Reconciling the International and Group Sunspot Numbers: Evidence from the Greenwich Photo-heliographic Results

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The RGO Printed Publications

- The RGO published the measured positions and areas of individual sunspots or distinct groups of sunspots in a series of publications that constitute the *Greenwich Photoheliographic Results (GPR)* 1874 – 1976:
- Greenwich Observations (1874 1955)
- Royal Greenwich Observatory Bulletins (1956 – 1961)
- Royal Observatory Annals (1962 1976)

Supplementary Results: 1874 – 1885 (Published 1907)



The RGO Printed Publications

The RGO printed publications are divided into three main sections:

- "Measures of the Positions and Areas of Sun Spots and Faculae on Photographs Taken at [List of the Relevant Solar Observatories] With the Deduced Heliographic Longitudes and Latitudes." [Footnotes give the duration and type of each group.]
- "Ledgers of Areas and Positions of Groups of Sun Spots Deduced From the Measurement of the Solar Photographs for Each Day in the Year [e.g., 1884]."
- "Total Projected Areas of Sun Spots and Faculae for Each Day in the Year [e.g., 1884]."

The RGO Printed Publications: Measures

The Greenwich Civil Time at which the Photograph was taken is expressed by the Day of the Year and decimals of a day, reckoning from Midnight, January 1^d 0^h. For convenience of reference, the Month and Day of the Month (Civil Reckoning) are added.

The areas of Spots and Faculae are expressed in Millionths of the Sun's visible Hemisphere. [These values have been corrected for foreshortening.]

The RGO Printed Publications: Ledgers

The Greenwich Civil Time at which the photograph was taken is expressed by the month, day of the month (civil reckoning), and decimal of a day, reckoned from Greenwich Mean Midnight.

The Projected Area of the Umbrae and Whole Spots is the area as it is measured on the photograph, uncorrected for the effect of foreshortening, and expressed in millionths of the Sun's apparent disk.

The RGO Printed Publications: Ledgers

Dates for which the decimal [part] of the day is not given indicate days for which no photographic record is at present available [1907]. In these cases the means have been taken of the areas and positions of the spot-groups as measured on the day immediately preceding, and that immediately following the day for which the photograph is lacking. These interpolated values are enclosed in brackets, but are used in taking the final means for each spot-group.

The RGO Printed Publications: Total Projected Areas (1874 – 1877)

The Projected Area is the area as it is measured on the photograph, uncorrected for foreshortening, and expressed in millionths of the Sun's apparent disk.

The Greenwich Civil Time is expressed by the month, day of the month (civil reckoning), and decimal [part] of a day, reckoned from Greenwich Mean Midnight. <u>The decimal [part] of the day has not</u> <u>been given for days when neither spots nor faculae</u> <u>were observed on the photographs.</u>

The RGO Printed Publications: Total Projected Areas (1874 – 1877)

The dates for which no photographic record is at present available are indicated by the words "No photograph". As these are numerous in the present table [1874 – 1877], no attempt has been made to supply approximate numbers for them by interpolation from the days immediately before and after those for which photographs are lacking.

The RGO Printed Publications: Total Projected Areas (1878 – 1885)

Dates for which the areas are given in brackets indicate days for which no photographic record is at present available [1878 – 1885]. In these cases the areas have been obtained by interpolation from the measures of photographs taken on days immediately preceding and following the day for which the photograph is lacking. These interpolated values have been used in taking the mean daily areas for each rotation and for each year, given in the last section of this volume [Section 4].

Supplementary Results: 1874 – 1885 (Published 1907)

1874 то 1885 BEING SUPPLEMENTARY RESULTS FROM PHOTOGRAPHS OF THE SUN TAKEN AT GREENWICH, AT HARVARD COLLEGE, U.S.A., AT MELBOURNE, IN INDIA, AND IN MAURITIUS IN THE YEARS 1874 то 1885: AND MEASURED AND REDUCED AT THE ROYAL OBSERVATORY, GREENWICH, UNDER THE DIRECTION OF SIR W. H. M. CHRISTIE, K.C.B., M.A., D.Sc., F.R.S., ASTRONOMER-ROYAL. (APPENDIX TO THE GREENWICH OBSERVATIONS, 1905.) EDINBURGH: PRINTED FOR HIS MAJESTY'S STATIONERY OFFICE

BY NEILL & CO., LIMITED, BELLEVU

Measures Section: April 1874

All and a state of the	and the second			-	No. of Concession, Name			State State	
		t for	erms -	Sun's	HELIOG	RAPHIC	SPO	TS.	FACULÆ.
Greenwich Civil Time,	Measurers.	No. of Group, and Lette Spot.	Distance from Centre in t of Sun's Radius.	Position Angle from Axis.	Longitude.	Latitude.	Area of UMBRA for each Spot (and for Day).	Area of WHOLE for each Spot (and for Day).	Area for each Group (and for Day).
1874. 106'485 Apr. 17	јв, в	82 Centre	0.388	° 61·2	。 113.3 (133.2)	+ 5 ^{.8} (- 5 [.] 3)	o (o)	113 (113)	(0)
107·506 Apr. 18	ЈВ, В	82 Centre	0.510	26.7	114 ·3 (119·7)	+ 5.6 (-5.2)	0 (0)	60 (60)	(0)
116.556 Apr. 27	JB, B	83 Centre	0.899	101.2	296·0 (0°1)	-12.4 (-4.4)	0 (0)	17I (17I)	(0)
117 [.] 574 Apr. 28	м, м	83 Centre	0.766	102.6	297°0 (346°7)	-12.4 (-4.3)	4 ^I (4 ^I)	221 (221)	(0)
118.663 Apr. 29	м, м	83 Centre	0.294	105.8	296.6 (332.3)	-12.6 (-4.2)	³³ (33)	189 (189)	(0)
119 ⁵⁷⁷ Apr. 30	ЈВ, В	83 84 Centre	0.428 0.284	112°1 316•8	296·3 331·5 (320·2)	-13.0 + 7.9 (-4.1)	40 0 (40)	205 24 (229)	(0)

Measurers: 1874 – 1877

The second column contains the initials of the two persons measuring the photograph; the initial on the left being that of the person who measured the photograph on the left of the centre of the measuring instrument, and that on the right being that of the person who measured on the right of the centre.

> B = W. Baker JB = F. J. Bell M = E. W. Maunder

Ledgers Section: April 1874



Total Areas Section: April 1874

Greenwich Civil Time.		Projected Areas.						
		Umbræ.	Whole Spots.	Faculæ.				
187	74. d							
Apr.	17.5	0	208	0				
	18.5	0	117	0				
	19	No	photo	graph.				
	20	0	0	0				
	2 I	0	0	0				
	22	0	0	0				
	23	0	0	0				
	24	No	photo	graph.				
	25	No	photo	graph.				
	26	No	photo	graph.				
	27.6	0	150	0				
	28.6	53	285	0				
	29.7	53	306	. 0				
	30.0	72	415	0				
	Second Second							

Date	Group No.	Measures	Ledgers	Total Areas	H&S	W&W
1874 Apr 17	82	1	1	[1]	1	1
1874 Apr 18	82	1	1	[1]	1	1
1874 Apr 19	No entry	No entry	No entry	No photo	-99	-99
1874 Apr 20	No entry	No entry	No entry	0,0 (F=0)	-99	0
1874 Apr 21	No entry	No entry	No entry	0,0 (F=0)	-99	0
1874 Apr 22	No entry	No entry	No entry	0,0 (F=0)	0	0
1874 Apr 23	No entry	No entry	No entry	0,0 (F=0)	0	0
1874 Apr 24	No entry	No entry	No entry	No photo	0	-99
1874 Apr 25	No entry	No entry	No entry	No photo	-99	-99
1874 Apr 26	No entry	No entry	No entry	No photo	-99	-99
1874 Apr 27	83	1	1	[1]	1	1
1874 Apr 28	83	1	1	[1]	1	1
1874 Apr 29	83	1	1	[1]	1	1

Errata Section: 1874 – 1877

MEASURES OF POSITIONS AND AREA OF SUN SPOTS AND FACULÆ ON PHOTOGRAPHS TAKEN IN THE YEARS, 1874-1877.

Photographs taken on the following additional dates show neither Spots nor Faculæ :--

1874, April 20, 21, 22, 23. June 8, 9. October 26, 27, 29. December 3. 1875, January 28. February 15, 16. 1876, March 3. September 12, 20. November 24, 27, 30. December 1, 2, 7, 12, 14. 1877, May 30. June 12, 17, 18, 19, 20, 21, 22. July 6, 7, 13, 24, 25, 26, 29. August 9, 12, 16, 17, 18, 20, 21. September 22. October 2, 3, 8, 9, 11, 12, 15, 16, 18, 20. November 20. December 28.

Date	Group No.	Measures	Ledgers	Total Areas	H&S	W&W
1874 Jun 01	90, 91	2	2	[2]	2	2
1874 Jun 02	90, 91	2	2	[2]	2	2
1874 Jun 03	No entry	No entry	No photo	No photo	2	-99
1874 Jun 04	90, 91	2	2	[2]	2	2
1874 Jun 05	90, 91	2	2	[2]	2	2
1874 Jun 06	No entry	No entry	No entry	No photo	-99	-99
1874 Jun 07	No entry	No entry	No entry	No photo	-99	-99
1874 Jun 08	No entry	No entry	No entry	0,0 (F = 0)	-99	0
1874 Jun 09	No entry	No entry	No entry	0,0 (F = 0)	-99	0
1874 Jun 10	No entry	No entry	No entry	No photo	-99	-99
1874 Jun 11	92	1	1	[1]	1	1
1874 Jun 12	92	1	1	[1]	1	1
1874 Jun 13	92, 93	2	2	[2]	2	2

Date	Group No.	Measures	Ledgers	Total Areas	H&S	W&W
1874 Oct 01	124, 126, 127	3	3	[3]	3	3
1874 Oct 02	No entry	No entry	No photo	No photo	2	-99
1874 Oct 03	126, 127	2	2	[2]	2	2
1874 Oct 04	No entry	No entry	No photo	No photo	1	-99
1874 Oct 05	127	1	1	[1]	1	1
1874 Oct 06	No entry	No entry	No photo	No photo	1	-99
1874 Oct 07	No entry	No entry	No photo	No photo	1	-99
1974 Oct 08	127, 128	2	2	[2]	2	2
1874 Oct 09	No entry	No entry	No photo	No photo	2	-99
1874 Oct 10	127, 128, 129	3	3	[3]	3	3
1874 Oct 11	No entry	No entry	No photo	No photo	1	-99
1874 Oct 12	No entry	No entry	No photo	No photo	1	-99
1874 Oct 13	129	1	1	[1]	1	1

Date	Group No.	Measures	Ledgers	Total Areas	H&S	W&W
1875 Jan 01	No Entry	No Entry	No Entry	No Photo	-99	-99
1875 Jan 02	141	1	1	[1]	1	1
1875 Jan 03	No Entry	No Entry	No Photo	No Photo	1	-99
1875 Jan 04	No Entry	No Entry	No Photo	No Photo	1	-99
1875 Jan 05	141	1	1	[1]	1	1
1875 Jan 06	No Entry	Faculae	No Entry	0,0 (F≠0)	-99	0
1875 Jan 07	No Entry	No Entry	No Entry	No Photo	-99	-99
1875 Jan 08	No Entry	No Entry	No Entry	No Photo	-99	-99
1875 Jan 09	No Entry	No Entry	No Entry	No Photo	-99	-99
1875 Jan 10	No Entry	No Entry	No Entry	No Photo	-99	-99
1875 Jan 11	No Entry	No Entry	No Entry	No Photo	-99	-99
1875 Jan 12	No Entry	No Entry	No Entry	No Photo	-99	-99

Date	Group No.	Measures	Ledgers	Total Areas	H&S	W&W
1875 Dec 01	No entry	No entry	No entry	No photo	0	-99
1875 Dec 02	No entry	No entry	No entry	No photo	0	-99
1875 Dec 03	No entry	No entry	No entry	No photo	0	-99
1875 Dec 04	No entry	No entry	No entry	No photo	0	-99
1875 Dec 05	No entry	No entry	No entry	No photo	0	-99
1875 Dec 06	No entry	No entry	No entry	No photo	0	-99
1875 Dec 07	No entry	No entry	No entry	No photo	0	-99
1875 Dec 08	No entry	Faculae	No entry	0, 0 (F≠0)	0	0
1875 Dec 09	No entry	No entry	No entry	No photo	0	-99
1875 Dec 10	No entry	No S or F	No entry	No photo	0	???
1875 Dec 11	No entry	No entry	No entry	No photo	0	-99
1875 Dec 12	No entry	No entry	No entry	No photo	0	-99

Date	Group No.	Measures	Ledgers	Total Areas	H&S	W&W
1881 Jan 01	403,4, 5, 406	4	4	[4]	4	4
1881 Jan 02	No entry	No entry	No photo	No photo	3	-99
1881 Jan 03	404,5,6,407*	4*	4	[4]	4	4
1881 Jan 04	404,5,6,407*	4*	4	[4]	4	4
1881 Jan 05	405, 406, 407	3	3	[3]	3	3
1881 Jan 06	406,407	2	2	[2]	2	2
1881 Jan 07	407	1	1	[1]	1	1
1881 Jan 08	No entry*	No entry*	No photo	No photo	1	-99
1881 Jan 09	407*	1*	1	[1]	1	1
1881 Jan 10	407*	1*	1	[1]	1	1
1881 Jan 11	407*	1*	1	[1]	1	1
1881 Jan 12	407*	1*	1	[1]	1	1

Additional Publication (Published 1891) (Provided data qualified by an asterisk)



Number of RGO Solar Photographs Available

Year	No. of Photographs	Days	Coverage (%)	Year	No. of Photographs	Days	Coverage (%)
1874	141	259	54	1885	359	365	98
1875	263	365	72	1886	363	365	99
1876	271	366	74	1887	361	365	99
1877	235	365	64	1888	359**	366	98
1878	347	365	95	1889	360	365	99
1879	318	365	87	1890	361	365	99
1880	341	366	93	1891	363	365	99
1881	348	365	95	1892	362	366	99
1882	343	365	94	1893	362	365	99
1883	340	365	93	1894	364	365	100
1884	315	366	86	1895	364	365	100

Move of the Photoheliograph from Greenwich to Herstmonceux

The RGO photoheliograph was moved from Greenwich to Herstmonceux Castle, Sussex, on 1949 May 02.

The last photograph of the Sun taken at Greenwich was on May 02, although a second photograph was taken on the same day with the re-erected Dallmeyer photoheliograph strapped to the 6¼-inch refractor in the 22-foot dome at Herstmonceux Castle (Howse, 1975).

Date	Place	Measures	Footnotes	Total Areas	H&S	W&W
1949 May 01	GREN	11	11	[11]	11	11
1949 May 02	GREN	10	10	[10]	10	10
1949 May 03	CAPE	9	9	[9]	9	9
1949 May 04	CAPE	10	10	[10]	10	10
1949 May 05	CAPE	10	10	[10]	10	10
1949 May 06	HERS	10	10	[10]	10	10
1949 May 07	CAPE	10	10	[10]	10	10
1949 May 08	HERS	9	9	[9]	9	9
1949 May 09	CAPE	8	8	[8]	8	8
1949 May 10	HERS	7	7	[7]	7	7
1949 May 11	CAPE	8	8	[8]	8	8
1949 May 12	CAPE	7	7	[7]	7	7

Move of the Photoheliograph from Greenwich to Herstmonceux

Even if there were initial problems with the move of the RGO photoheliograph from Greenwich to Herstmonceux, these would have been identified immediately (and rectified) because of the "interleaving" with photographs from the Cape.

Weather conditions in the UK usually prevented long runs of measured solar photographs from either Greenwich or Herstmonceux!

Provisional Conclusions

- The Hoyt and Schatten Sunspot Group Numbers have not been derived from the Greenwich Photo-heliographic Results in a <u>completely</u> consistent manner. This will affect the monthly means.
- Discrepancies are most likely to occur in the interval 1874 1877 because of the number of days without photographs.
- A clear decision needs to be made on what should be done about days for which no solar photograph was available for measurement. [Should –99 <u>always</u> be used?]
- What policy was adopted by individual observers regarding days on which observations were impossible? Was this policy <u>completely</u> consistent between the various observers? Also, have Hoyt and Schatten been <u>completely</u> consistent in their interpretation of the results for the various observers?

Comments from Doug Hoyt (13 May 2012)

- "Here is what I have for 1875 for RGO:" [Hoyt and Schatten Table for 1875 for RGO in standard format].
- "Missing days weren't filled in for individual observers. When all observers were combined and a day was still missing, then interpolation was made."
- "I think these values come from the Ward tape, which in turn comes from the yearly volumes of RGO."
- "There is a lot of disagreement between observers on the number of groups. There is even more disagreement when you get to individual spots within a group."

Future Research

- Check the Hoyt and Schatten sunspot group numbers, as observed by the Royal Greenwich Observatory, for the interval 1874 – 1894.
- Revise the monthly means for the early years, as necessary.
- Evaluate the standard deviations of these monthly means, whenever possible.
- It is important to estimate the uncertainties in the monthly means. [This will be problematic if there are only a few observations in a month.]