When the Heliospheric Current Sheet [Figure 1] overtakes the Earth (or a spacecraft) an abrupt change of magnetic polarity (away from the Sun or towards the Sun) is observed: a Sector Boundary (SB).

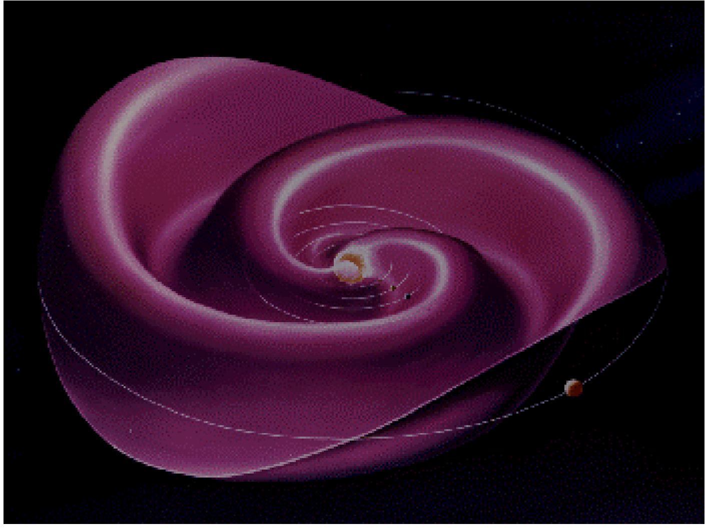


Figure 1. The warped Heliospheric Current Sheet in the inner solar system (inside of 6 AU). The surface divides the heliospheric magnetic field into twp regions with oppositely directed field lines. The surface is here shown for a 4-sector structure at a time intermediate between solar minimum and solar maximum.

A SB (observed at Earth) maps back to a magnetic neutral line at central meridian in the corona and also in the originating photospheric magnetic field about 4.5 days earlier, being the transit time of the solar wind. The latter neutral line is on average meridional, i.e. along longitudes.

Active regions have a photospheric neutral line too. The neutral line divides opposite polarities in opposite hemispheres (Hale's law). The portion [in a hemisphere] of a SB neutral line where the polarity change is the same as that for an active region was called a Hale Boundary by Svalgaard and Wilcox [ref], see Figure 2:

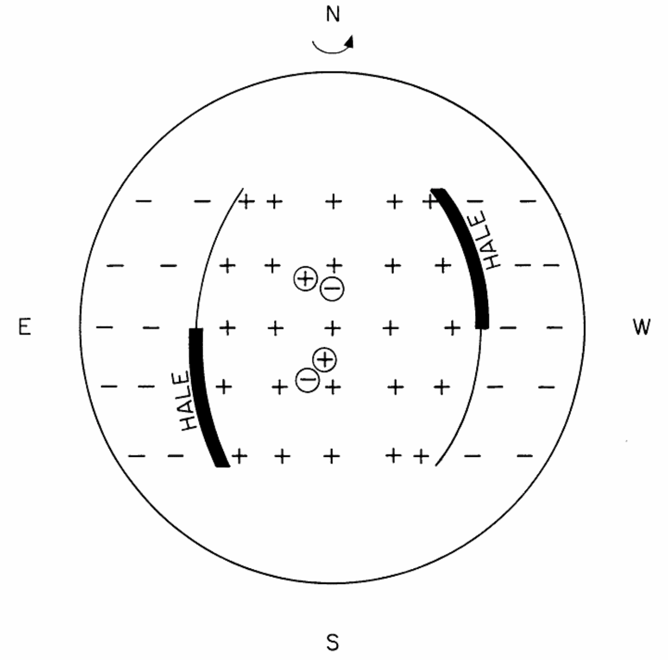
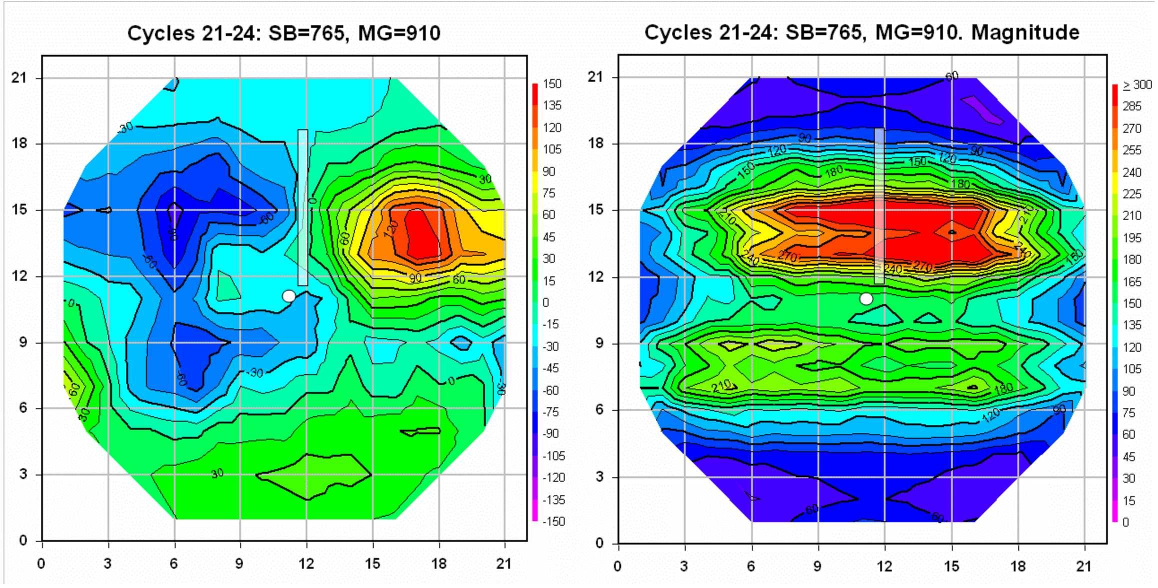


Figure 2. Schematic of the solar disk showing the portion of a SB that is designated a Hale boundary, that portion of a sector boundary that is located in the solar hemisphere in which the change of magnetic polarity across the SB is the same as the change of magnetic polarity from a preceding spot to a following spot. The spot polarities shown in the small circles correspond to even-numbered cycles.

They showed that above a Hale portion of a SB, the green corona has a maximum in brightness, while above a non-Hale boundary, the green corona has minimum brightness. Using synoptic maps of the magnitude of the photospheric field strength observed at Mt. Wilson Observatory during 1967 to 1973 it was also found that the unsigned magnetic field flux is at a maximum at the Hale boundary, in concert with the green corona brightness.

We have recently repeated the analysis using all available date from the Wilcox Solar Observatory (WSO). We superpose full-disk magnetograms from the times where a SB was at [i.e. within a day] central meridian. We can take advantage of the polarity changes and treat (-,+) boundaries as (+,-) boundaries by reversing the sign of the magnetic field, and of the Hale magnetic cycle by reversing hemispheres between cycles to construct a 'nominal' magnetogram for a (+,-) Hale boundary averaged over solar cycles 21-24, Figure 3.


Cycles 21-24: SB=765, MG=910

Cycles 21-24: SB=765, MG=910. Magnitude

Figure 3. The average magnetograms for a nominal (+,-) Hale boundary during solar cycle 23. 910 magnetograms superposed on 765 SBs using the WSO observations 1976-2010. Some data has been mirrored and sign-reversed as described in the text to reduce all data to the situation for cycle 23. The Hale portion of the sector boundary is marked by the semi-transparent bar. Left Figure shows the average signed field, while the right-hand Figure shows the average unsigned [total] field.

It is now evident, that on average, what causes the 'warps' in the current sheet (anmd hence the SB at Earth) originates strongly from one hemisphere, namely that which has the Hale boundary (the Northern in Figure 3). Coronal holes are often found co-located with the interiors of the sectors.

One important (the only?) source of the open flux is dispersing flux from active regions with strong magnetic fields so we expect the concentration of total flux at the Hale boundary as shown in the right-hand side of Figure 3. The closed field lines associated with the active regions would trap coronal material, explaining the enhanced brightness of the green corona at Hale boundaries.

We would also expect flares and microflares to preferentially occur near the Hale boundary. Using the RHESSI flare list covering the interval March 2002 to March 2008 (wholly within cycle 23) we find, indeed, that to be the case, Figure 4:

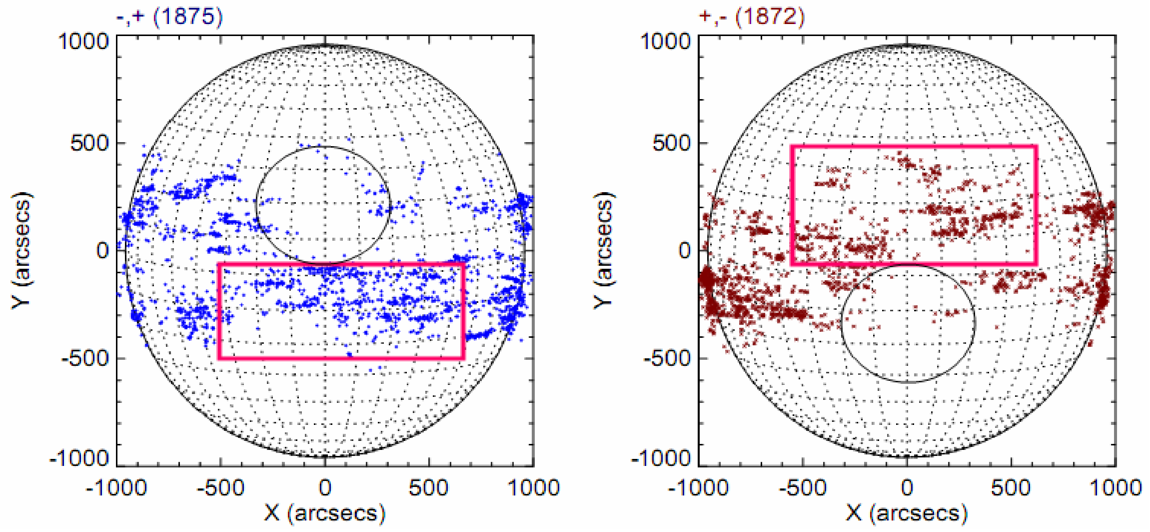


Figure 4. Distribution of RHESSI flares on the day a SB was mapped back to central meridian for part of solar cycle 23, March 2002 to March 2008. The red boxes show where flares are expected based on association with strong magnetic fields: at the Hale boundary. The circles show that hardly any flares occur near a non-Hale boundary.

GOES flares for May 1996 to January 2009 (cycle 23) show the same distribution, albeit with much poorer statistics because of the smaller number of cases:

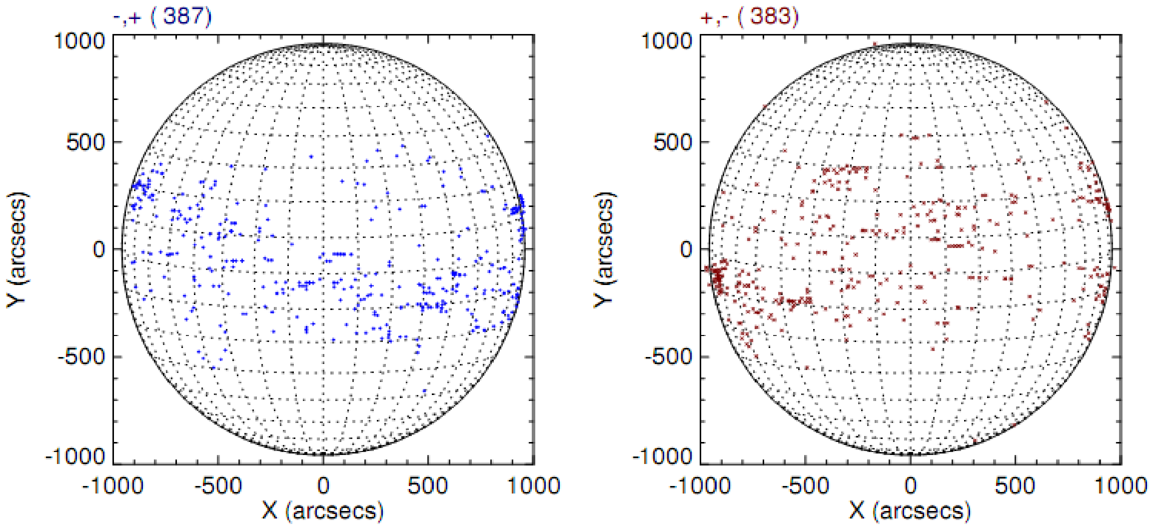


Figure 5. As Figure 4, but for the GOES spacecraft, May 1996 to Jan. 2009.

We can quantify the asymmetry by integrating the count in longitude between 30 degrees on either side of Central Meridian, Figure 6:

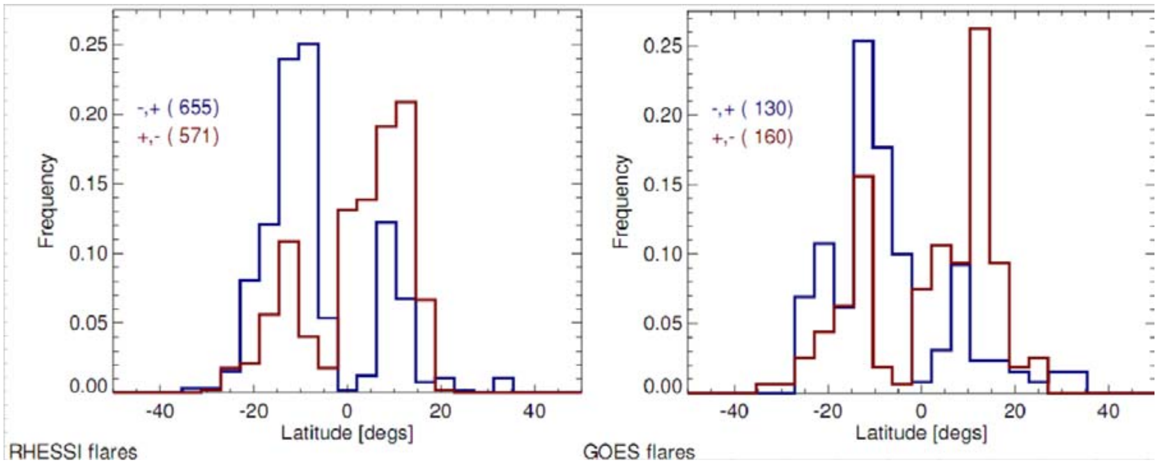


Figure 6. Number of flare events within ±30 degrees of Central Meridian as a function of latitude.

The correlation between the polarity of the solar Mean Field (over a smaller disk centered on the sun-Earth point) and the polarity of the Heliospheric Magnetic Field maximizes for a disk radius of 0.5 solar radius, justifying the choice of 30 degrees on either side of Central Meridian.

In a sense, all this is trivial, i.e. just what we would expect, were it not for the fact that the solar sector structure is very organized and long lived, indicating that solar activity is not random, but enjoys the same degree of spatial and temporal structure.