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Measuring the Large-Scale Solar Magnetic Field

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The Sun's large-scale magnetic field is important for determining global structure of the corona and for quantifying the evolution of the polar field, which is sometimes used for predicting the strength of the next solar cycle.
Accurate measurement of large-scale solar magnetic field is difficult because the field is often near the detection limit, various observing methods each measure something a little different, and various systematic effects can be very important.
We compare resolved and unresolved observations of the large-scale magnetic field from the Wilcox Solar Observatory (WSO), Helioseismic and Magnetic Imager (HMI), SOLIS (NSO), and the Michelson Doppler Imager (MDI).
Cross comparison does not enable us to establish an absolute calibration, but it does allow us to discover and compensate for instrument problems, such as the sensitivity decrease seen in the WSO measurements in late 2016 and early 2017.

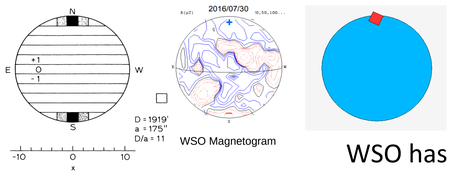


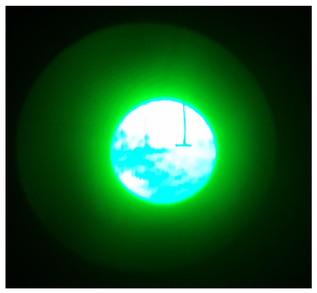
Figure 1

WSO has measured the solar mean field in a consistent way since 1975 and has made low-resolution magnetograms since 1976. Modern observations measure with much higher spatial resolution, but with less attention paid to weak field and zero-level accuracy. Cross calibration is important to extend existing records both forward and backward in time and to detecting errors.

Figure 1 shows the low-resolution scanning pattern, a WSO magnetogram and the relative size and orientation of the aperture. We can reproduce the WSO mean field by averaging the entire disk and synthesize WSO magnetogram pixels by averaging field measurements in HMI and MDI.

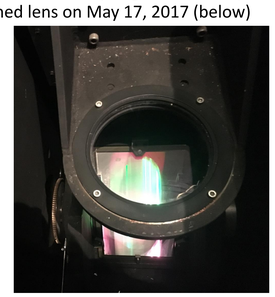
On or after 6 December 2016 the WSO Littrow lens was contaminated (Fig 2), which reduced the overall sensitivity of WSO measurements. But by how much?

Figure 3 shows the WSO mean field and the SOLIS full-disk average magnetic field scaled in two ways. The scaling changed in December 2016 and changed back in May 2017 when the Littrow lens was cleaned.

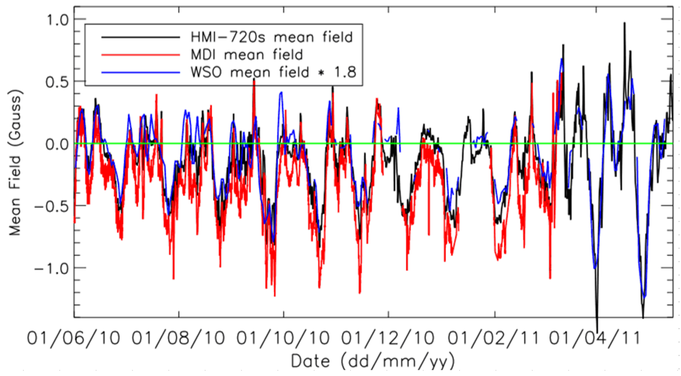


Littrow lens contamination (enhanced) seen from 75' in spring 2017 (above). Cleaned lens on May 17, 2017 (below)

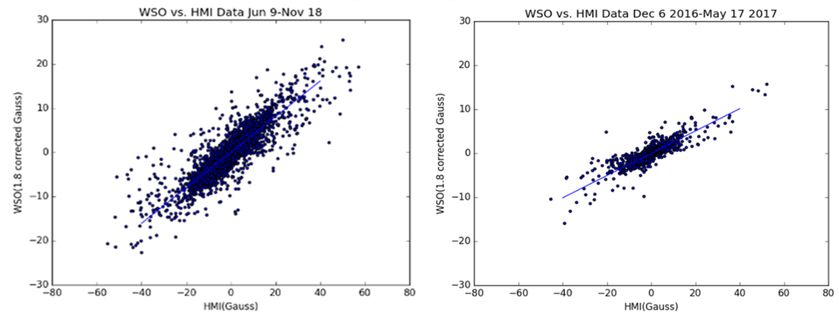
Figure 2



2010 Mean Field Comparison: WSO, MDI, HMI



WSO-HMI Magnetogram Comparison

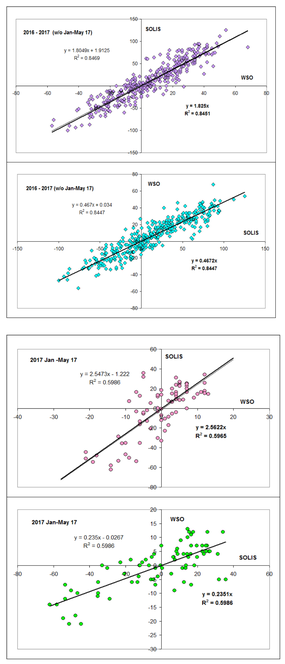


We synthesize the 195 WSO pixels for each magnetogram during normal (441) and reduced-sensitivity (99) time intervals from the nearest 720s 4k*4k HMI image. We account for orientation and location of each pixel. This gives us many more measurements of the sensitivity difference than the daily mean field. We found WSO/HMI ratios of 0.454 and 0.293 during normal and reduced sensitivity times.

This gives a magnetogram correction factor of 1.55

Detailed WSO-SOLIS Mean Field Comparison

The ratio gives a MF correction factor of 1.68



Normal Mean Field Comparison

SOLIS = 1.825 WSO
WSO = 0.548 SOLIS (=1/1.825)

WSO = 0.4672 SOLIS
SOLIS = 2.14 WSO (=1/0.4672)

Average
WSO = 0.51 SOLIS
SOLIS = 1.97 WSO

During the 2017 Sensitivity Problem

SOLIS = 2.5622 WSO
WSO = 0.390 SOLIS (=1/2.5622)

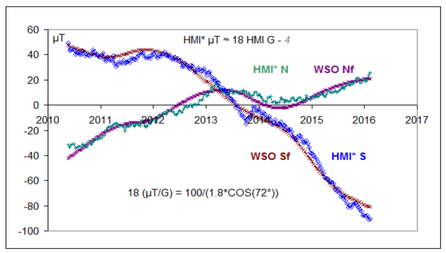
WSO = 0.2351 SOLIS
SOLIS = 4.254 WSO (=1/0.2351)

Average
WSO = 0.303 SOLIS
SOLIS = 3.303 WSO

Combining the two methods we correct WSO by a factor of 1.62

Discussion: Each of the measurements is different. WSO uses the average intensity in large pixels to determine the line-of-sight field. SOLIS, MDI and HMI measure the field in small pixels and average them with no intensity weighting. WSO measures MFs and magnetograms differently; for MFs an image of the Sun is at the contaminated Littrow lens location; for magscans there is an image of the pupil. This could cause differences in sensitivity to contamination. With recalibrated data we can now compare the polar field measurements of WSO, HMI and other observatories.

Comparison of WSO & HMI Polar Field



WSO: The pole-most aperture measures the field above 55°. A 20nHz low pass filter eliminates yearly geometric projection effects.

HMI: 12-hour observations have been averaged into the WSO window and reduced to the WSO scale accounting for saturation and projection.

Current HMI Polar Fields

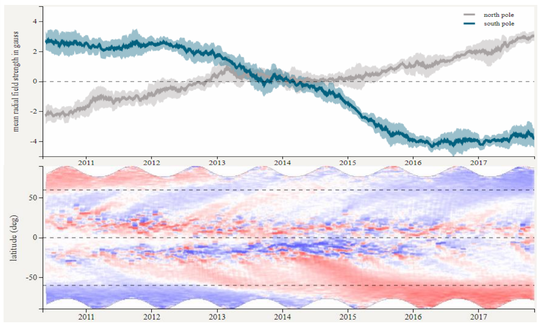
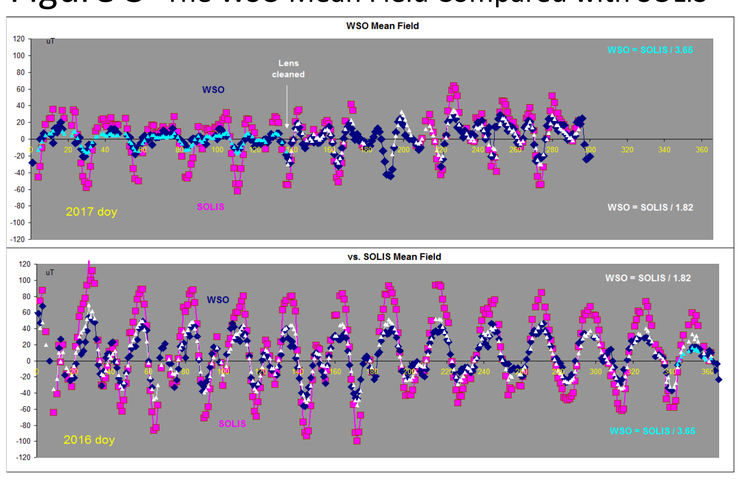
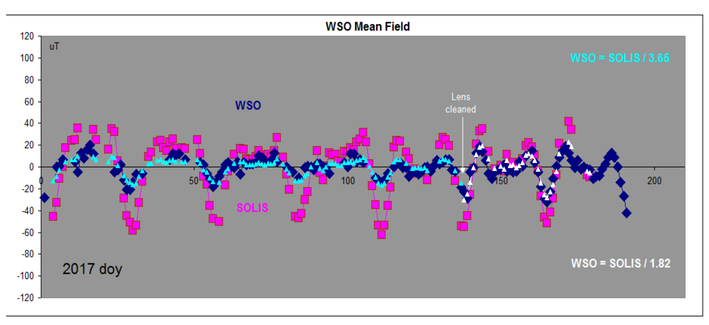


Figure 3 The WSO Mean Field Compared with SOLIS



Cleaning the lens solved the problem

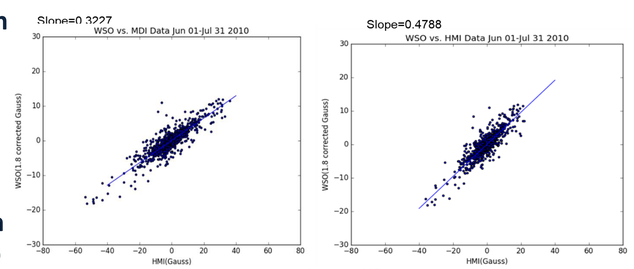


The Mean Field after the cleaning [marked with white triangles] again follow the SOLIS measurements with the usual factor of ~2 instead of the ~4 when the lens was dirty.

Future work: More extensive comparison of WSO and other observatories over time. In particular MDI observations in the last cycle could help with calibration of the polar field measurements and also help refine calibration corrections of earlier WSO issues in 2001.

WSO-HMI and WSO-MDI Comparison

MDI vs. HMI



Approx. Scale=1.4837