A Super-Synoptic Map of HMI Flux Density

Leif Svalgaard, Stanford University
January 5, 2018

Roger Ulrich invented the concept of a 'super-synoptic map' [or chart], see http://obs.astro.ucla.edu/torsional.html. To construct such a map, you reverse the time direction [from right to left] on ordinary synoptic maps to have the data run from left to right [i.e. increasing time], and then divide the map into pole-to-pole strips in longitude of a width sufficient to smooth out the smallest structures. Juxtaposing all the strips from rotation to rotation yields a time-history of the changing magnetic field on the surface. Figure 1 shows an example of a Mount Wilson Observatory [MWO] super-synoptic map for the years 2011-2012.

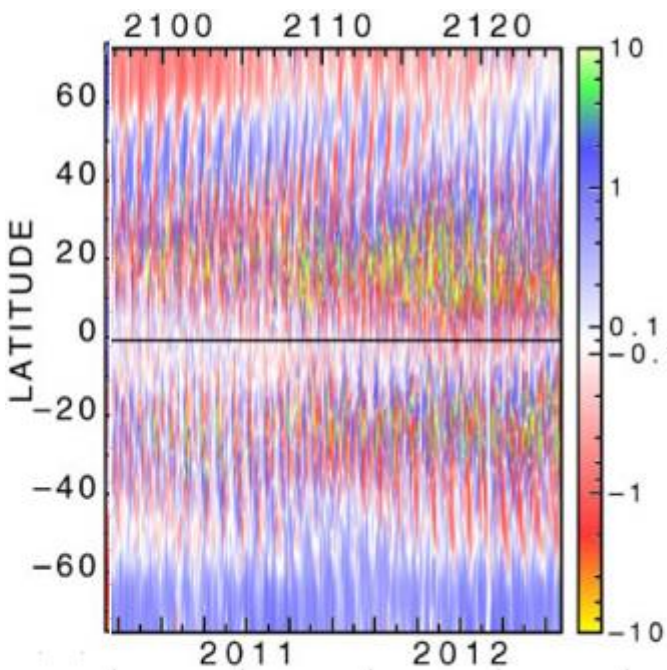

Figure 1: An MWO Super-Synoptic-Map (Chart) for years 2011-2012. Carrington Rotation numbers are given at the top of the plot. Flux densities in Gauss [=Mx/cm^2] are color coded from -10 G (reddish colors) to +10 G (bluish colors). Each synoptic map was divided into 9 strips (of width 40°). You can watch the migration of flux from the sunspot zones towards to poles. Note that both polarities march towards the poles often in parallel. This is no news, of course (Topka et al. SPD Meeting, 1980, BAAS, 12, 893, B1).

In this nugget I present a Super-Synoptic Map constructed for the Helioseismic and Magnetic Imager [HMI] for SDO, covering the time since launch (Spring 2010). As input synoptic maps I use the series hmi.synoptic_mr_720s [there is some confusion about the use of capital letters – they don't matter]. The series start with Carrington Rotation 2097 [start May 19, 2010] and the latest one available at the time of writing is 2198 [end Dec. 30, 2017]. The values represent nominally radial flux densities computed from the line-of-sight magnetic flux measurements averaged over 720 seconds [12 minutes] assuming a radial field, and are further averaged into 36 bins 10° in longitude (100 points each) and 10 values of sine(latitude), i.e. 144 bins from pole-to-pole. At least six data points must be present for a bin-value to be computed; that automatically excludes times when a pole is not visible. As large scale features are sought for, all flux density ['field'] values above 5 G are plotted with the same color (blue for positive, out of the sun, and red for negative, into the) sun), Figure 2:

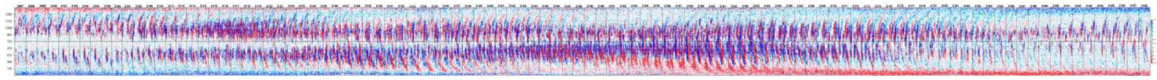

Figure 2: An HMI Super-Synoptic-Map (Chart) for years 2010-2017. Carrington Rotation numbers are given at the top of the plot. Flux densities in Gauss [Mx/cm^2] are color coded from -5 G (reddish colors) to +5 G (bluish colors). Each synoptic map was divided into 36 strips (of width 10°) and the 1440 values from pole-to-pole were averaged into 144 bins of sine(latitude). Click on the image to see a [much] larger version or go to http://www.leif.org/research/SuperSyn-HMI.png .

There are many interesting features that show up in this high-resolution representation, e.g. the recent migration of mid-latitude flux to the poles, Figure 3:

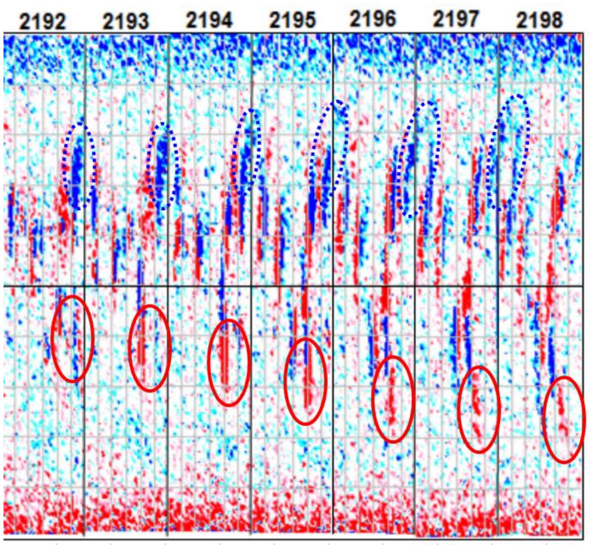

Figure 3: The most recent rotations 2192-2198 for the last half of the year 2017. Negative flux (red ovals) can be seen as narrow 'streaks' moving towards the South Pole, helping to build a stable polar cap field there. Positive flux (dashed line blue ovals) is moving towards the North Pole, helping to establish a stable north polar cap field. The ordinate is the ordinal number of sine(latitude) projected on the 1440-pixel height of the synoptic maps. The color scale is as in Figure 2.

The high-resolution super-synoptic maps makes it easy to identify the evolution of the polar fields and [possibly] to extrapolate them in the short-term.

In Figure 2, the reversal of the polar fields is vividly displayed, especially the dominant contributions from just a very few flux concentrations. Another feature of note is the waning and waxing of the polar fields in *place*, rather than the often supposed varying 'tilt' of the dipole through the solar cycle [1], or worse: 'rotation' of the dipole by 180° from pole to the other pole [2].

References

[1] Pipin, V. V., Moss, D., Sokoloff, D., & Hoeksema, J.T. 2014, A&A 567, A90.
[2] Sanderson, T. R., T. Appourchaux, J. T. Hoeksema, & K. L. Harvey 2003, J. Geophys. Res., 108, 1035.