Conversion Factor for MDI to HMI

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MDI and HMI overlap from May 2016 to April 2017 so it should be possible to determine the conversion factor of the magnetic flux from MDI to HMI. Now, the factor depends on the time-resolution and the binning method [as the spatial resolutions are different]. Also, it makes a difference if one compares Line-of-Sight [LOS] data with Radial-Assumption [RAS] data. In this note, I shall compare 720-sec [i.e. 12-min average] LOS HMI data with 5-min integrations of LOS MDI data for 2010-5-1 through 2017-11-30 at 96-minute cadence. From all available magnetograms during each UT day [version 1.8 for MDI and current version for HMI] we compute the total unsigned magnetic flux over the disk out to radius 0.99 with no thresholding of the field-values. The values are in units of 10^{22} Mx. If pseudo field strengths in Gauss are wanted divide by the area of the solar disk, 1.5×10^{22} cm^2.

Due to the failure of the gyroscopes [and other problems, including human and programming errors] the SOHO spacecraft is turned 'upside-down' every three months to enable data transmission to Earth. The turning angle is recorded in keyword CROTA2 and is nominally 180° or 0°, but since 2010-10-30 has been approximately 173±0.5° and 0±2.6°. The result of the comparison for daily values is shown in Figure 1:

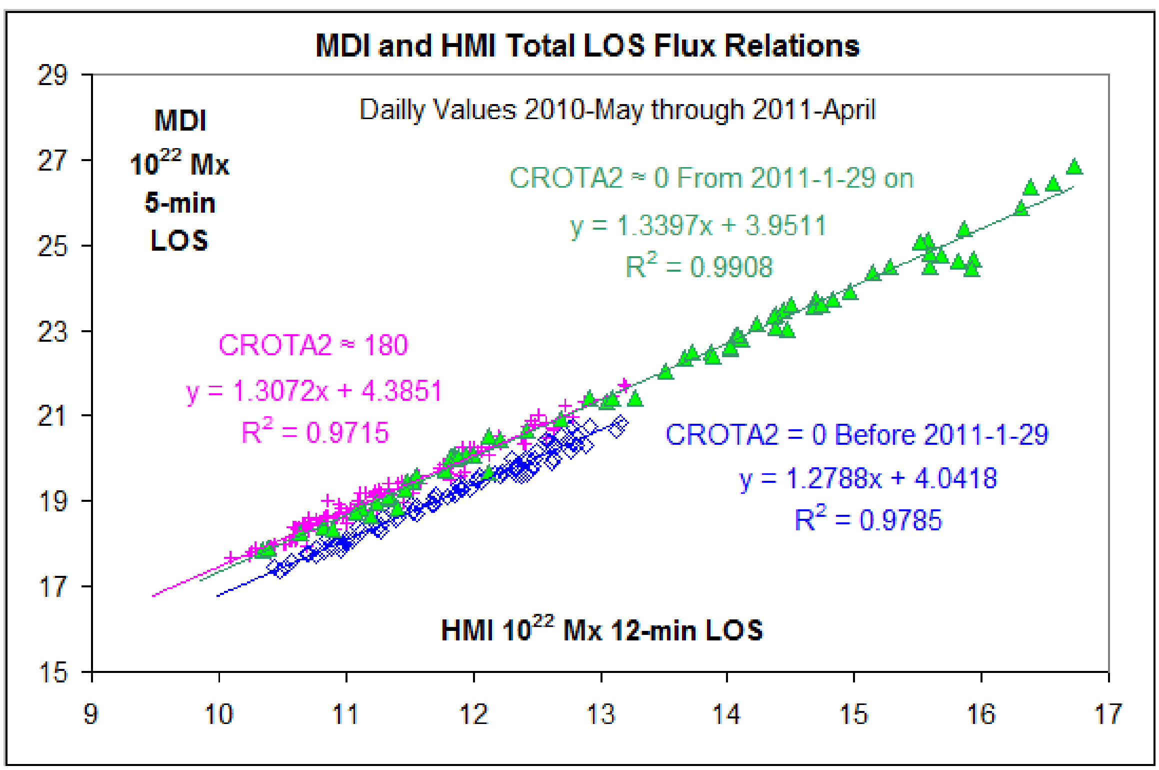

Figure 1. Comparison between total solar disk Line-of-Sight magnetic flux for MDI and HMI for the time of overlap.

It is evident that the conversion factor [=slope of the linear regression line] depends on the rotation angle CROTA2. For 180° and 173° the factor [pink symbols] seems to be the same: MDI = 1.3072 HMI + 4.3851, while there is a marked difference with the factor for rotations near 0°, especially for the observations before [blue symbols] and after [green symbols] 2011-1-29. The causes of these differences are not clear although there are several [subtle] candidates.

Figure 2 shows the regression coefficients for monthly averages [perhaps more suitable for synoptic charts]:

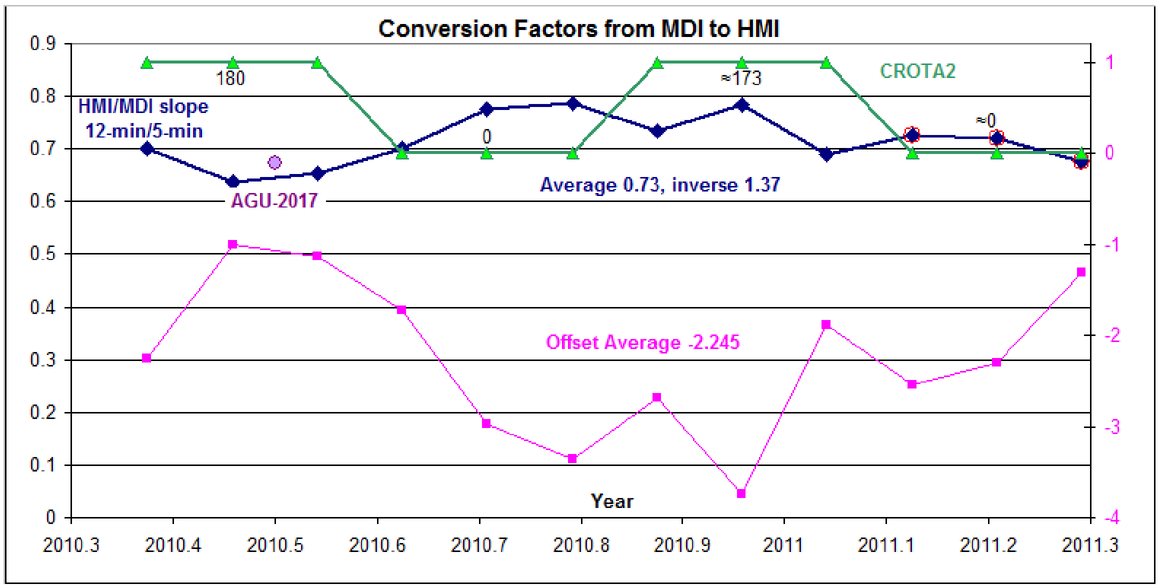

Figure 2. Month-by-month evolution of the conversion factor for MDI to HMI (blue symbols), the offset [zero-level error for MDI](pink symbols), and the rotation angle (green symbols. The data after 2011-November are marked with red circles. For 2010-June through 2010-July we found the factor marked with a purple dot.

There are no obvious dependencies over time. At the AGU 2017 Fall Meeting we presented a poster [http://www.leif.org/research/AGU-2017-Fall-SH51C-2497.pdf] with a conversion factor of 1/1.4837 = 0.674, this result is marked with a purple dot. For the entire interval we could adopt a factor 0.73 for conversion of MDI to HMI [or 1.37 for the other way]. It would seem that a recalibration of MDI is in order. We should at least try to understand the various anomalies.

Adopting a single HMI = MDI* = 0.73 MDI – 2.4 conversion [because the CROTA2 is not always recorded] we can convert the entire MDI record set to the HMI scale. The result is shown in Figure 3,

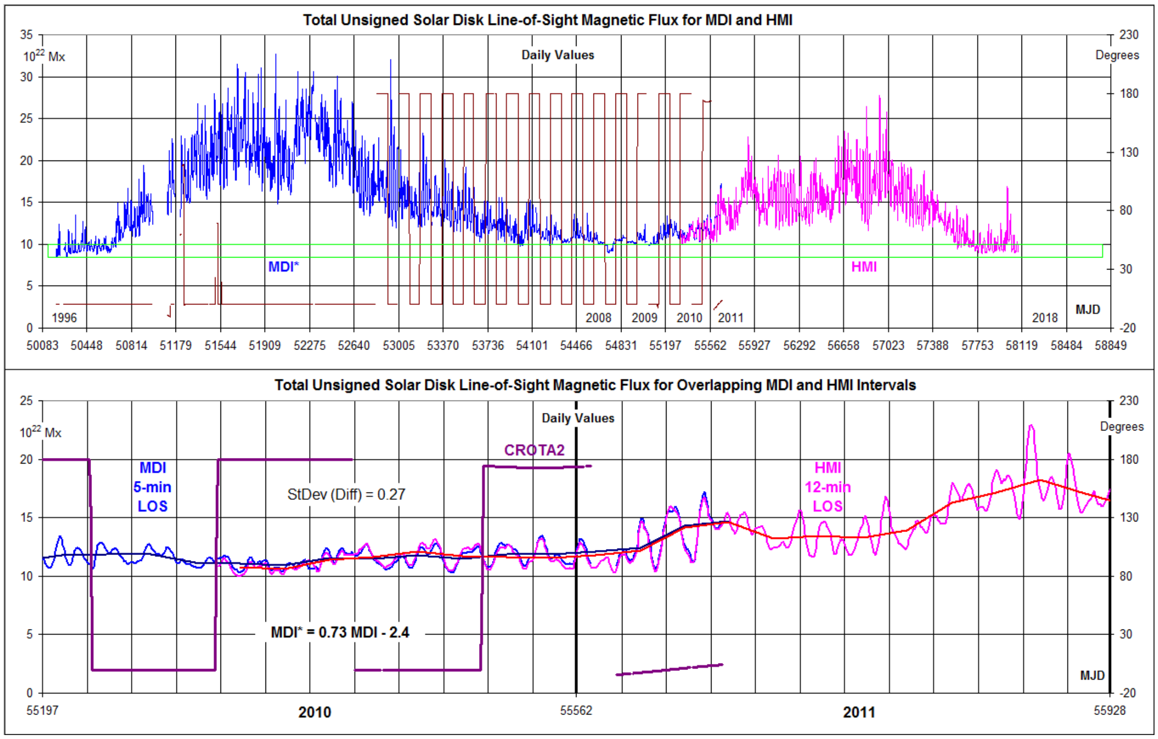

Figure 3. (Upper panel) Scaled 5-minute integration MDI* (blue curve) and HMI (pink curve) daily total unsigned LOS magnetic flux of the solar disk out to radius 0.99. The value of CROTA2 is shown by the (brown) 'tooth' curve. (Lower panel) as above, but only for the years (2010-2011) of overlap. Smooth curves are centered 12-month running means.

MDI used two different integration times: 5 minutes and 1 minute. In the whole MDI data sets there were 4294 days with 5-minute integrations (286 for the overlap with HMI) and 4863 days with 1-minute integrations (306 for the overlap). Figure 4 shows that the conversion factor to HMI depends on the integration time:

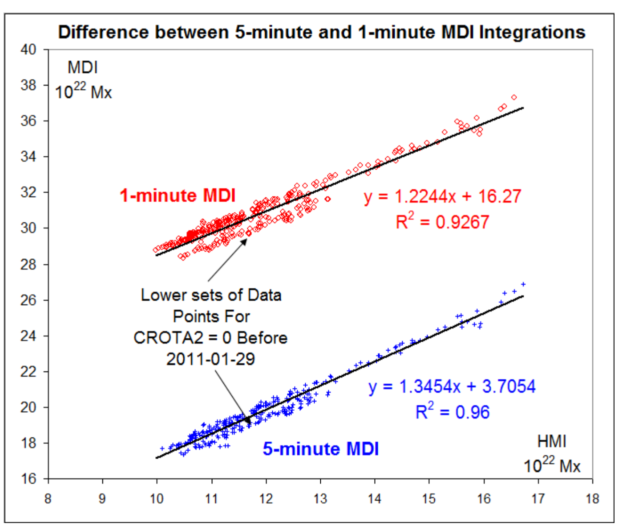

Figure 4. The corresponding daily values of the disk total unsigned LOS magnetic flux for MDI and HMI for 1-minute integrations of the magnetic signal (red symbols) and for 5-minute integrations (blue symbols). For each dataset there is a parallel set of data points, namely those for CROTA2 = 0 before 2011-01-29.

If we interpret the offset (16 for 1-minute data, and 3.7 for 5-minute data) as an indication of the noise level of MDI we see that the noise is lowest for the longer integration time, which is what we would expect.

What was the integration time for the magnetograms that were used to construct Synoptic Charts? The documentation at http://soi.stanford.edu/magnetic/index6.html states "Full-disk 2-arc second MDI magnetograms are observed every 96 minutes. The calibrated disk images are remapped to a high resolution Carrington coordinate grid and converted to a radial field. Projection corrections to the field strengths have been made assuming that MDI makes line-of-sight measurements of a radial magnetic field […] Two kinds of synoptic magnetograms are provided by MDI: single-minute and 5-minute averages. The five-minute averages have lower noise, at the few gauss level. We combine a varying number of the two types of magnetograms at each longitude to produce a uniform noise level, equivalent to averaging 20 single-minute observations. The noise level for the recalibrated charts is approximately 5 Gauss. The noise level in the original [≈20 G] magnetograms increases with distance from the center of the disk and is higher toward the bottom right of the disk due to velocity signal leakage caused by MDI filter non-uniformity. Thus the noise characteristics change somewhat depending on the orientation of the spacecraft."

I don't know the reason for the difference (different noise levels) for the non-rotated images (CROTA2 = 0) after 2011-01-29, but not before that date. It is clear, however that the anomaly is for MDI and not HMI.