Calibration of Mount Wilson Observatory Magnetograms

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For each magnetogram taken at the 150-Foot Solar Tower at Mount Wilson Observatory (MWO), a Magnetic Plage Strength Index (MPSI) value is calculated. To determine MPSI, the magnetic field strengths for all pixels where the absolute value of the magnetic field strength is between 10 and 100 gauss are summed. This number is then divided by the total of number of pixels (regardless of magnetic field strength) in the magnetogram. The average MPSI for every day with observed data since 1970 is available at ftp://howard.astro.ucla.edu/pub/obs/mpsi_data/index.dat .

Figure 1 shows monthly means of the MPSI and F10.7 radio flux since 1970. It is clear that highly correlated short time scale variations from month to month are present in both time series, but also that there are significant differences in the long-term behavior, *e.g.* that cycles 21 and 22 are similar in F10.7, but very different in MPSI. This is an indication that the calibration of the MWO magnetic data is not constant over time.

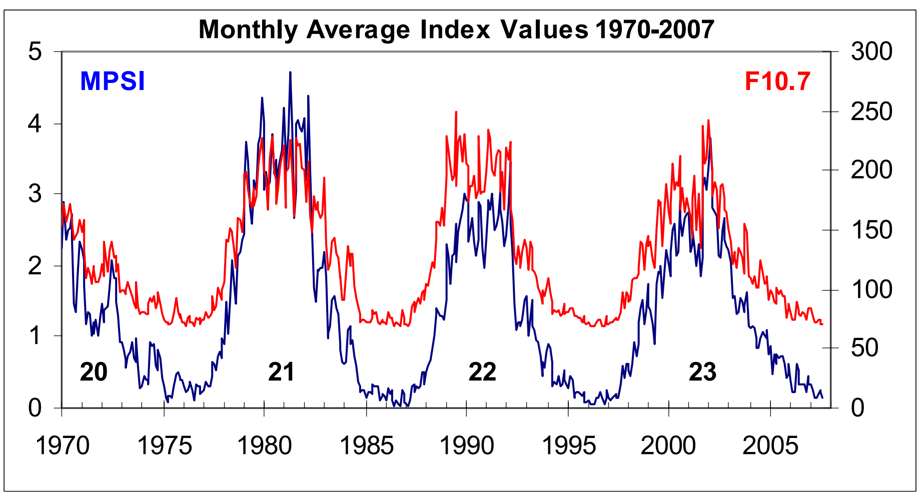


Figure 1

In fact, as Figure 2 shows, the MPSI is 35% too high before the magnetograph upgrade in 1982.5. The MPSI is proportional to the part of F10.7 flux above 63.5 sfu. We find that

$$MPSI = 0.0257\ (F10.7 - 63.5) \qquad \text{before 1982.5, and}$$

$$MPSI = 0.0191\ (F10.7 - 63.5) \qquad \text{after 1982.5.}$$

The ratio 0.0257/0.0191 = 1.35 gives the correction factor necessary to bring the magnetic measurements on the same scale. Figure 3 shows that applying this factor produces a very good correspondence between the MPSI and the F10.7 flux, thus bolstering our contention that F10.7 can be used to check the calibration of the magnetic data.

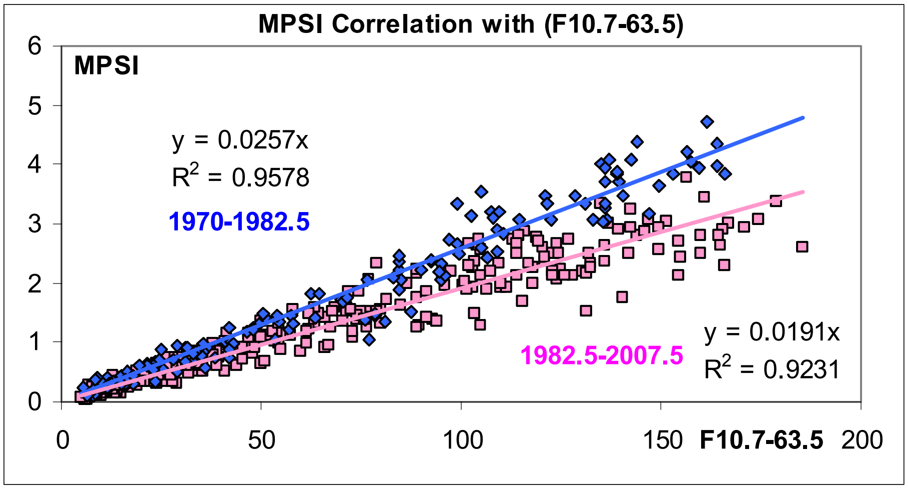
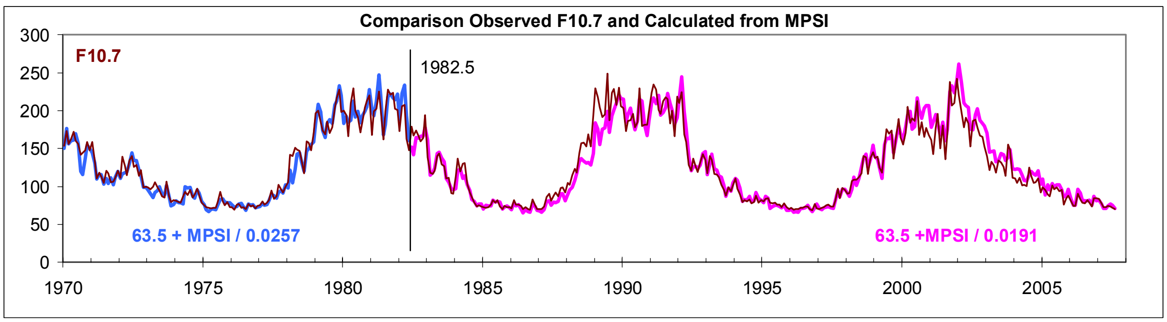


Figure 2

Figure 3 ↓



Wang and Sheeley [2002] employed Carrington Rotation maps from the Mount Wilson Observatory and the Wilcox Solar Observatory (WSO). At both observatories the magnetograph measurements are made in the Fe I 525 nm line which "saturates" for higher field strengths and yields an underestimate of the magnetic flux. Wang and Sheeley scaled both the MWO and WSO data upward by the same factor, which varies from 4.5 at the equator to 2 at the poles. This factor, while appropriate for MWO after 1982, is not applicable for WSO for which a constant factor of 1.8 has been found [Svalgaard et al, 1978; Svalgaard, SHINE 2006]. In part because of calibration problems affecting the MWO magnetograph after it was rebuilt at the end of 1981, Wang and Sheeley used WSO observations for the period 1976–1995 and MWO observations during 1971–1976 and 1995–2000. They did not employ photospheric field maps from the National Solar Observatory/Kitt Peak (in the Fe I 868.8 nm line) because of their uncertain zero level.

Figure 4 shows their comparison of the open flux calculated using the potential field source surface (PFSS) model and the radial component of the IMF near the Earth at 1 A.U. The seemingly good agreement is often taken as an indication that:

1: The photospheric magnetic data is good
2: The “saturation” factor for MWO should be used for WSO data
3: The PFSS model is good

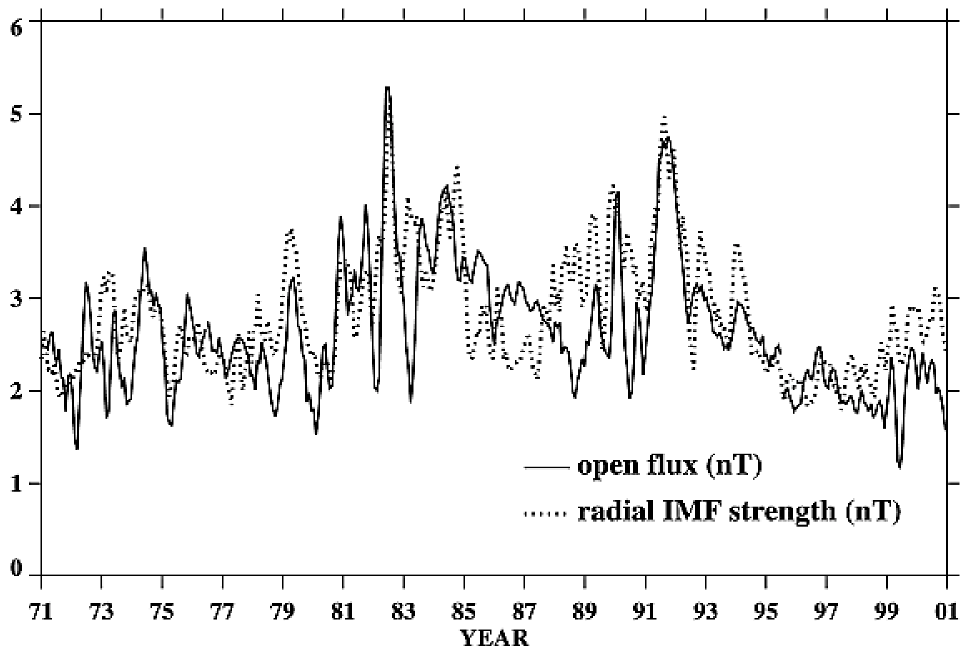


Figure 4

Lowering the open flux during 1971-1976 by a factor of 1.35 (from ~2.5 nT to ~1.8 nT) would seriously impair the agreement, and will, in fact, bring the open flux down to the same level as during 1997-2000, where it was also ~35% lower than the radial IMF. At any rate, Figure 4 is based on applying, inappropriately, the saturation factor valid for one observatory on data from another observatory, and ignoring (or not knowing about) the calibration of MWO data changing with time, resulting in quite fortuitous agreement.

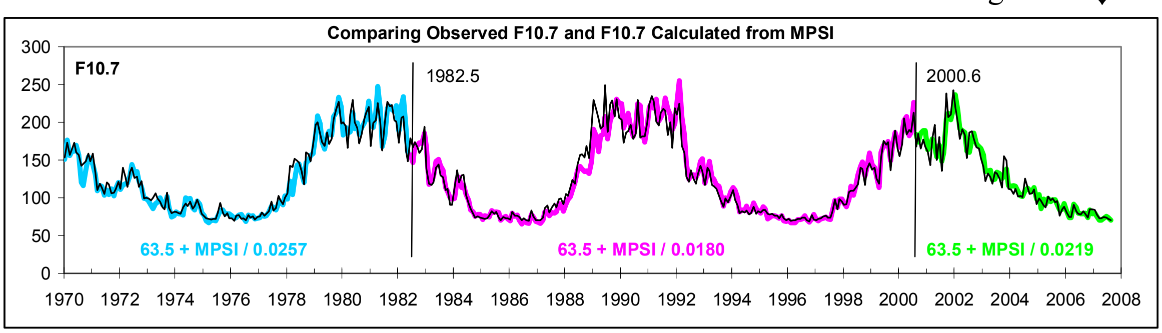
Careful inspection of Figure 3 reveals that there is yet another discontinuity in 2000. If we take that one into account, we get three regression equations and the fit in Figure 5:

$MPSI = 0.0257\ (F10.7 - 63.5)$ before 1982.5

$MPSI = 0.0180\ (F10.7 - 63.5)$ between 1982.5 and 2000.6

$MPSI = 0.0219\ (F10.7 - 63.5)$ after 2000.6.

Figure 5. ↓



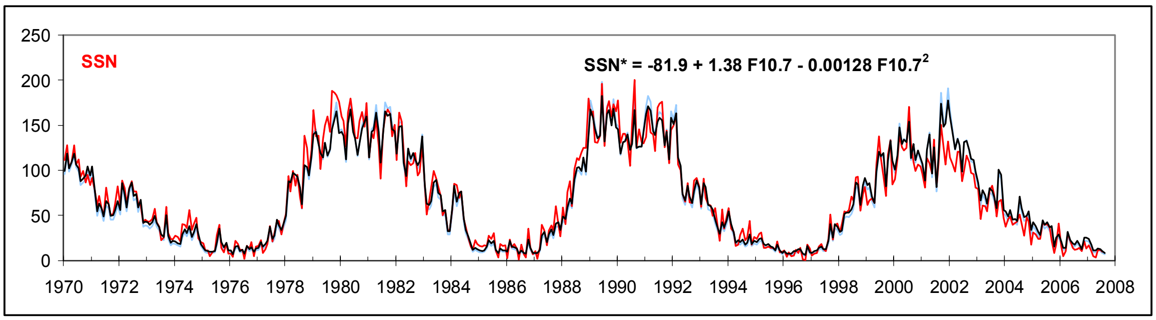
The correction factor is now even larger, 0.0257/0.0180 = 1.42 instead of 1.35.

How do we know that F10.7 is correct and that MPSI needs correction? Every long-term dataset eventually deteriorates. As an example, F10.7 is given as two "parallel" datasets, one that is the actually observed flux (and even this need correction for atmospheric effects) and one that is corrected for the varying Sun-Earth distance. There are indications that before 1969 the "observed" values are actually the "adjusted" values and the "adjusted" values have been adjusted twice. So what ensures the stability of F10.7?

The sunspot number (SSN) [R_z or R_i] is highly correlated with the F10.7 flux, *e.g.* for monthly averages:

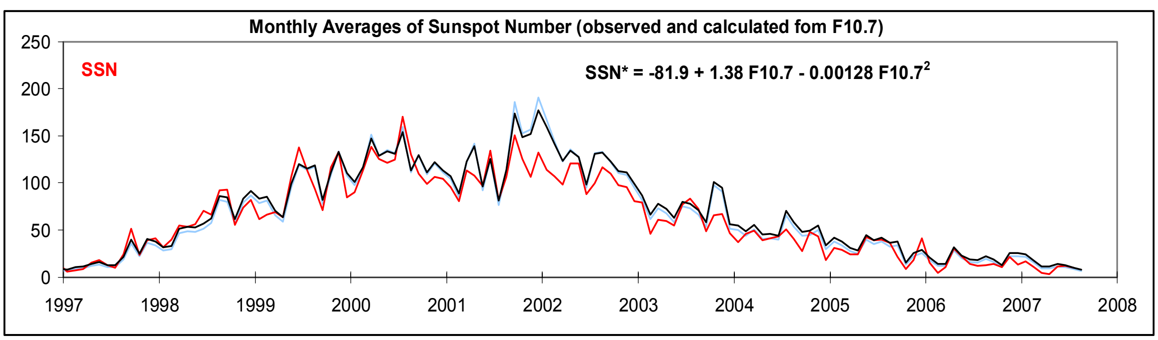
$$SSN = -81.9 + 1.39\ F10.7 - 0.00128\ F10.7^{\,2}, \qquad R^2 = 0.9493$$

Figure 6. ↓



There is a well-known disagreement around 2002.0 (some disagreement possibly continuing to the present, Figure 7 - The Mg II or Ca II K-line data might be useful to settle this), but otherwise the two series support each other.

Figure 7. ↓



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