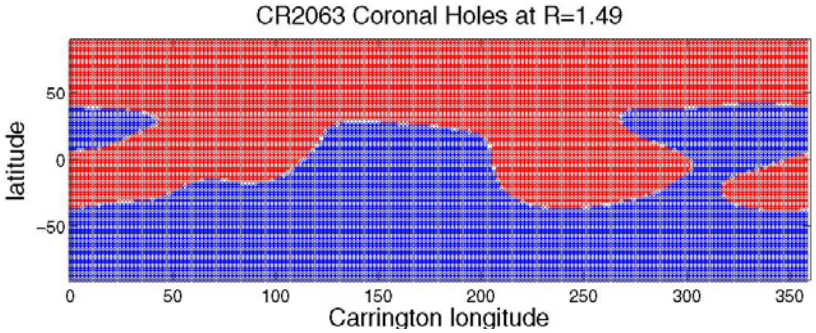
(E. Benevolenskaya website)

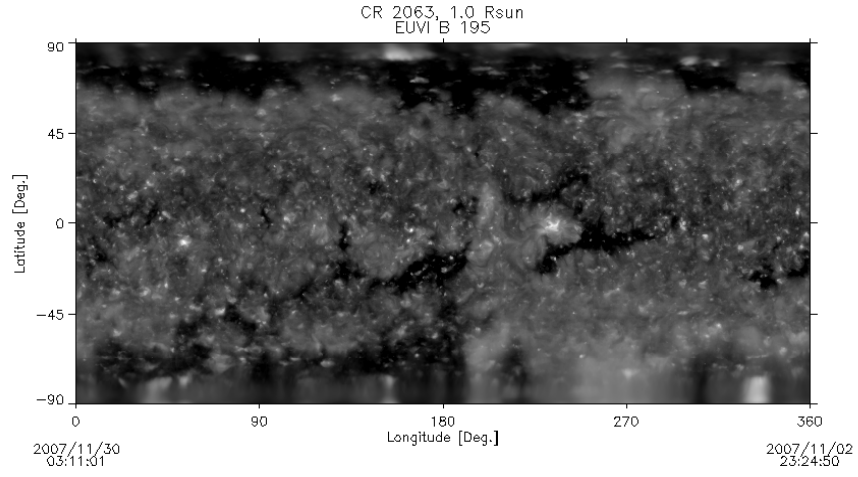
CR2063: A smaller effective source surface may exist at this time due to the weaker solar wind mass flux

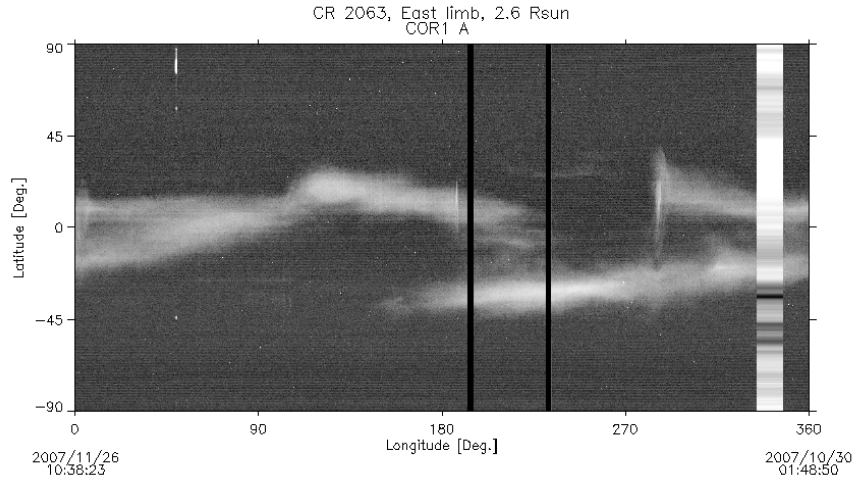






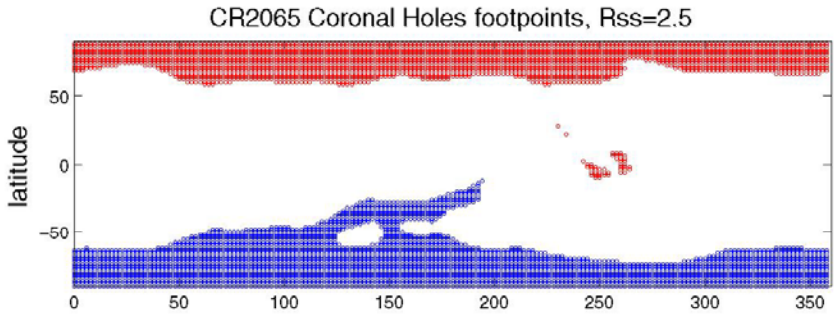


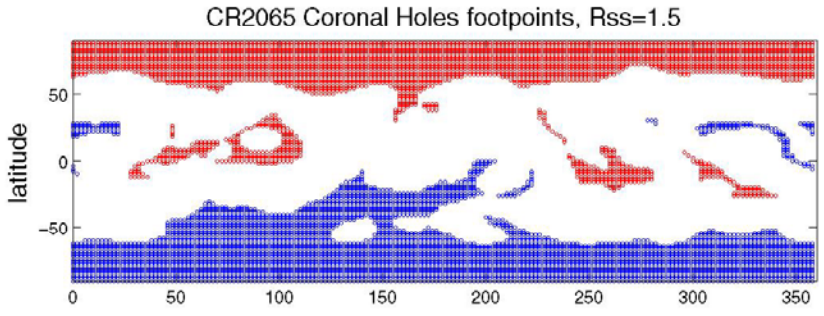


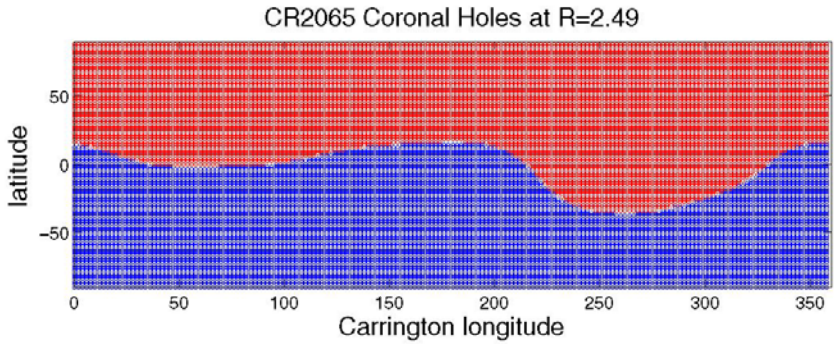


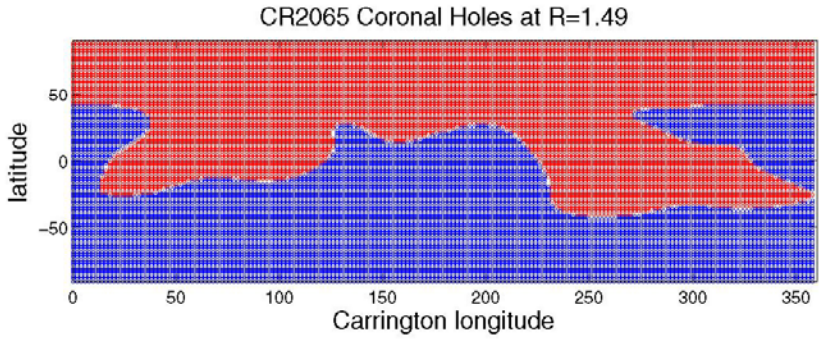
Top: MWO-based PFSS models; Bottom: STEREO SECCHI EUVI and COR data

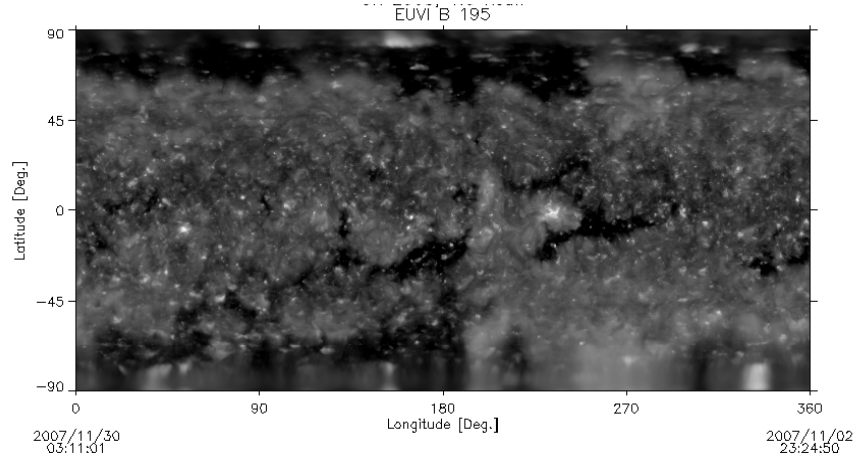
CR2065: A smaller effective source surface may exist at this time due to the weaker solar wind mass flux

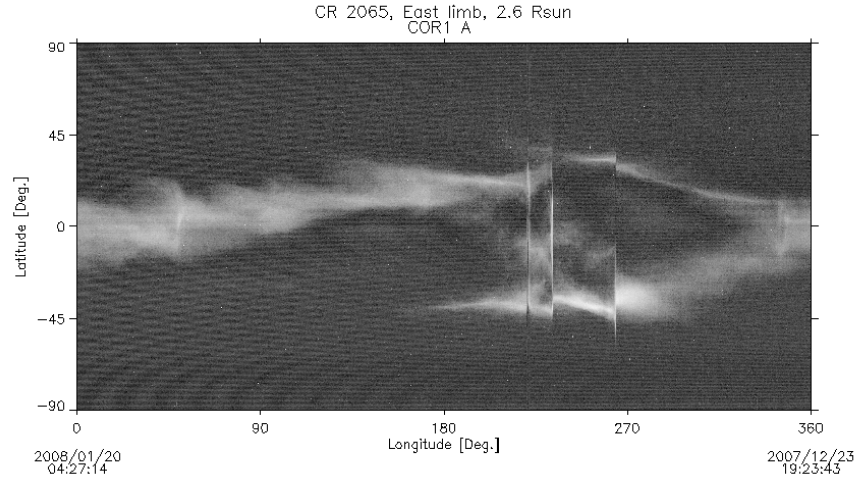






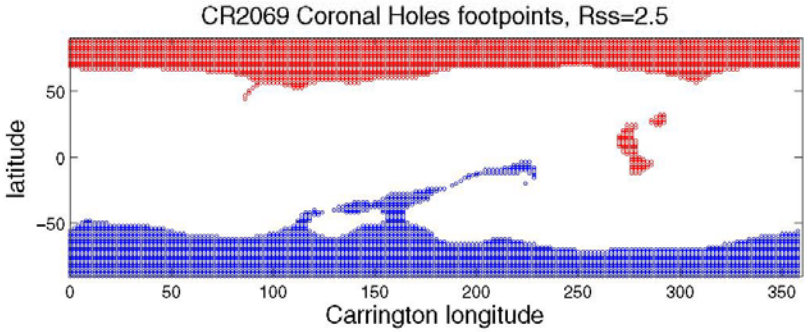


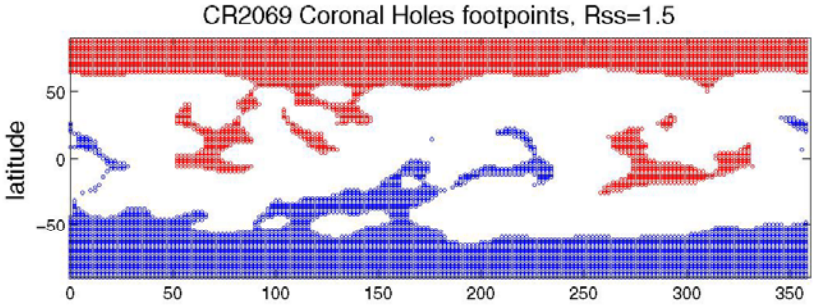


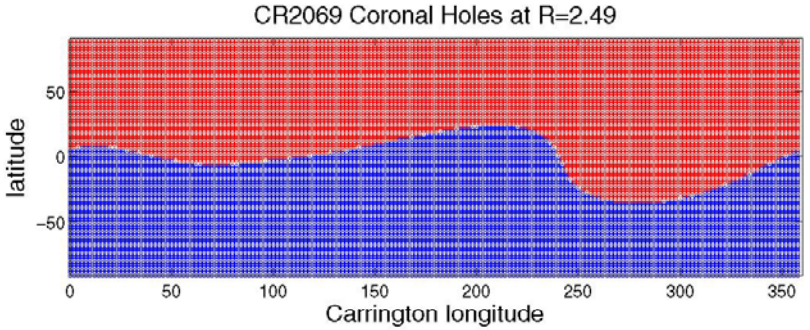


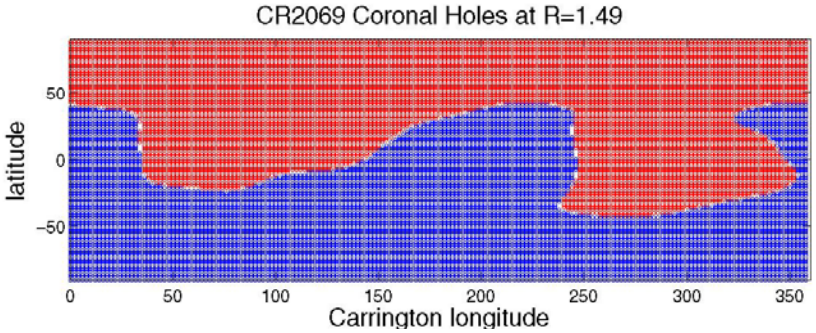
Top: MWO-based PFSS models; Bottom: STEREO SECCHI EUVI and COR data

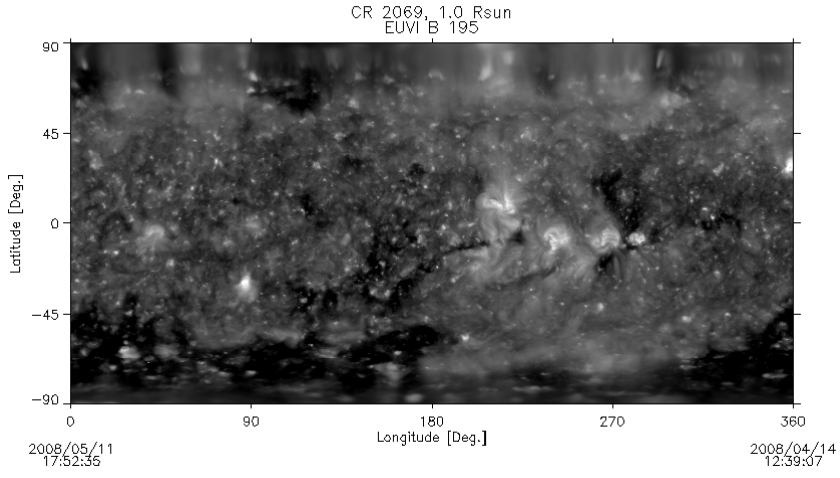
CR2069: A smaller effective source surface may exist at this time due to the weaker solar wind mass flux

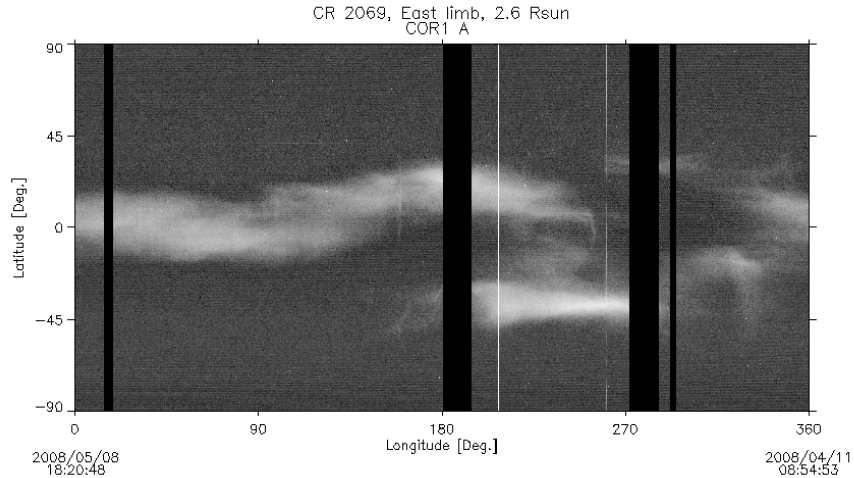






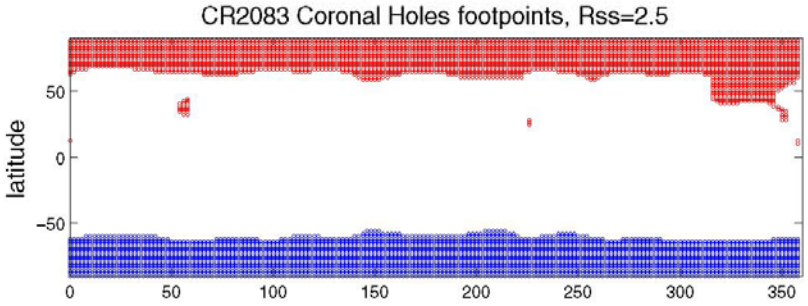


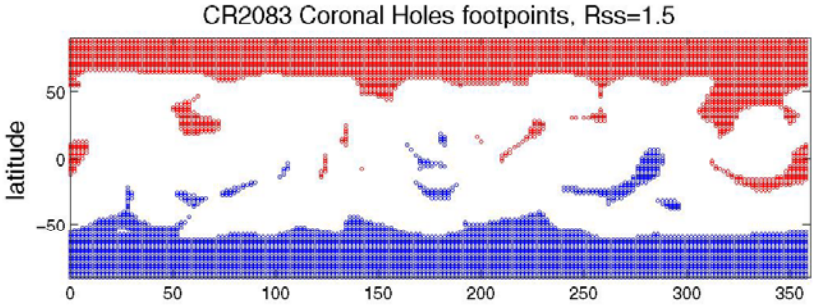


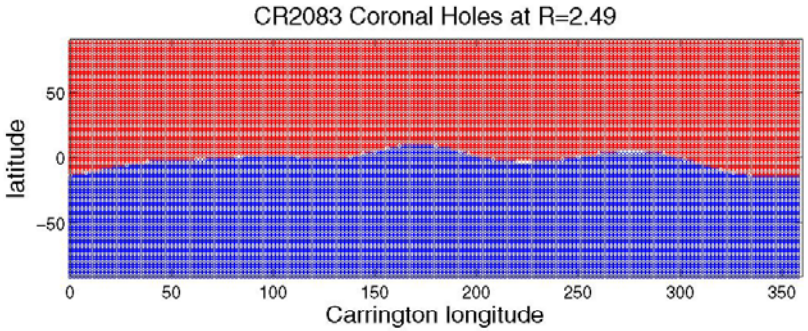


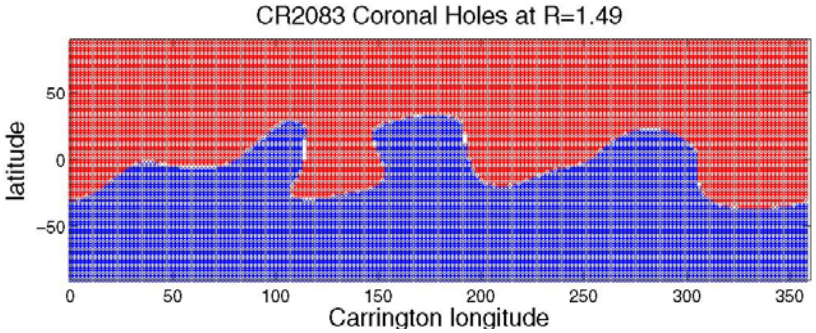
Top: MWO-based PFSS models; Bottom: STEREO SECCHI EUVI and COR data

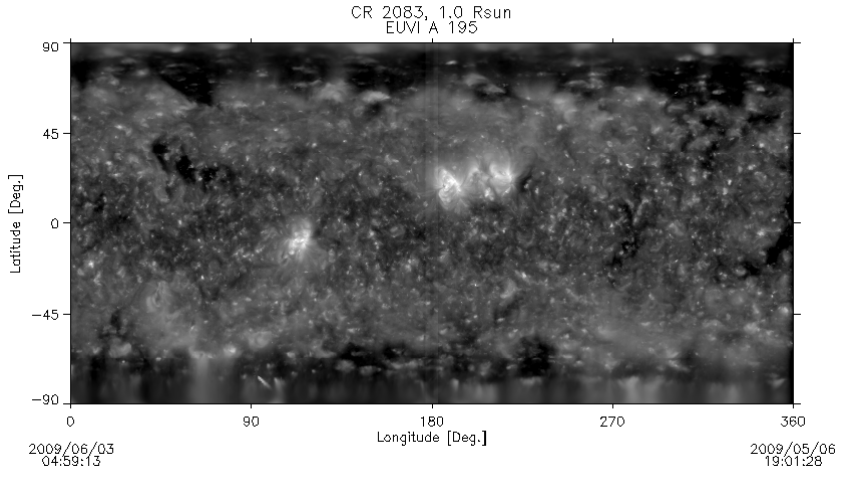
CR2083: A smaller effective source surface may exist at this time due to the weaker solar wind mass flux

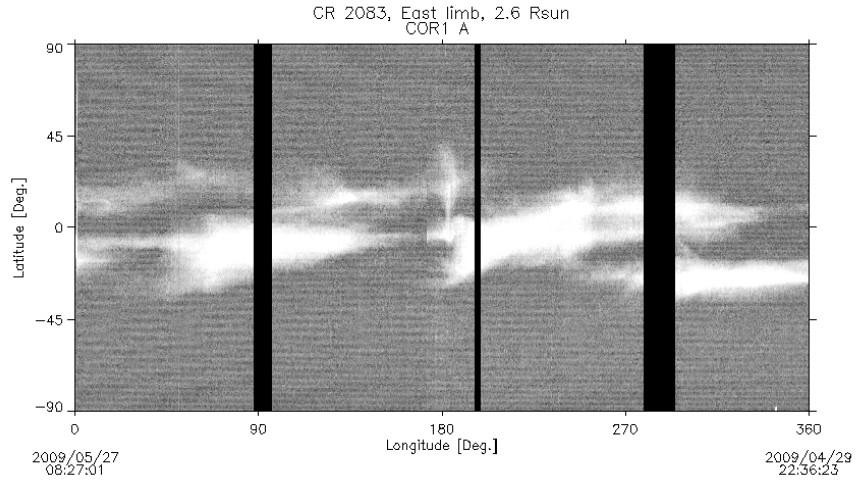






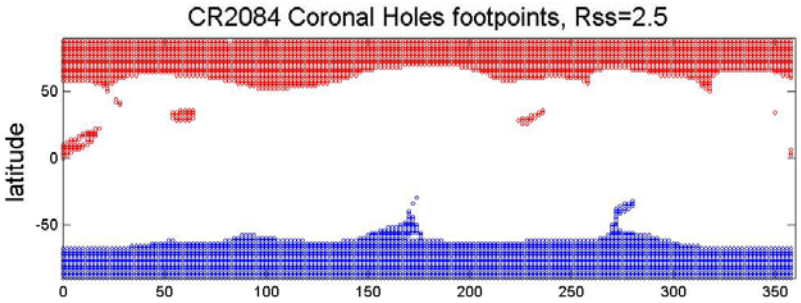


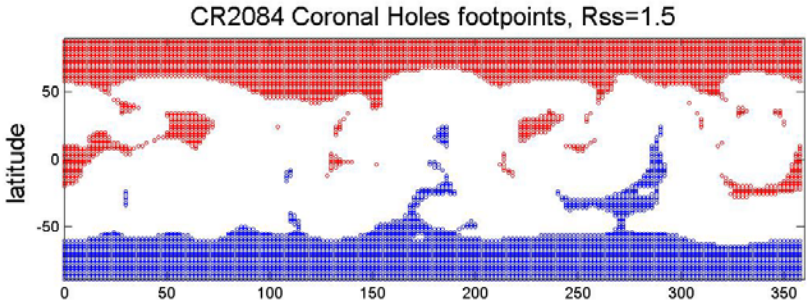


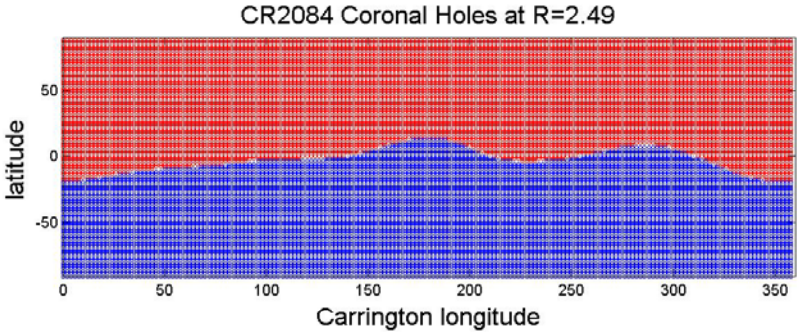


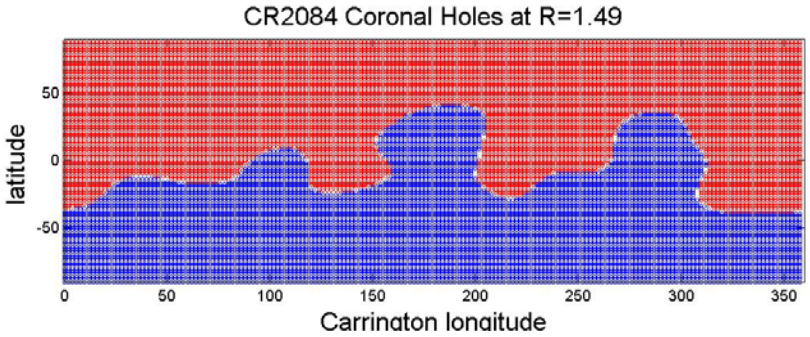
Top: MWO-based PFSS models; Bottom: STEREO SECCHI EUVI and COR data

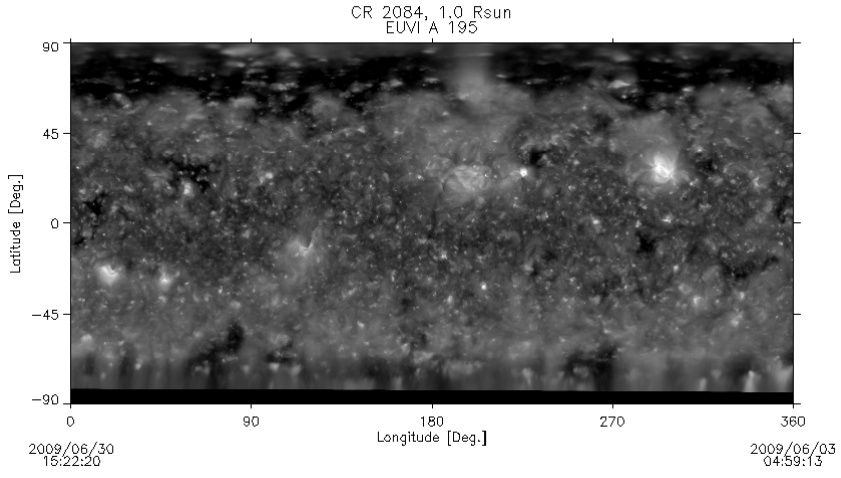
CR2084: A smaller effective source surface may exist at this time due to the weaker solar wind mass flux

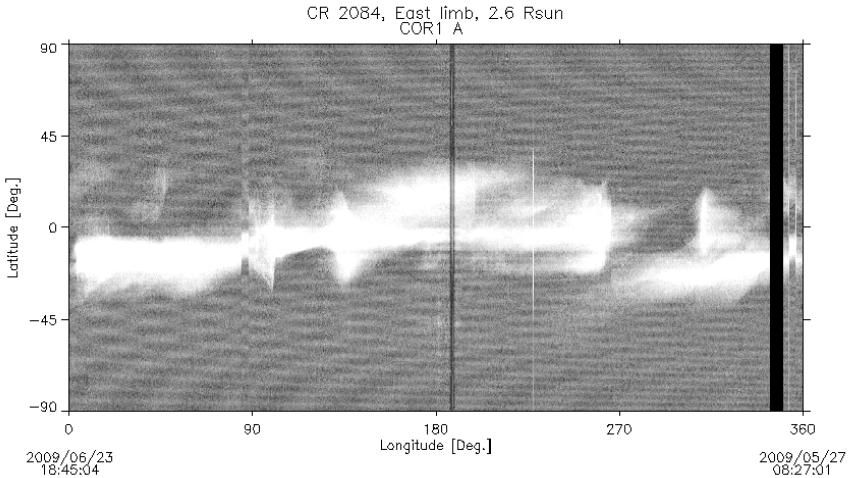






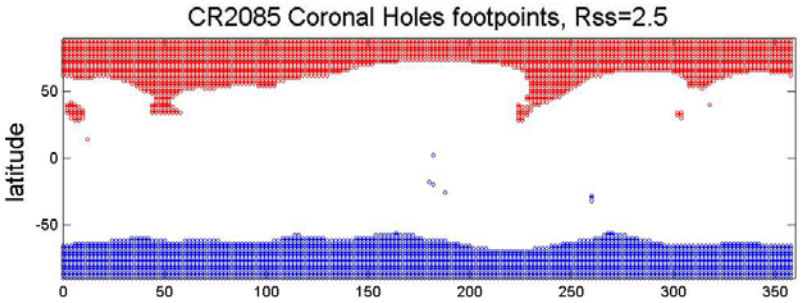


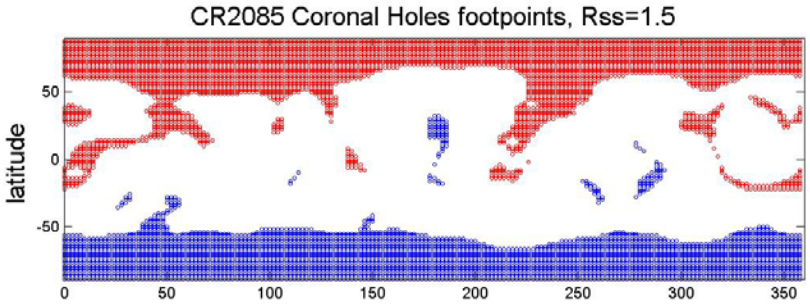


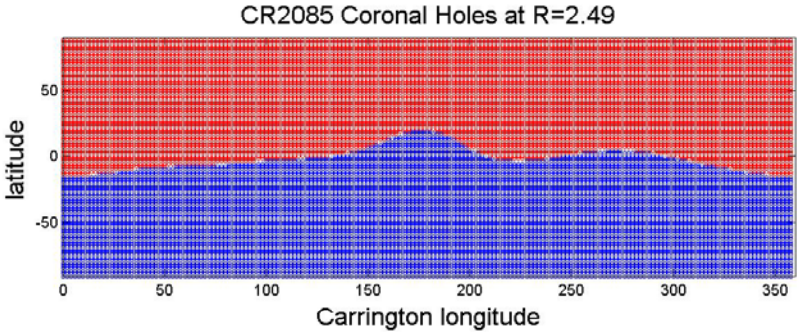


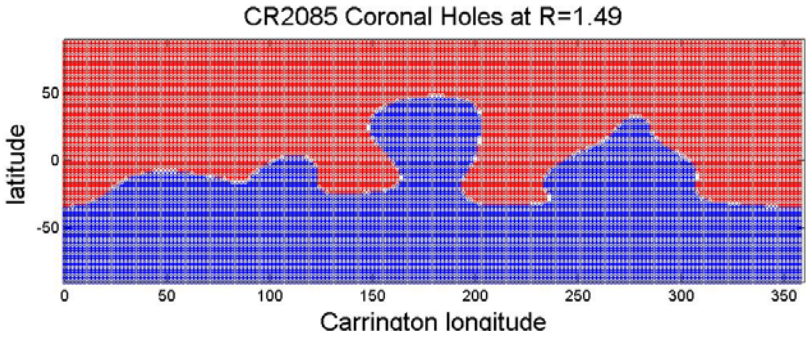
Top: MWO-based PFSS models; Bottom: STEREO SECCHI EUVI and COR data

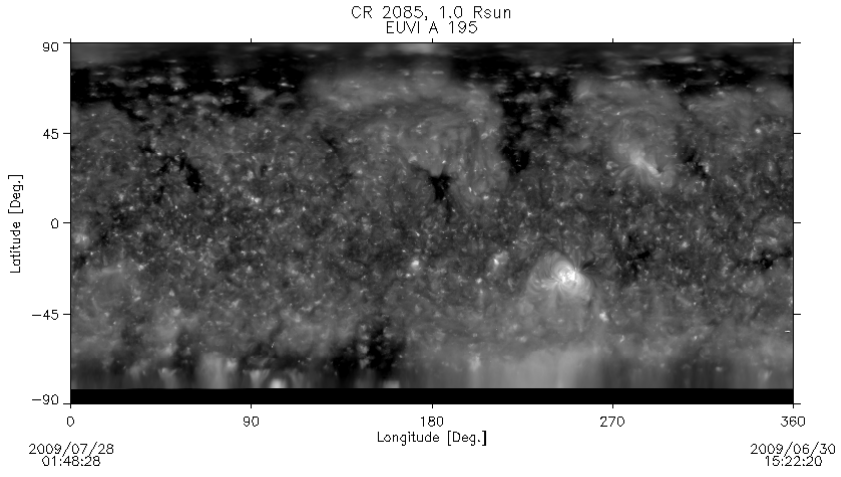
CR2085: A smaller effective source surface may exist at this time due to the weaker solar wind mass flux

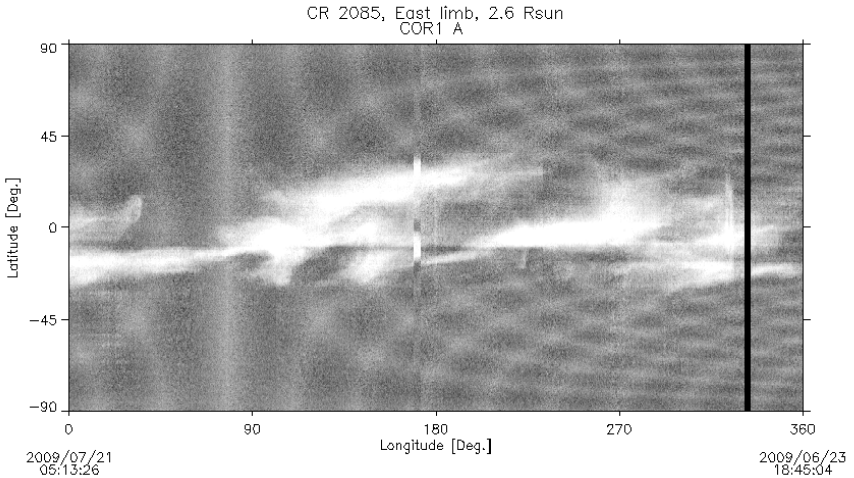






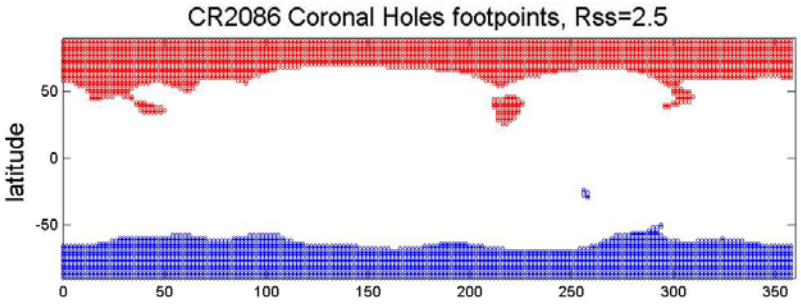


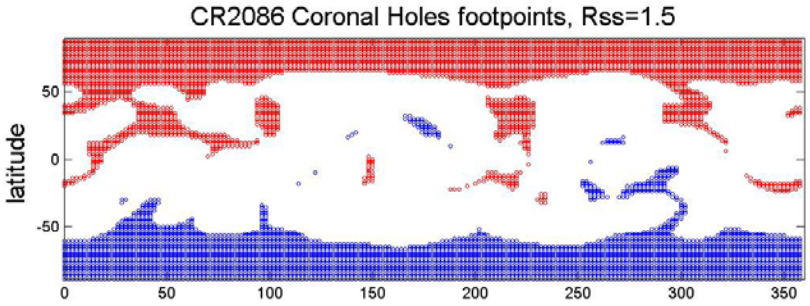


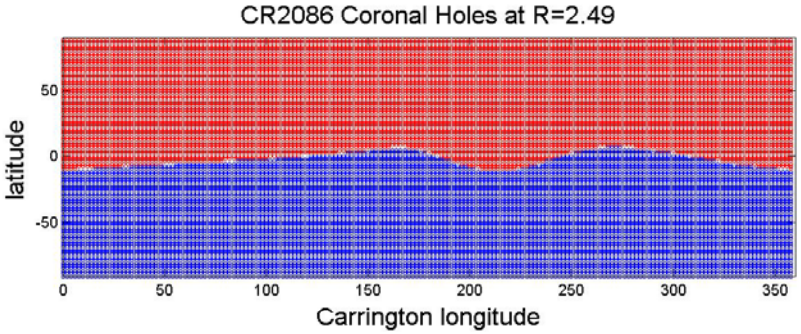


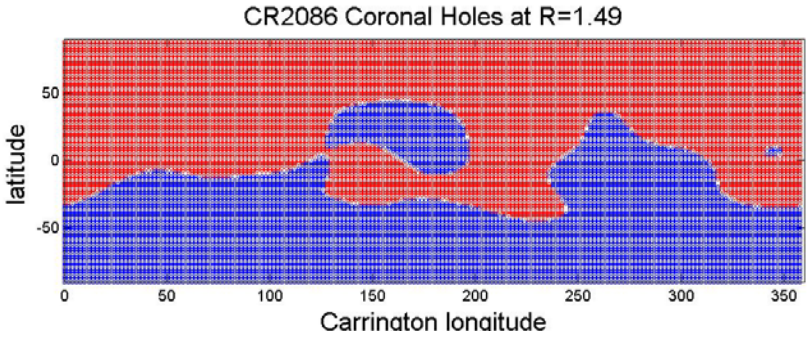
Top: MWO-based PFSS models; Bottom: STEREO SECCHI EUVI and COR data

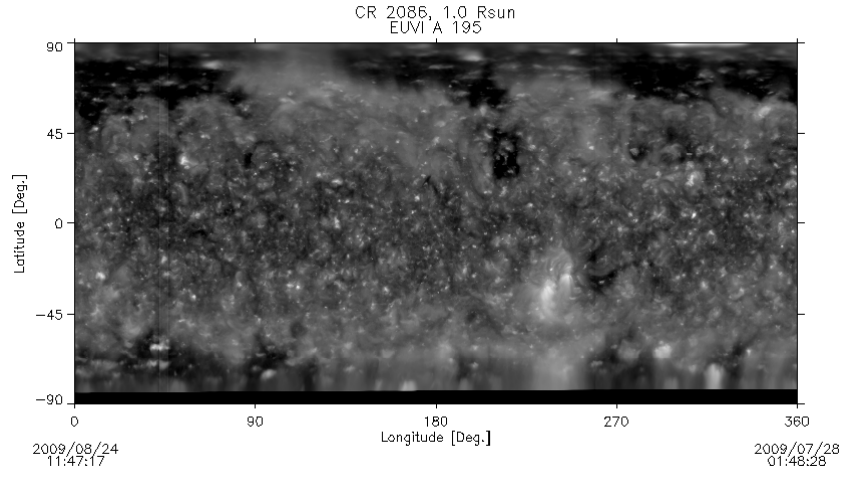
CR2086: A smaller effective source surface may exist at this time due to the weaker solar wind mass flux

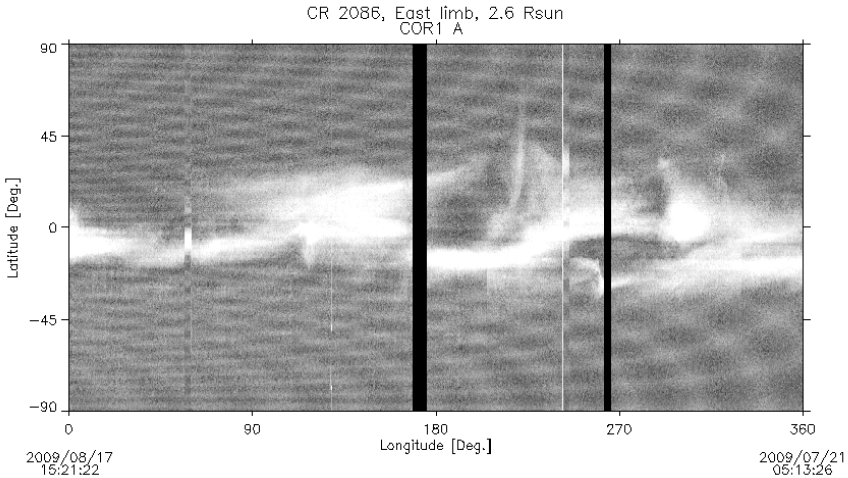






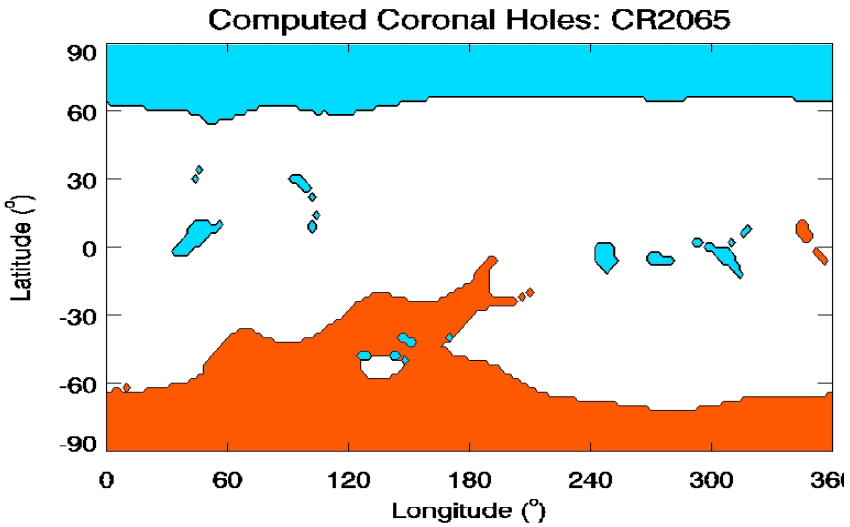


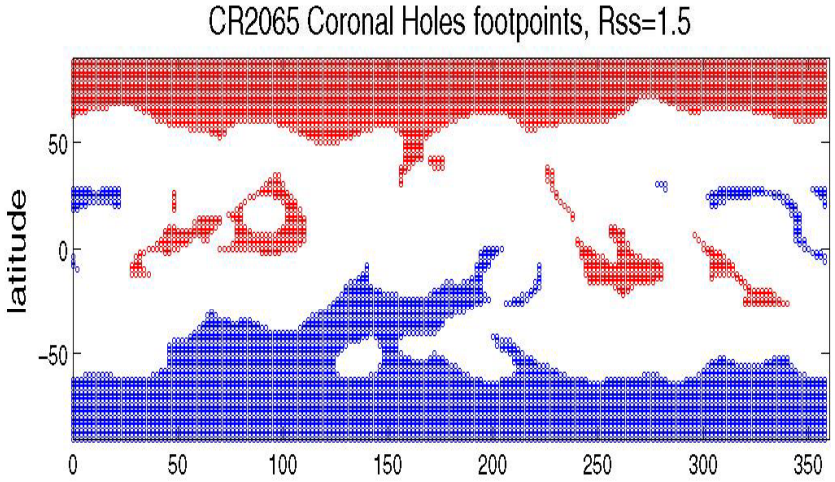


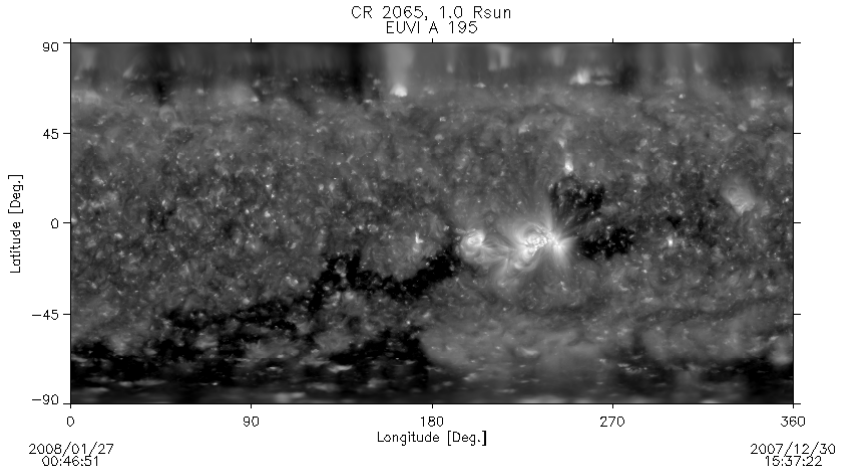


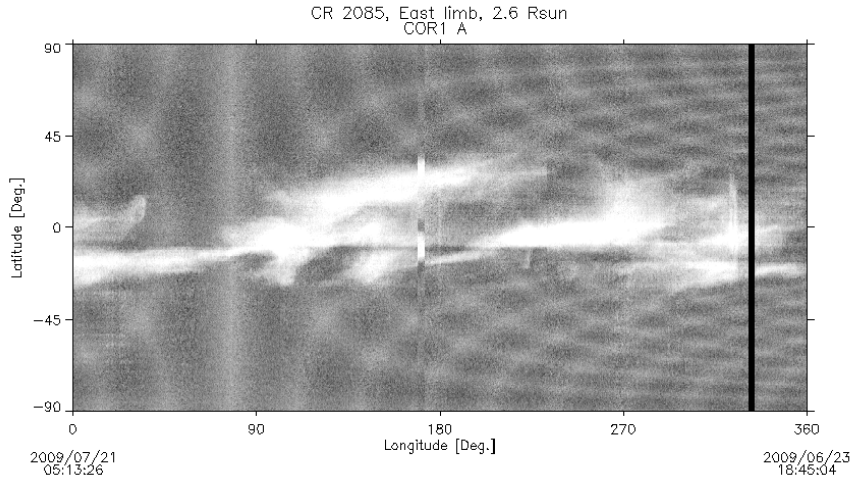
Top: MWO-based PFSS models; Bottom: STEREO SECCHI EUVI and COR data

The MAS MHD model (polytropic version) naturally captures the more open configuration (www.predsci.com): e.g. CR2065



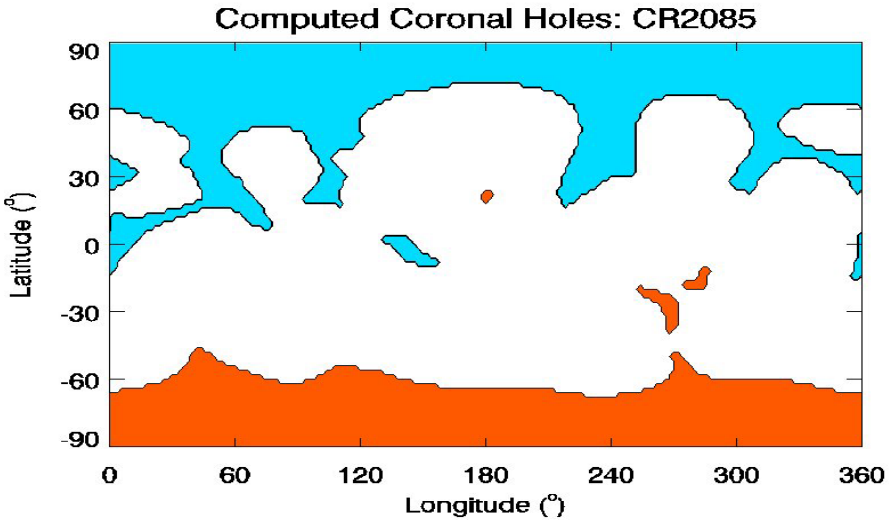


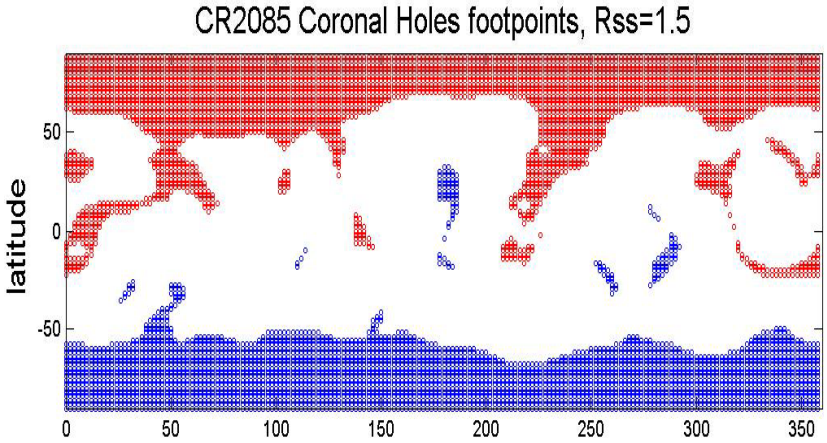


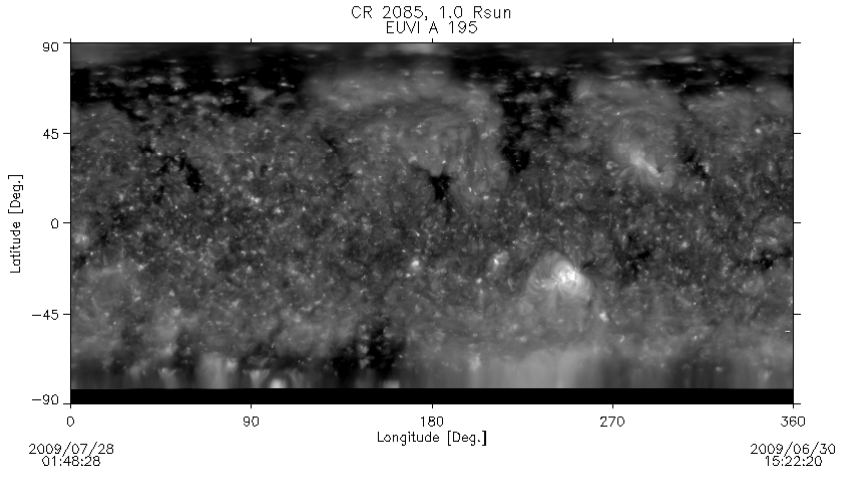


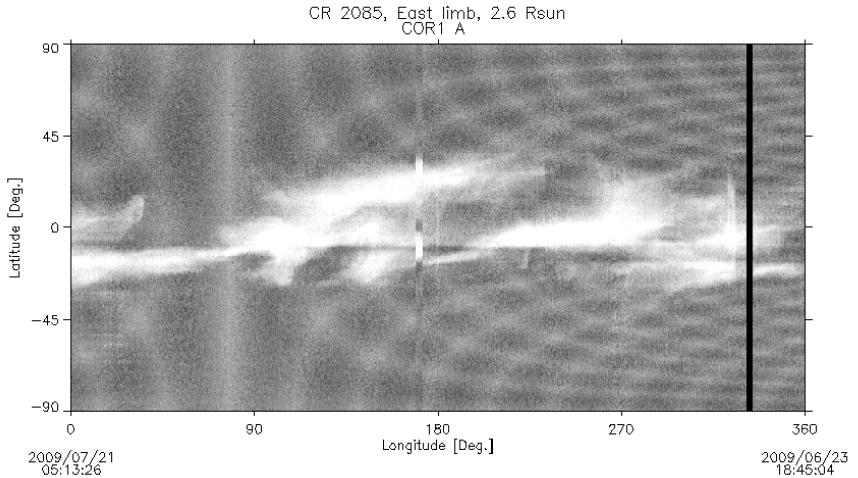
Top: MWO-based PFSS and MHD models; Bottom: STEREO SECCHI EUVI and COR data

The MAS MHD model (polytropic version) naturally captures the more open configuration (www.predsci.com): e.g. CR2085



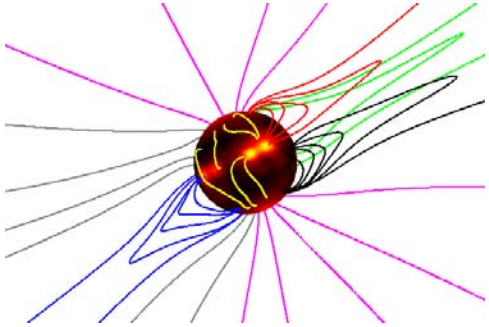


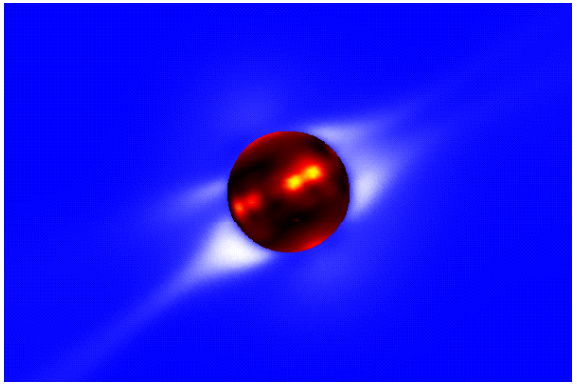


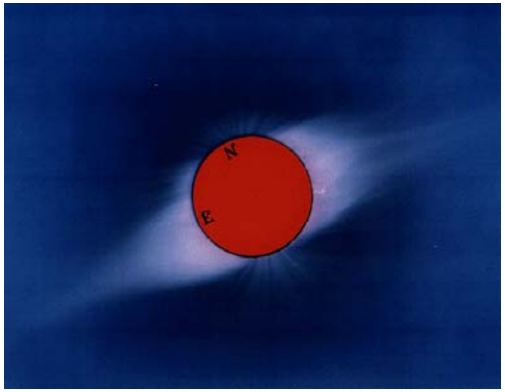


Top: MWO-based PFSS and MHD models; Bottom: STEREO SECCHI EUVI and COR data

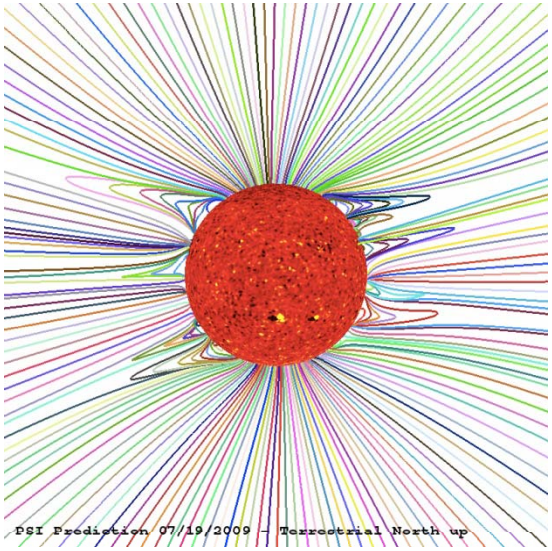
PSI (SAIC) Recent Eclipse Predictions also suggest a more multipolar corona now

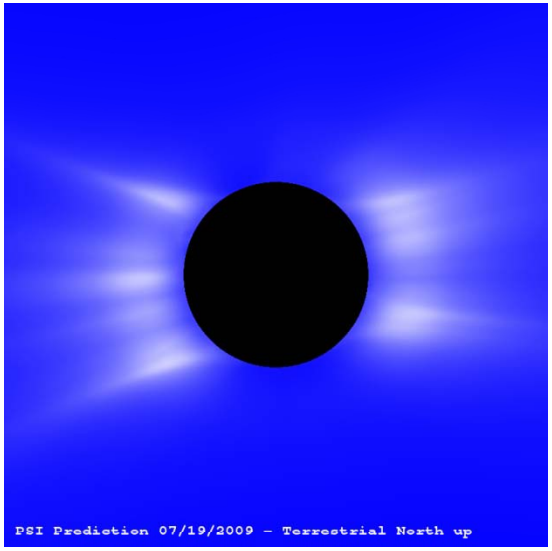


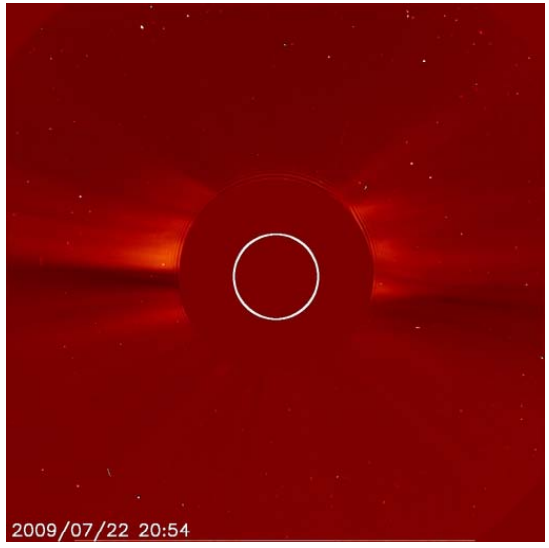




October ‘95 eclipse







July 2009 eclipse

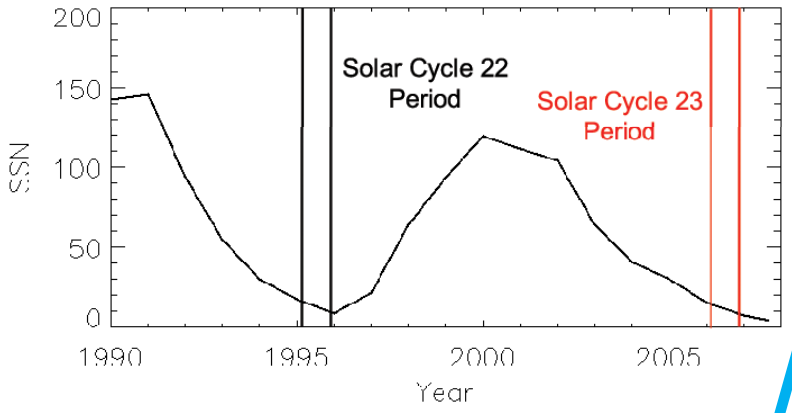
(Images from PSI corona website and SOHO LASCO C2)

Bottom line(s):

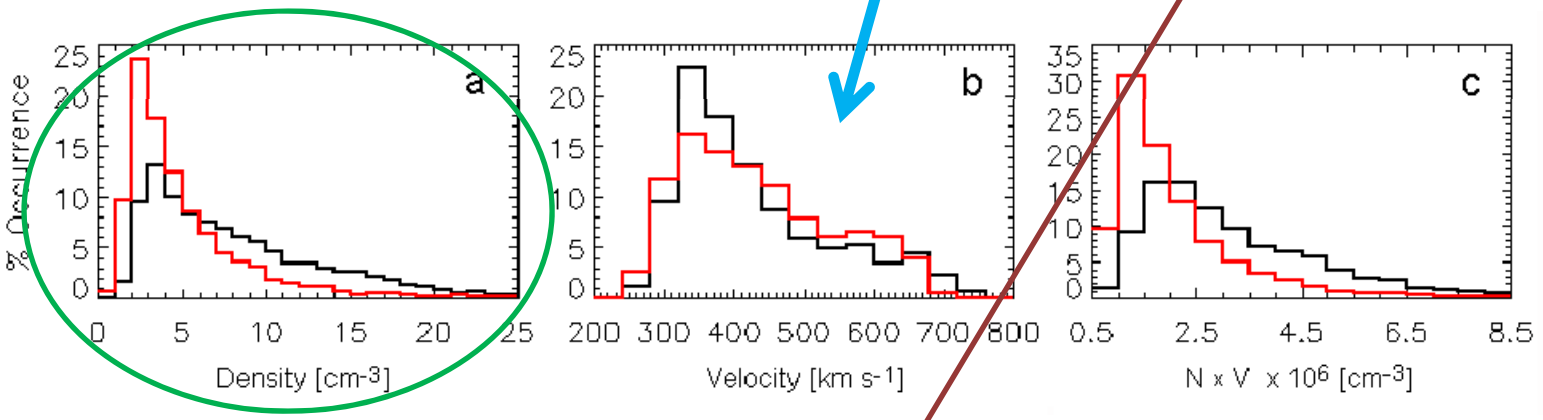
Weak interplanetary magnetic fields (IMFs) are observed at both high latitudes (Smith et al., GRL 2008) as well as in the ecliptic plane (e.g. Lee et al., 2008, also her oral presentation at this meeting, as well as that of C.T. Russell). See the following plot for the in-situ data result.

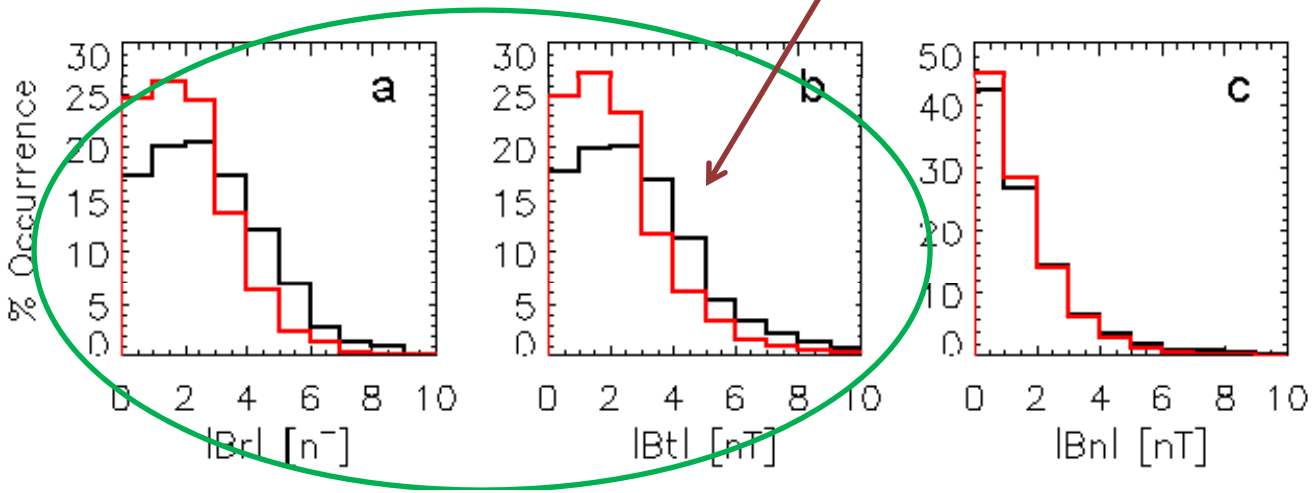
We know that the solar magnetic field is globally weaker this cycle (see the last plot from WSO), but its relationship to the IMF depends on what flux is mapped out into the heliosphere as open field. If the coronal hole area has changed together with the solar field, this requires further modeling of the flux mapping based on the combination of area and magnetic flux in the coronal holes.

We also know that the solar wind mass flux is weaker (McComas et al., GRL, 2008). Is the mass flux proportional to the area of the open field footpoints, or some property at the footpoints such as the magnetic field strength? The relationship between the mass flux, footpoint fields, and coronal hole area may provide additional insight on solar wind source mechanisms.

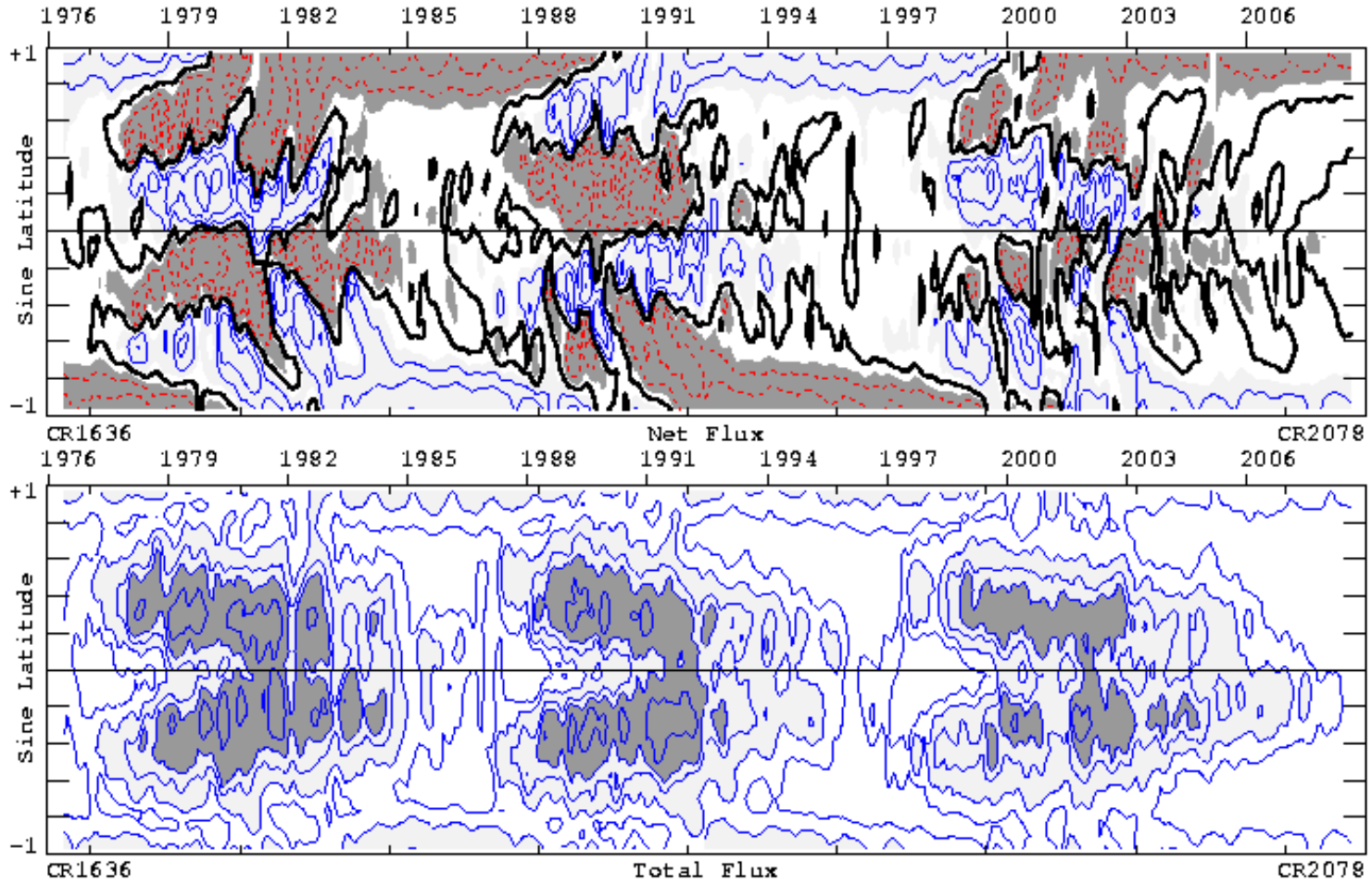


Velocity statistics are similar, but 1 AU (OMNI) solar wind magnetic fields and densities are significantly lower





(C.O. Lee et al., Sol. Phys. 2009)



Low photospheric field appears to characterize this entire cycle (data from WSO website)-not just low polar field.