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An Explanation of the Differences Between the Sunspot Area Scales of the Royal Greenwich and Mt. Wilson Observatories, and the SOON Program

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Abstract Several studies have shown that the sunspot areas recorded by the Royal Greenwich Observatory (RGO) between 1874 – 1976 are about 40 – 50 % larger than those measured by the NOAA/USAF *Solar Observing Optical Network* (SOON) since 1966. We show here that while the two measurement sets provide consistent total areas for large spots, the impossibility of recording small spots as anything except dots in the SOON drawings leads to an underestimate of small spot areas. These are more accurately recorded by the RGO and other programs that use photographic or CCD images. The large number of such small spots is often overlooked. A similar explanation holds for the RGO umbral areas, which amount to 40 % more than those measured from Mt. Wilson data between 1923 and 1982. The neglected small spots have a much lower photometric contrast. Our explanation suggests, therefore, that the adjustment to spot *irradiance blocking* at the 1976 transition from RGO to SOON areas is smaller than the almost 50 % correction advocated by some recent, purely statistical, studies.

1. Introduction

A continuous daily record of sunspot areas was compiled at the Royal Greenwich Observatory (RGO) between 1874 and 1976. Several shorter records exist; the most widely used since the RGO measurements ceased is that initiated in 1966 by the Space Environment Laboratory (SEL) of NOAA, together with the US Air Force. This program was renamed the *Solar Optical Observing Network* (SOON) in the late 1970s and continues to the present. We refer here to the entire NOAA/USAF program since 1966 as SOON. The areas we discuss are values corrected for projection unless stated otherwise.

A number of studies over the past three decades have drawn attention to scale differences between the various records (*e.g.* Hoyt, Eddy, and Hudson, 1983; Fligge and Solanki, 1997; Hathaway, Wilson, and Reichmann, 2002; Balmaceda *et al.*, 2009; Baranyi *et al.*, 2001; Fröhlich, 2011; Baranyi, Kiraly, and Coffey, 2013). Some differences are to be expected

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given the different instruments and procedures. But the report that SOON areas were systematically smaller by 40 – 50 % than those measured by RGO (Hathaway, Wilson, and Reichmann, 2002) was surprising. Equally puzzling is the finding (Hathaway, Wilson, and Reichmann, 2002) that the umbral areas measured by Howard, Gilman, and Gilman (1984) appear to be about 40 % smaller than the RGO umbral areas.

These area scale uncertainties translate into uncertainties in the sunspot-blocking of total solar irradiance (TSI). The value of spot-blocking has little influence on the irradiance variations calculated with regression-based reconstructions (*e.g.* Foukal and Lean, 1986; Fligge and Solanki, 1997). But a substantial *change* in scale of unknown origin does produce a correspondingly large irradiance uncertainty over the period of the reconstruction. Knowledge of the absolute magnitude of the spot and facular contributions to TSI variation is also important for discerning the possible contribution to the TSI variation of photospheric brightness temperature inhomogeneities located *outside* photospheric flux tubes (*e.g.* Parker, 1995; Foukal and Bernasconi, 2008).

Various contributions to the differences between the many area records have been suggested (*e.g.* Gerlei, 1987; Györi, 1998; Baranyi *et al.*, 2001; Balmaceda *et al.*, 2009), but no satisfactory explanations for the large RGO/SOON or RGO/MWO differences have emerged. Meanwhile, our ability to remember detailed procedures used in these programs declines as the original observers retire and memories fade. Therefore it is important to address these scale differences while there is still some hope of understanding their origin.

In Section 2 we consider several lines of evidence that narrow the range of possible explanations. In Section 3 we suggest that the RGO/SOON difference arises mainly from an underestimate of the areas of the large number of small spots. In Section 4 we test this explanation using spot statistics. Section 5 deals with the related explanation of the smaller MWO umbral areas, and draws attention to a contribution from the thickness of the measurement cross-hair. In Section 6 we find that irradiance blocking calculated from the RGO and SOON data probably requires correction by a smaller factor than the 1.4 – 1.5 based on the ratio of the areas. In Section 7 we test our findings against radiometry of the TSI. We present our conclusions in Section 8.

2. Explanations of the RGO/SOON Difference That Can Be Ruled Out

2.1. Error in SOON Overlays

We first investigated the possibility that the scale difference might simply be produced by an error in the transparent overlays used to measure spot areas in the SOON program. These overlays were introduced in 1981 to simplify the procedure previously used, which relied on a counting of 1 mm squares. This explanation can be ruled out. For one, our remeasurement of the overlays, provided to us by P. McIntosh (private communication, 2005), showed them to be accurate. Moreover, the scale difference was present already in 1966, when the NOAA/USAF measurements began in Boulder, Colorado (Baranyi, Kiraly, and Coffey, 2013). The difference has persisted since that time, as shown in Figure 1. Some readjustment of the scale can be seen around the time of the introduction of the overlays in 1981, but it is temporary. Whatever causes the difference has remained remarkably stable for almost half a century.

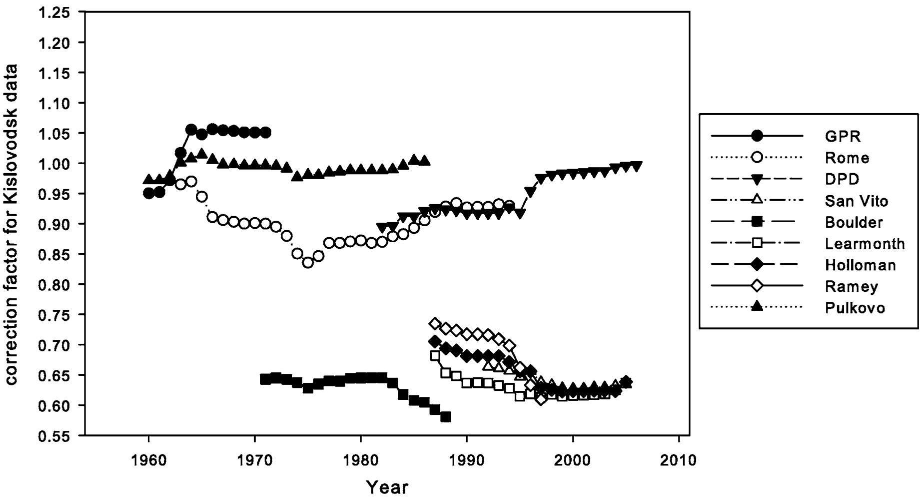


Figure 1 The scale difference between RGO (filled circles) and SOON-Boulder (filled squares) illustrated using smoothed data since 1966 (from Baranyi, Kiraly, and Coffey, 2013). Kislovodsk data are used here as reference.

2.2. Errors Due to Neglect of Spots near the Limb

Spots near the limb were treated differently in the RGO and SOON programs. Groups located even partly outside of 80 degrees from the central meridian passage were omitted in the RGO daily disk sums (*e.g.* Hohenkerk, Ladley, and Rudd, 1967). This would cause a systematic underestimate of the projection-corrected daily area of about 10 – 15 %. SOON observers were instructed to apply a projection correction to spots located outside of about 0.7 of the solar radius, equal to the correction at that limb distance (J. Kennewell, private communication, 2013). This under-correction for projection would generate an area underestimate of about 20 %, so the two errors should roughly cancel. Perhaps more important, as shown below, the large scale difference we seek to explain clearly exists in spot areas measured near disk center, which means that it cannot arise from effects that are generated near the limb.

2.3. Possible Measurement Errors Anywhere on the Disk

Several possible errors of measurement (as opposed to selection effects) have been suggested, which might apply anywhere on the disk. For one, the RGO measurements were taken from photographic plates, whereas the SOON measurements were made on pencil drawings of the projected disk. A difference in areas measured in these two ways would be consistent with the relatively close agreement seen in Figure 1 between the RGO, Rome, and Debrecen Observatory time series, which were all measured from photographic plates or CCD images.

The report (Hathaway, Wilson, and Reichmann, 2002) that the photographically observed umbral areas measured by Howard, Gilman, and Gilman (1984) are about 40 % smaller than the RGO umbral areas for the same period from 1921 to 1976 would seem to argue against an explanation in terms of photographic records *versus* drawings. But we show in Section 4 below that the difference in umbral areas probably has a different explanation that sheds no light on the distinction between photographic *versus* drawing-based records.

To examine the possibility of a difference between photographically and visually measured areas, we compared the diameters of two large, simple spots each measured on two days. These were spots for which we were able to locate i) the SOON drawings and areas; ii) large-scale white-light photographs; and iii) photometric scans across the spot diameter. These spots are of sufficient size (30 – 40 arcsec) to minimize uncertainties in measuring the drawings caused by telescope resolution, seeing, and the thickness of the pencil line. An image of the 27 July 1966 spot and two sets of photometric scans (Wilson and McIntosh, 1969; Wittmann and Schröter, 1969) are reproduced in Figure 2(a, b). The corresponding SOON drawing of the disk is shown in Figure 2(c).We first re-measured these spot areas from the SOON drawings using a reticule eyepiece and scale graduated in 0.5 mm increments (SOON used a 1 mm scale to measure the same size of image). We found them to agree to within 5 % with the SOON values, so we see no evidence of large systematic error caused, *e.g.* by coarseness of the SOON measurement scale. We next measured the penumbral diameters from the photographs. These were found to agree to ≈ 10 % with the diameters in the drawings. Moreover, the diameters measured from the photometric scans of these photographs agree to about 10 % with the diameters measured with a reticule eyepiece. Our measurements are shown in Table 1. We see no evidence in these measurements for a systematic diameter difference approaching 20 – 25 % (*i.e.* an area difference of 40 – 50 %) between i) photographic and visually measured spot diameters; ii) diameters measured visually from a white-light photograph and those measured from a calibrated photometric scan of the same spot photograph.

Other possibilities have been suggested. For one, areas measured from photographic negatives might differ from those obtained from positives. We investigated this by reversing the contrast on a full-disk image from Mt Wilson Observatory (Figure 3). Our trial was not accurate enough to test for possible small effects, but we saw no evidence of a change of the size that we seek to explain here. These findings indicate that while effects of the kind considered above may contribute at 5 – 10 % of the diameter level, they cannot explain a systematic area scale difference of 40 – 50 %.

3. An Explanation of the RGO/SOON Scale Difference

The main reason for the higher RGO values for *group* areas (the only ones RGO published at the time of the overlap with SOON) seems to have a simple explanation. It is impossible to draw the contour of spots of a corrected area smaller than about 10 μh, even near disk center, because of the width of the thinnest (roughly 0.3 mm) line that can be drawn with the 4H pencils used by the SOON observers. Consequently, they were instructed by P. McIntosh to simply count the small spots in a group and to assign to each an area of 2 μh. A SOON drawing of an active Sun is shown in Figure 4 to illustrate the large number of small spots that were counted, but were too small to draw as contours.

The RGO measurement, by comparison, was limited only by the resolution of the optics, atmospheric seeing, and grain of the photographic plate. The plate scale was similar, but the reticle used was graduated in 1/100ths of an inch (approximately 1/4 mm), thus more finely than the 1 mm squares used by the SOON observers. Therefore the RGO procedures enabled reasonably accurate measurements of spot areas down to 2 μh. Consequently, the SOON total area for a group underestimated the true area by an amount equal to the difference between the true areas of the small spots and the estimate $2N$ μh, where N was the number of spots that were too small to draw. For large groups generally $20 < N < 150$, so if the

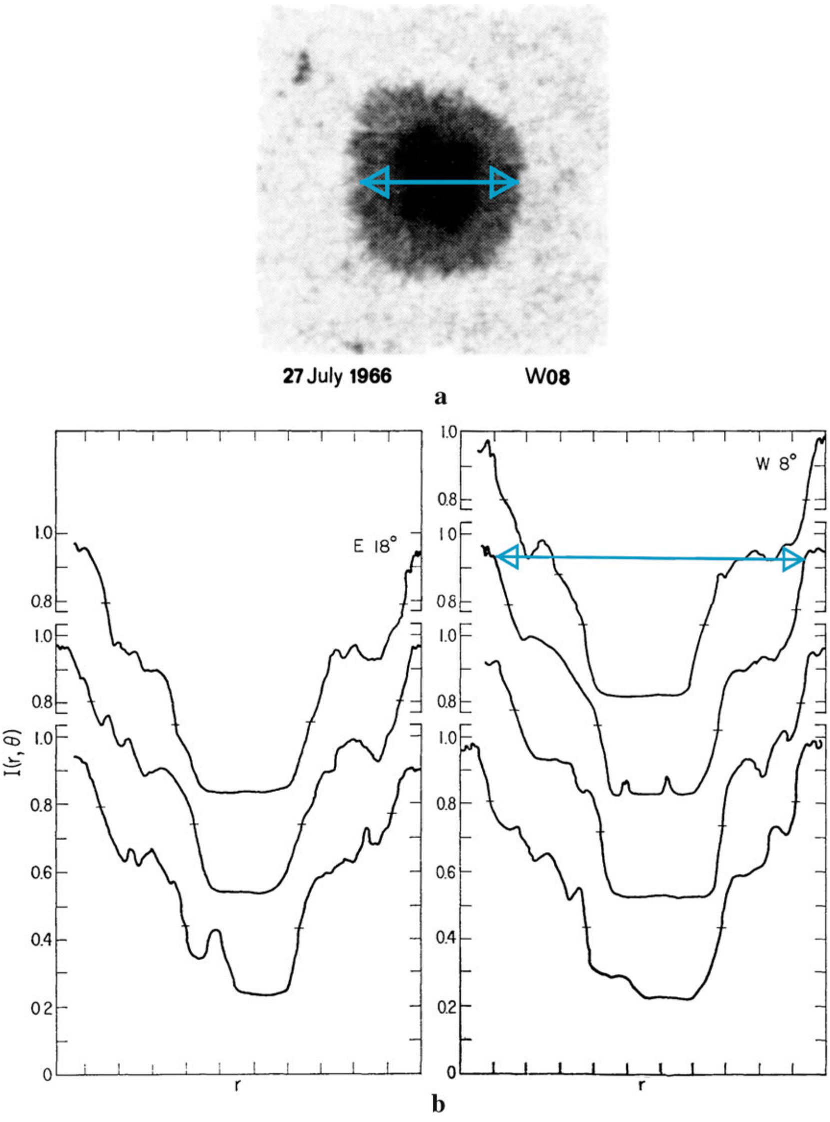
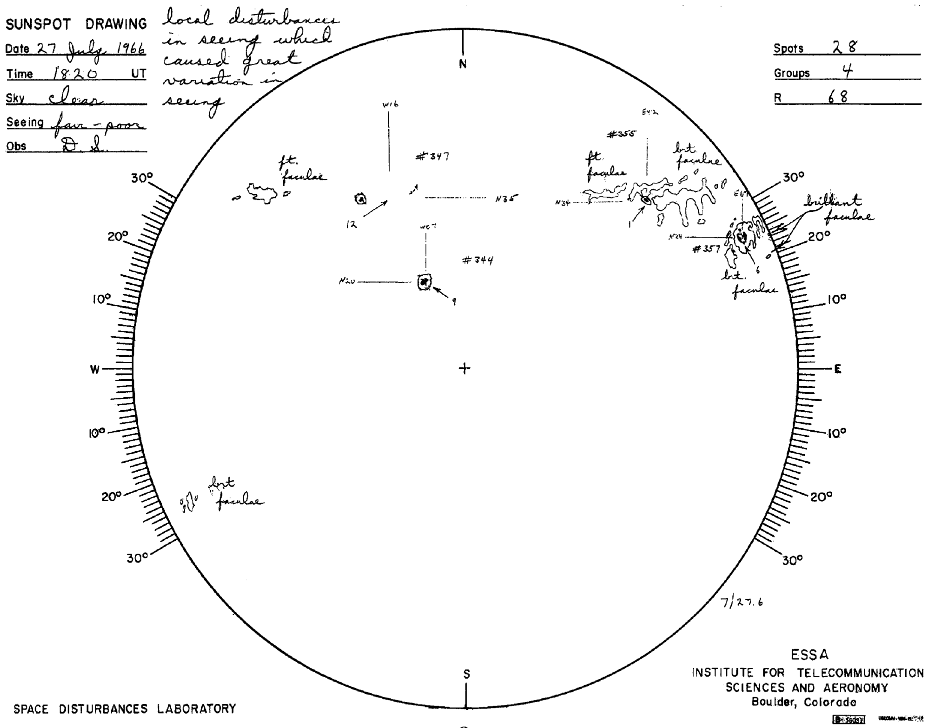


Figure 2 (a) White-light image of the p spot in NOAA region 244 on 27 July 1966 (from Wilson and McIntosh, 1969); (b) photometric scans across the spot in Figure 2(a) on 25 July 1966 (left panel) and 27 July 1966 (right panel) (reproduced from Wilson and McIntosh, 1969); (c) SOON drawing on 27 July 1966, showing a relatively inactive Sun with 28 spots and AR 244 near disk center (from the National Geophysical Data Center). The arrow lengths in panels (a) and (b) represent approximately 30 000 km.

mean underestimate per spot was ≈ 10 μh, the total underestimate could be similar to the area in the larger spots. This appears to be the main reason for the higher values published by RGO.

However, the RGO values were higher even for spots that were big enough to draw. This is illustrated in Figure 5, which shows a plot of RGO-measured areas *versus* SOON-measured areas for individual spots (not groups). Our sample ranges in size from the smallest



c

Figure 2 (*Continued.*)

Table 1 Sunspot diameters [*D* km] measured from SOON drawings, from photometric scans, and from photographs. Sources of scans and photos: Wilson and McIntosh (1969); Wittmann and Schröter (1969).

Date	*D* (drawing)	*D* (scan)	*D* (photo)
26 July 1966	32 000	31 000	32 000
27 July 1966	32 000	37 000	33 000
18 September 1966	45 200	...	44 000
19 September 1966	57 400	51 000	...

spots identified (about 2μ hemispheres) to the largest single spots on the SOON drawings that are unaccompanied by more than one or two tiny satellite spots. These were the only groups for which the RGO data yielded the area of individual spots. They are relatively rare and had to be located individually by inspection of the daily SOON drawings. We see from Figure 5 that for spots with an area smaller than approximately 100 μh, the RGO area is about 50 % larger than the SOON value. For larger spots, however, the curve flattens, and for spots > 300 μh the areas equalize. Such large recurrent spots tend to dominate the daily spot-area variation of the active Sun.

This means that the difficulty of drawing accurate contours seems to have yielded an underestimate of area even for medium-sized spots that SOON did measure individually.

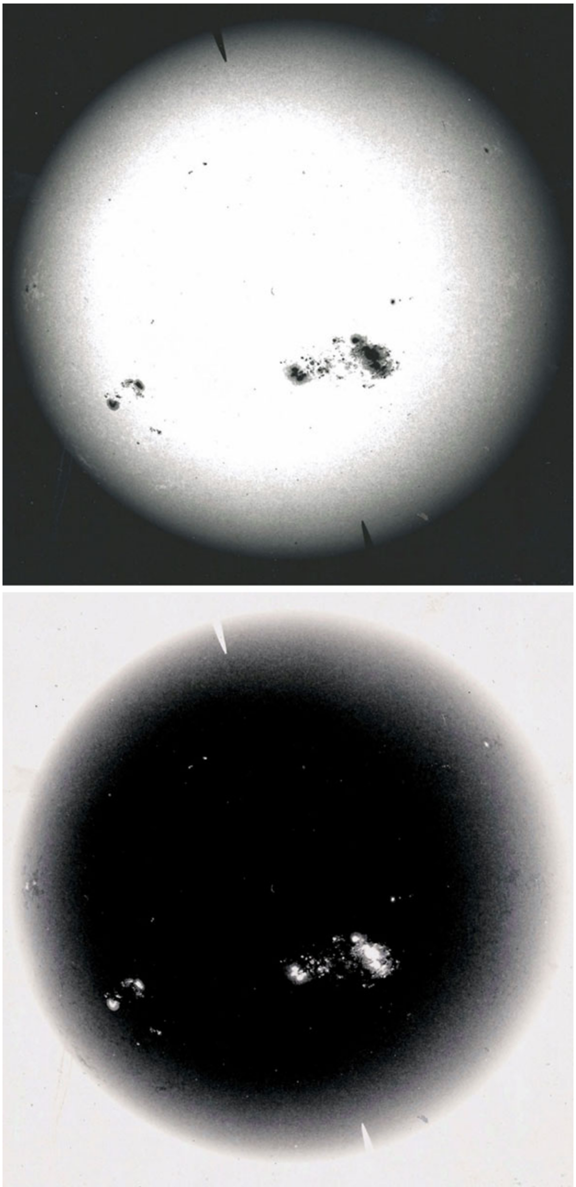


Figure 3 Positive (top) and negative images of a print from Mt. Wilson Observatory, reproduced to similar contrast. They show the great spot of April 1947.

Image motion and seeing will certainly introduce noise into any attempt to capture a spot's contour on paper, but it is not clear why this noise should produce a systematic underestimate of size. Unfortunately, the original SOON observers no longer remember whether, *e.g.*, they might have systematically drawn the pencil line inside instead of along the penumbral outer boundary. As seen below in Section 5, a similar tendency by the MWO observers can explain why the areas of even the large umbrae that they measured were too small.

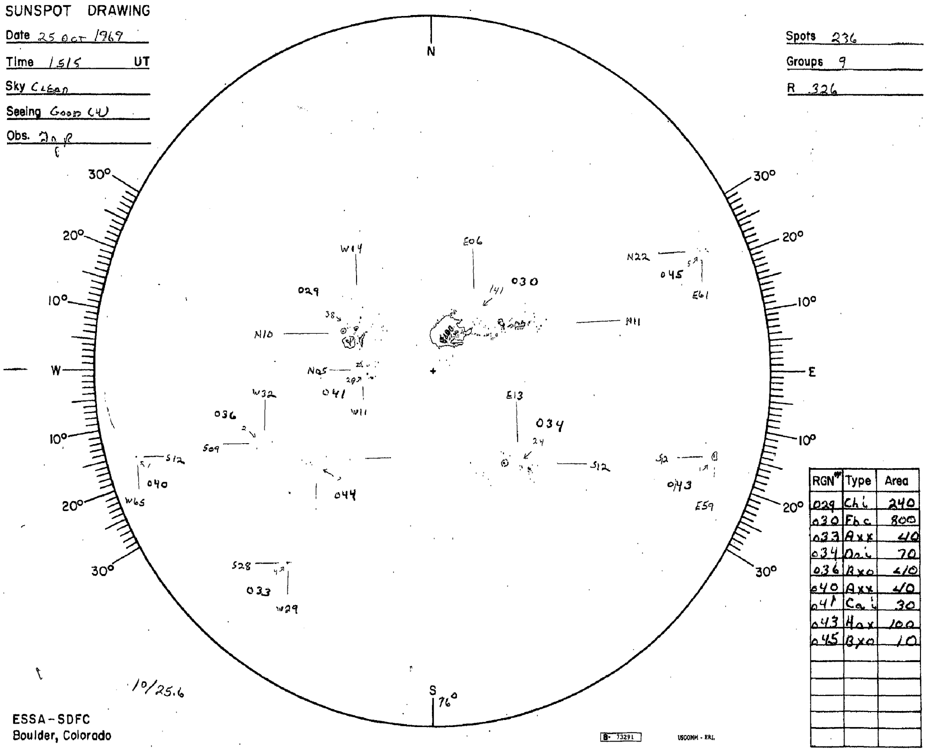


Figure 4 A SOON drawing of an active Sun on 25 October 1969 when $f = 236$ spots were observed in $g = 9$ groups, so $R = 10g + f = 326$. Note that only about 16 of the spots were large enough to draw as contours, although 141 spots are counted in AR 030 near disk center (from the National Geophysical Data Center).

4. Testing the Importance of SOON's Neglect of Small Spots

The importance of SOON's neglect of small spots might be tested most directly if the areas of the individual small spots measured by RGO were available for the period between 1966 and 1976, when the RGO and SOON measurements overlapped. As noted above, this is not the case, but we can still check as follows. Our hypothesis is that the spot areas, SOA and RGA, measured by the SOON and RGO programs, respectively, are related by

$$\mathrm{SOA} = \mathrm{RGA} - \gamma N. \tag{1}$$

Here N is the number of spots that were too small for the SOON observers to measure (but that were identified and counted by both the SOON and RGO observers), and γ is the mean area deficit [in μh] between the area of these spots as measured by RGO and by SOON. Essentially, this is the difference between the smallest area measurable by SOON and the value of 2 μh (or sometimes zero) assigned by SOON to the smallest spots.

The sunspot number [R] is defined by

$$R = k(10g + f), \tag{2}$$

where g = number of groups, f = number of individual spots on the disk, and k is an empirical correction factor between measurements made by different observers with differing

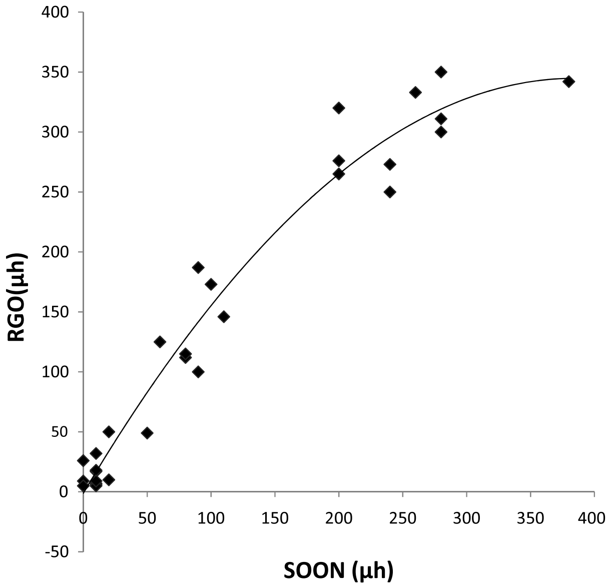


Figure 5 RGO *versus* SOON areas (in μ hemispheres) for a sample of individual spots observed between 1967 and July 1976. The quadratic line fit has an r^2 value of 0.96.

equipment and procedures. A value of $k = 0.6$ has been adopted for use with the international spot number scale (D. Hathaway, private communication, 2013; F. Clette, private communication, 2013).

From examination of the SOON drawings over a range of moderate to high solar activity between 1966 and 1976, we find that $N \approx (f - 2g)$ and $g \approx R/15$ are reasonable estimates. For example, in Figures 2(c) and 4, on two days when $g = 4$ and 9, we can discern about 7 and 16 spots (so ≈ 2g) with contours that might have been measurable. Our estimate of g from R is consistent with the value given by Allen (1964), taking into account that its value increases with activity.

It then follows, with RGA/SOA = 1.4, that

$$\gamma = \mathrm{RGA}/3R. \tag{3}$$

Inserting annual mean values of RGA and R for 1916 – 1976 in Equation (3), we find that over this period $3 < \gamma < 6$.

This range of γ implies that our explanation is reasonable if the SOON program essentially neglected the areas of spots smaller than approximately 10 μh. This agrees with our examination of the SOON drawings, which generally assign total areas in multiples of 10 μh to groups consisting of only about 10, 20, or fewer tiny spots. As mentioned earlier, this spot size is also about the (optimistic) smallest that can be rendered by SOON observers, even near disk center (the smallest measurable spot-corrected area increases nearer the limb).

5. An Explanation of the Smaller MWO Umbral Areas

Our explanation also seems consistent with the finding (Hathaway, Wilson, and Reichmann, 2002) that disk sums of umbral areas measured from Mt. Wilson Observatory plates between 1921 and 1982 by Howard, Gilman, and Gilman, 1984) were about 40 % lower than the RGO umbral areas. Review of the procedures used by Howard, Gilman, and Gilman (1984), reveals that they also (like SOON) assigned areas of 2 μh to umbrae too small to measure

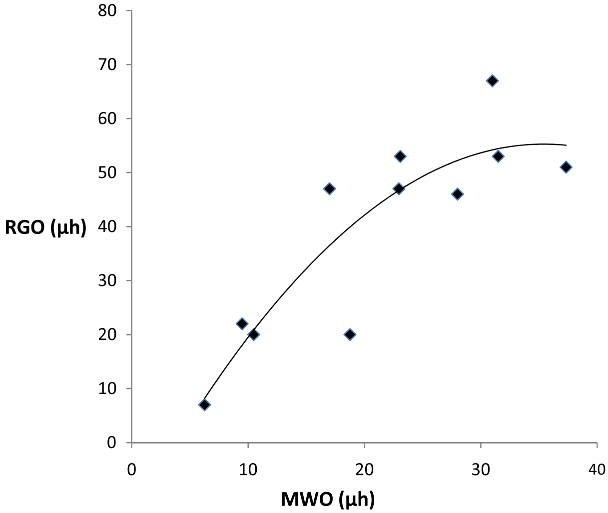


Figure 6 The areas of some umbrae measured by both RGO (ordinate) and by Howard, Gilman, and Gilman (1984) using MWO data (abscissa). The line represents a quadratic fit of $r^2 = 0.78$.

accurately with their apparatus (which used photographic plates like RGO, but was designed to measure primarily spot positions and motions and not areas). So it appears that at least some of the area deficit of umbrae found from comparing their data with the RGO areas can be explained in the same way as the SOON spot-area deficit. But closer examination of the evidence for individual umbrae suggests an additional effect.

Figure 6 shows the areas of some individual umbrae measured by both the RGO and MWO observers. As described above in Section 3 for the total areas of individual spots, it was necessary to locate these umbrae by comparison of RGO and MWO data and the SOON drawings. Only in this way was it possible to have confidence in finding umbrae that met the required criteria of being single, and also circular enough to yield a useful area using the cursor method employed by the MWO workers. Few umbrae of significant size in the 1966 – 1976 overlap period of these three data bases meet these criteria. We see, as in Figure 5, that the RGO areas are larger by an amount that becomes proportionately smaller for larger umbrae. But unlike the total areas of individual spots plotted in Figure 5, we see in Figure 6 that the RGO areas remain 40 % larger even for relatively large umbrae (umbrae of area ≈ 40 µh correspond to total areas of roughly 200 – 300 µh).

This suggests a significant contribution from an error that exists even for relatively large spots. The MWO observers measured areas by placing a cross-hair tangent to the umbral edge first on one side of the spot, then on the other. When seeing was an issue, the observer tended to place the cursor line of the cross-hair tangent to the *inside* of the umbral edge (P. Gilman, private communication, 2013). So the area would tend to be under-estimated by a factor determined by the 0.3 mm thickness of the cross-hair line relative to the radius of the umbra. This area contribution decreases from a factor of about 2.5 for a small umbra of 10 µh to 40 % for a 40 µh umbra. This explanation is consistent with the behavior seen in Figure 6.

The smaller residual SOON area underestimate for even medium-sized spots seen in Figure 4 might also be caused by drawing the spot contour inside the penumbral edge instead of along it. But the original SOON observers, P. McIntosh and D. Sutorik, were no longer able to confirm this.

6. Implications for Irradiance Blocking by Sunspots

Our explanation has implications for models of TSI blocking by sunspots based on the RGO areas because of the significant fraction of the RGO total area contributed by small spots whose photometric *contrast* decreases with size. Correction for this decrease in blocking models (*e.g.* Fröhlich, 2011) does not extend down to the smallest spot sizes at issue here, therefore such a model will tend to overestimate the blocking. Use of the SOON data, on the other hand, leads to an underestimate because they essentially neglect the *area* contribution of small spots.

The corrections to these two models can be estimated as follows. We represent the two models of irradiance variation based on the RGO and SOON spot areas as RGI and SOI, respectively. This yields the two relations:

$$\mathrm{RGI} = c(L + S) \quad \text{and} \tag{4}$$

$$\mathrm{SOI} = c(L + \alpha S), \tag{5}$$

where L is the area of large spots *resolvable* by SOON, S is the true area of small spots *unresolved* by SOON, c is the photometric contrast of large spots, β is the fractional (small/large) spot contrast, and α is the fraction of small spot area $[S]$ measured by SOON.

Our explanation implies that Equations (4), (5) should be modified to the form

$$\mathrm{RGI}^* = c(L + \beta S) \quad \text{and} \tag{6}$$

$$\mathrm{SOI}^* = c(L + \alpha\beta S). \tag{7}$$

Consequently, the required correction factors are

$$\mathrm{RGI}^*/\mathrm{RGI} = (L + \beta S)/(L + S) \quad \text{and} \tag{8}$$

$$\mathrm{SOI}^*/\mathrm{SOI} = (L + \alpha\beta S)/(L + \alpha S). \tag{9}$$

If the RGO/SOON area ratio ≈ 1.4, then $S \approx 2/5L$. Measurements of the photometric contrast of small spots are difficult due to seeing and scattered light, but values of $\beta \approx 1/5$ are consistent with present data for the visible (*e.g.* Steinegger *et al.*, 1996) and near-infrared (*e.g.* Moran, Foukal, and Rabin, 1992). For current SOON operations, $\alpha \approx 0$ (T. Henry, private communication, 2013), but previously, SOON observers assigned an area of 2 μh to the smallest spots (J. Kennewell, private communication, 2004), so then $\alpha \approx 1/3$ to $1/10$. Using these values, we find for the correction factors $\mathrm{RGI}^*/\mathrm{RGI} \approx 4/5$ and $1 < \mathrm{SOI}^*/\mathrm{SOI} < 1.08$.

This calculation suggests that current blocking calculations based on the RGO values to 1976 (and simple multiplication by ≈ 1.4 – 1.5 of the SOON values thereafter) overestimate spot-induced TSI decreases by ≈ 20 %. Use of the SOON data (without any correction after 1976) yields values that are underestimated by less than 10 %, but this better agreement is fortuitous – it does not imply higher measurement accuracy.

7. A Test of the Sunspot-Blocking Correction Using Radiometry of TSI

An independent test of this correction is possible by comparing the calculated and observed TSI dips produced by large sunspot groups. The amplitude of one of the largest sunspot groups, on 29 October, 2003, was measured to be 0.34 % by the TIM radiometer on the SORCE mission. For comparison, its amplitude was calculated using contrasts of 0.83 and 0.21 for the umbra and penumbra (*e.g.* Fontenla *et al.*, 2006), and spot areas from the listings

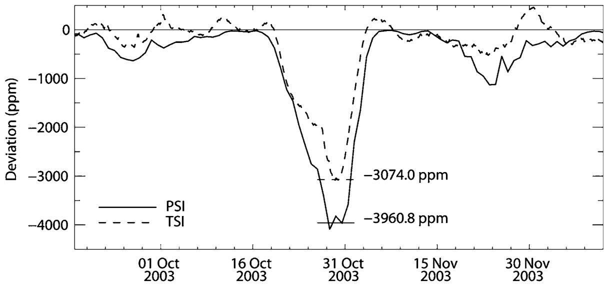


Figure 7 A comparison of the TSI dip caused by a large spot in October 2003, measured by the Physikalisch–Meteorologisches Observatorium Davos (PMOD) radiometer on the *Solar and Heliospheric Observatory* (SOHO) mission (dashed), with the dip modeled (solid) from the measured spot area (courtesy of C. Fröhlich, private communication, 2013).

of all spots down to pore size, provided by the Debrecen Observatory. (Cross-calibration of the Debrecen and RGO total daily areas indicates that they agree to within $< 10~\%$ (Gerlei, 1987; Baranyi, Kiraly, and Coffey, 2013).) The calculated dip amplitude of 0.46 % is thus about 35 % deeper than is measured radiometrically.

A similar finding that the calculated TSI dip exceeds the measured dip is obtained for that same event when the TSI from the VIRGO radiometers on SOHO is compared with a calculation using the SOON spot areas multiplied by 1.38 (C. Fröhlich, private communication, 2013). This comparison is shown in Figure 7. Neither calculation accounts for a possible facular contribution, but it must be small on this solar-rotational timescale, judging from the weak modulation of the TSI seen in Figure 7 outside of the sunspot dip. Certainly, this finding agrees with the tendency for calculated spot dips to be deeper, which was found in previous comparisons using facular areas and measured facular bolometric contrasts (Foukal and Bernasconi, 2008). Comparison with radiometry therefore seems consistent with our explanation of the RGO/SOON area difference and the corrections it implies for TSI blocking.

8. Conclusions

The main reason why spot areas recorded using photographic or CCD observations are $\approx 1.4 – 1.5$ times larger than those based on drawings seems to be that the areas of spots *too small to draw* are still individually measurable on good plates and CCD images. The large number of such very small spots on the active Sun is not widely appreciated, although they are marked (as dots) on daily drawings used to calculate the sunspot number. The "hidden" area of these small spots is essentially neglected in the SOON spot-area record, but it is included in the RGO record. This applies also to the photographic and CCD records derived at Pulkovo, Debrecen, and Rome.

Neglect of small spots in the analysis of MWO data by Howard, Gilman, and Gilman (1984) also helps to explain why their umbral areas are about 40 % smaller than the RGO umbral areas. But an important additional contribution here seems to arise from the observers' tendency to place a cross-hair of significant width *inside* instead of *on* the umbral boundary. Some contribution to the RGO/SOON difference may also arise from a similar effect in the SOON data caused by drawing the perimeter of medium-sized spots inside the penumbral boundary. Unfortunately, the documentation of SOON procedures is not adequate to demonstrate this.

The photometric contrast of the small spots neglected in the SOON records is much lower than values commonly used to calculate sunspot-blocking in reconstructions of solar-irradiance variation. We showed that because of this lower *contrast*, current reconstructions using the RGO total areas *overestimate* TSI blocking. The amount of the overestimate is uncertain, but is probably about 20 %. Those using SOON areas, which neglect the *areas* of small spots, probably *underestimate* the blocking by less than about 10 %. Consequently, the multiplicative factor applied to post-1976 spot-blocking based on SOON areas to bring it into agreement with pre-1976 values is probably closer to 1.2 than to the factor 1.5 suggested by some recent studies (*e.g.* Balmaceda *et al.*, 2009). More accurate estimates require better accounting for the actual spot-area distribution (roughly represented here by the factor L/S in Section 6) and better measurement of the bolometric contrast of small spots (*i.e.* the parameters c and β in that section).

Error in the absolute value of spot-blocking causes uncertainty in the competing contributions of spots and faculae to the TSI variation. An accurate blocking model is also necessary to distinguish the variations that they generate from other possible sources of TSI variation, such as convective efficiency variations that are not necessarily correlated with photospheric magnetic structures as reported by Foukal and Bernasconi (2008). Our findings here suggest that the greater depths of calculated spot dips reported in that article are caused by overestimation of spot-blocking and provide no evidence for, *e.g.*, the "convective stirring" suggested by Parker (1995).

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