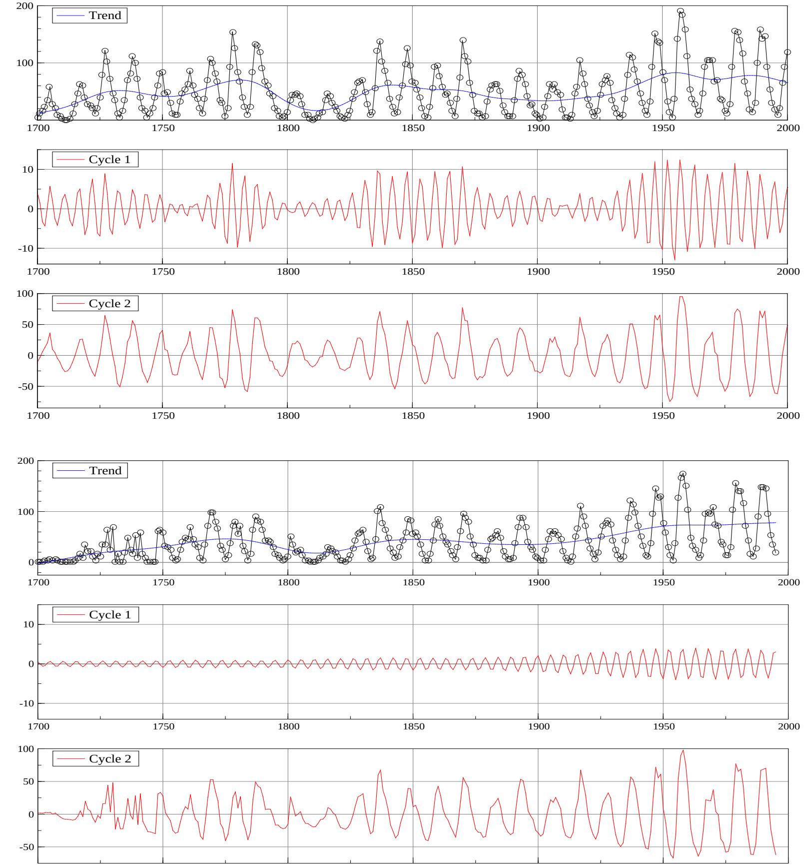
Rudolf Wolf and the Sunspot Number

2nd Sunspot Number Workshop

SIDC, Royal Observatory of Belgium, Brussels 21 – 25 May 2012

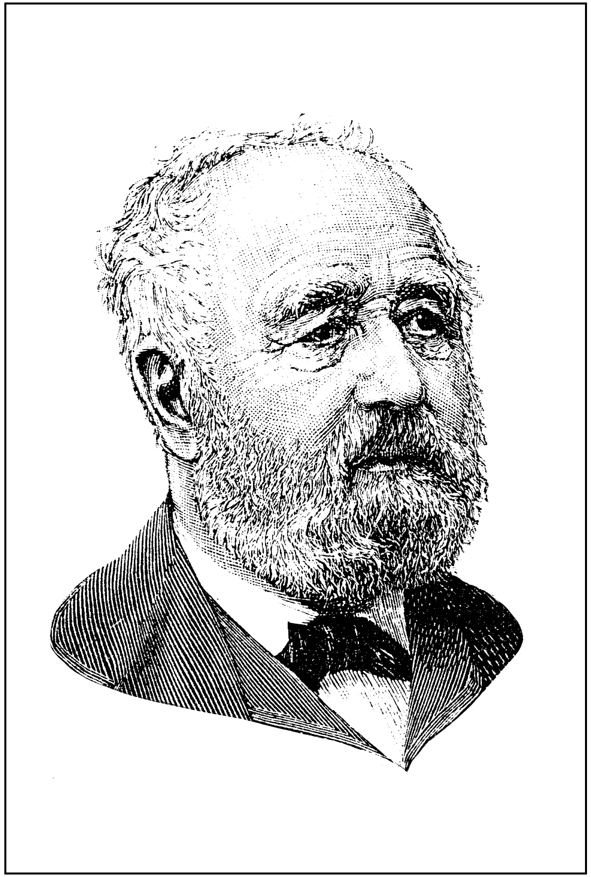
Dr. Thomas K. Friedli

“Do we have the right reconstruction of solar activity ?”

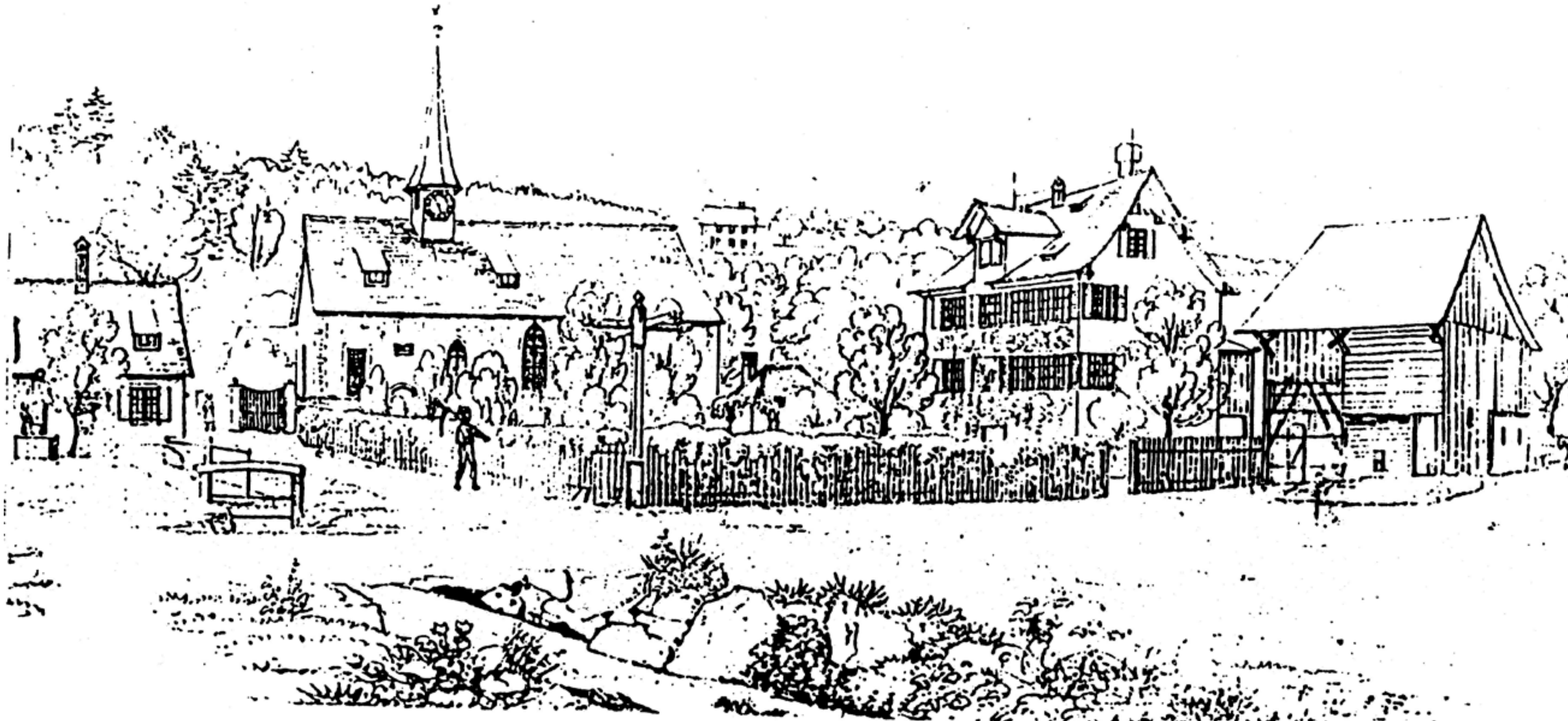


Contents

- Rudolf Wolf (1816 – 1893)
- Zurich Sunspot Number
- Wolf Series



Rudolf Wolf (1816 – 1893)



Rudolf Wolf (1816 – 1893)

- Born on 7th July 1816 in Fällanden as the youngest of 4 children of Pastor Johannes Wolf and Regula Gossweiler
- **1833 – 1836: Studies at the newly established University of Zurich**

  JOSEPH LUDWIG RAABE (Mathematics), ALBERT MOUSSON (Physics)
  JOHANNES ESCHMANN (Astronomy and Geodesy)
- **September 1836 – April 1838: Studies at Vienna**

  JOSEPH JOHANN VON LITTROW: Astronomy
  ANDREAS VON ETTINGSHAUSEN: Physics
- **April 1838**: Journey via Prague (Tomb of TYCHO BRAHE) and Dresden to Berlin. Studies under ENCKE (Astronomy), DIRICHLET (Analysis) and JAKOB STEINER (Geometry)
- **September 1838**: Journey via Göttingen (GAUSS), Gotha (Seeberg), Bonn (ARGELANDER), Brussels (QUETELET) to Paris (BOUVARD, ARAGO).
- Dezember 1838: Return to Zurich.
- «Now, I think, I know my life-task: If God permits I have to write two books: 1.) A complete textbook on pure and applied mathematics […] and 2.) A complete history of pure and applied mathematics containing only the essence of each epoch, but without sacrifying the details of the biografies of the individuals by naming them only.»

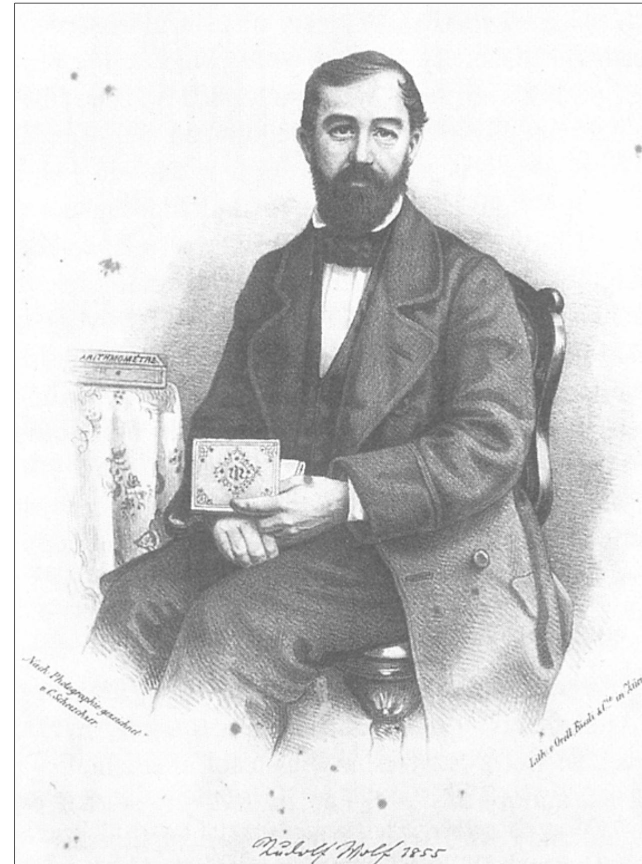
Rudolf Wolf (1816 – 1893)

1839 Teacher of pure and applied mathematics at the Realschule (private high school) in Bern

1841 Secretary of the Bernese Society of Naturalists

1843 Founder of the Notices of the Bernese Society of Naturalists

Librarian of the Swiss Society of Naturalists (located in Bern)



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Mittheilungen

der

naturforschenden Gesellschaft

in Bern

aus dem Jahre 1843.

Bern.

(In Commission bei Huber und Comp.)

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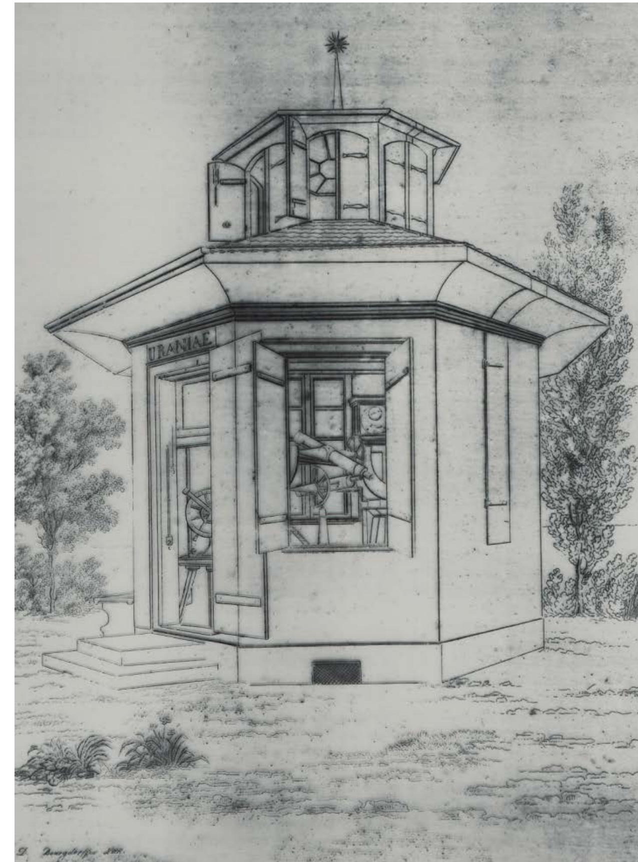
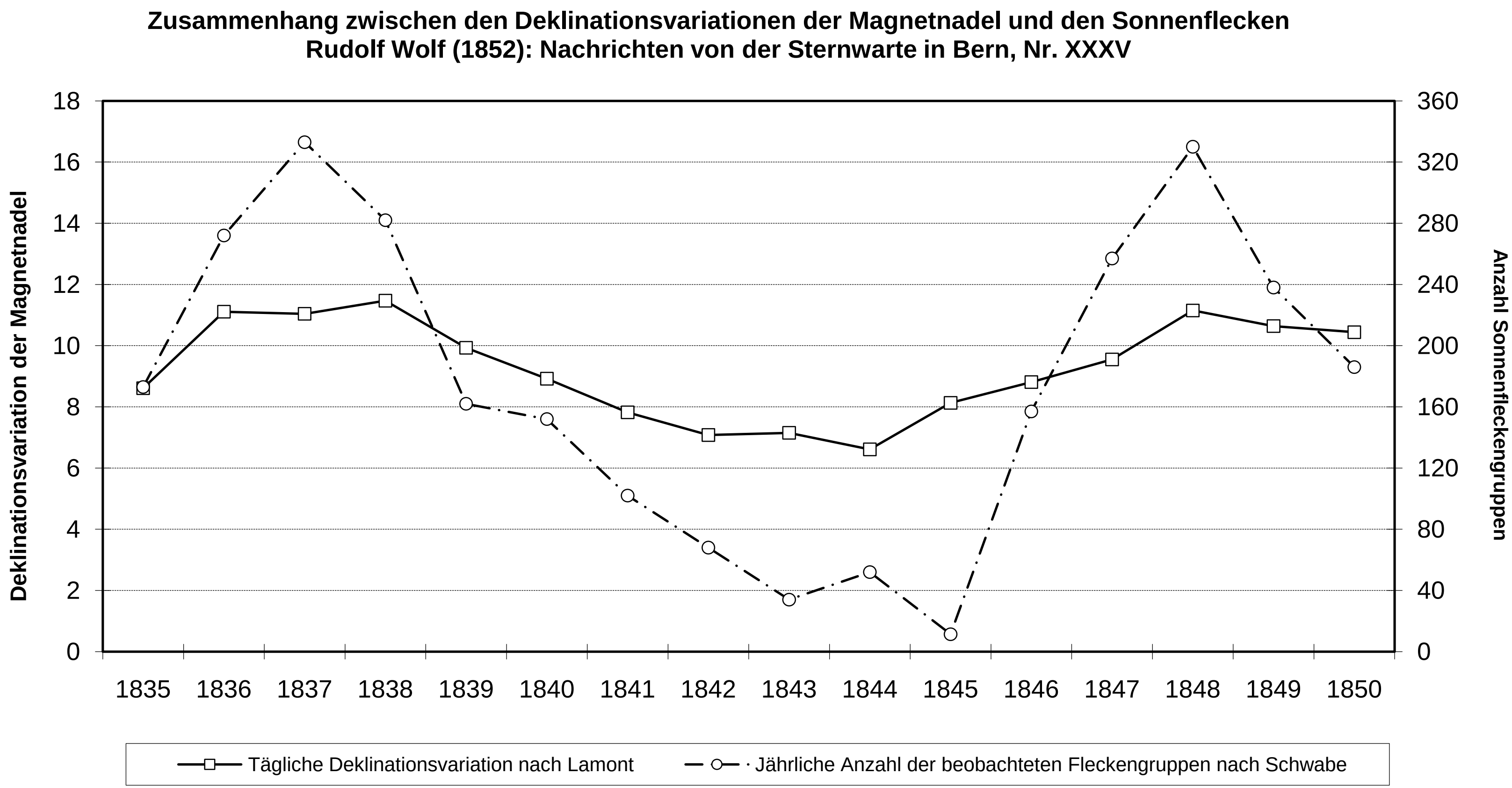


Rudolf Wolf (1816 – 1893)



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1847	Director of the Observatory in Bern
1852	Discovery of the parallelism of magnetic variations and sunspot activity
1853	Extraordinary Professor of Mathematics
1855	Call to Zurich as Professor of Astronomy at the Swiss Federal Institute of Technology and as Extraordinary Professor of Astronomy at the University of Zurich

Nr. 255 bis 257.

R. Wolf, Neue Untersuchungen über die Periode der Sonnenflecken und ihre Bedeutung.

(Vorgetragen am 6. November 1852.)

Die aus den langjährigen Sonnenbeobachtungen Schwabe's folgende Periode von circa 10 Jahren für die Häufigkeit der Sonnenflecken, hat durch die von Gautier [1], Sabine [2] und mir [3] nahe gleichzeitig und unabhängig von einander entdeckte Uebereinstimmung derselben mit der Periode der magnetischen Variationen, und der darin liegenden Causalbeziehung zwischen den Sonnenflecken und dem Erdmagnetismus ein allgemeineres Interesse erhalten. Ich glaubte daher die Mühe nicht scheuen zu sollen, auf den Bibliotheken von Basel, Bern und Zürich einige hundert Bände zu durchsuchen, um mir das nöthige Material für eine genauere Untersuchung dieser Periode zu verschaffen, und in der That hat mich das Studium dieses Materials, das durch die gütigen Mittheilungen Herrn Hofrath Schwabe's aus seinen Beobachtungsjournalen wesentlich vermehrt wurde, zu folgenden wichtigen Resultaten geführt, die mir jede Mühe reichlich belohnten:

I. Genauere Bestimmung der Länge der Sonnenfleckenperiode.

Um die Länge der Periode mit grösserer Genauigkeit zu bestimmen, stellte ich aus den vorliegenden Beob-

[1]) Bibliothèque universelle, juillet et août 1852.
[2]) Philos. Transactions 1852; Philos. Magazine, Sept. 1852.
[3]) Mittheilungen Nr. 245; Comptes rendus 13 sept. 1852; Astronomische Nachrichten Nr. 820.

(Bern. Mitth. November 1852.)

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1893	Death on 6th December

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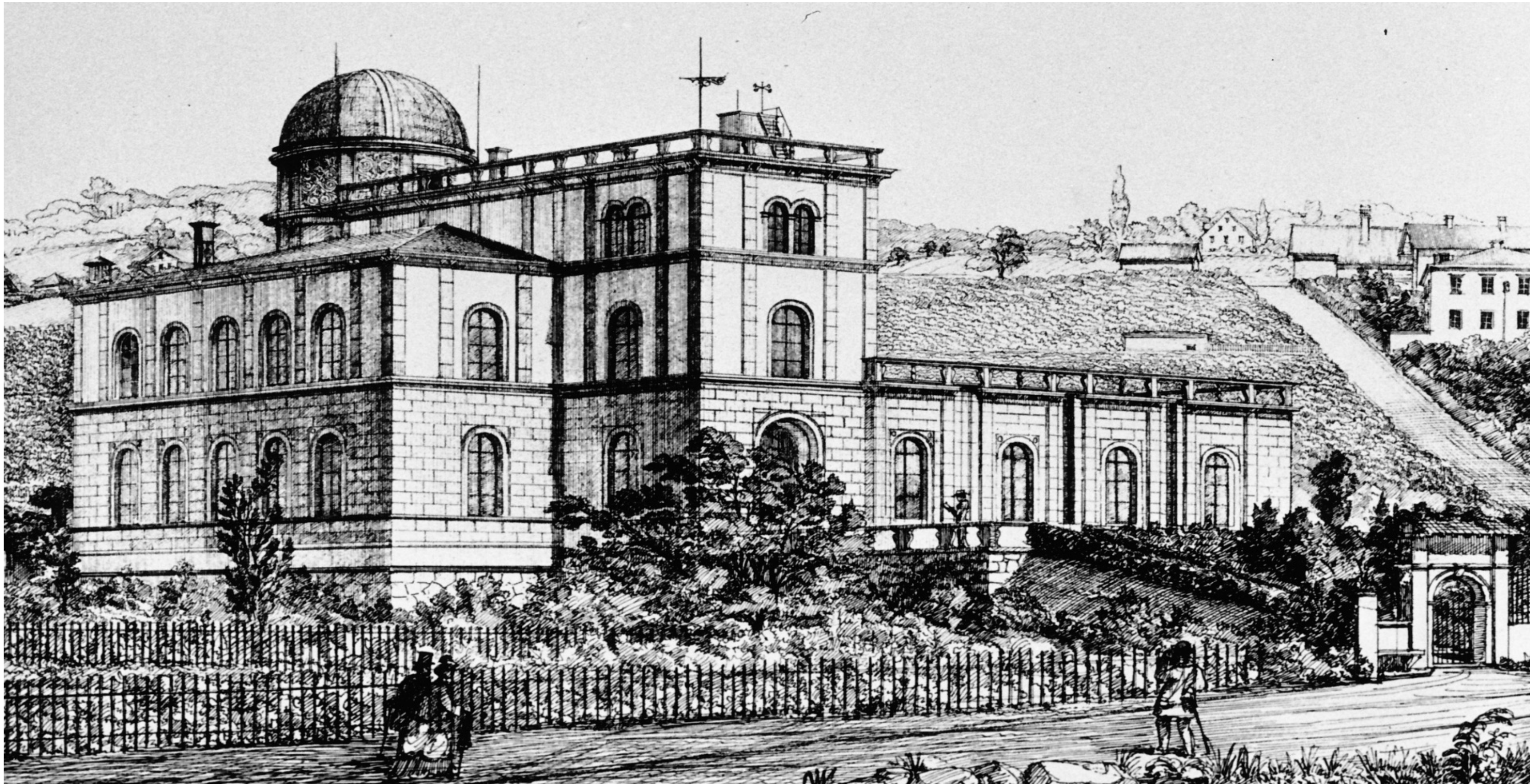

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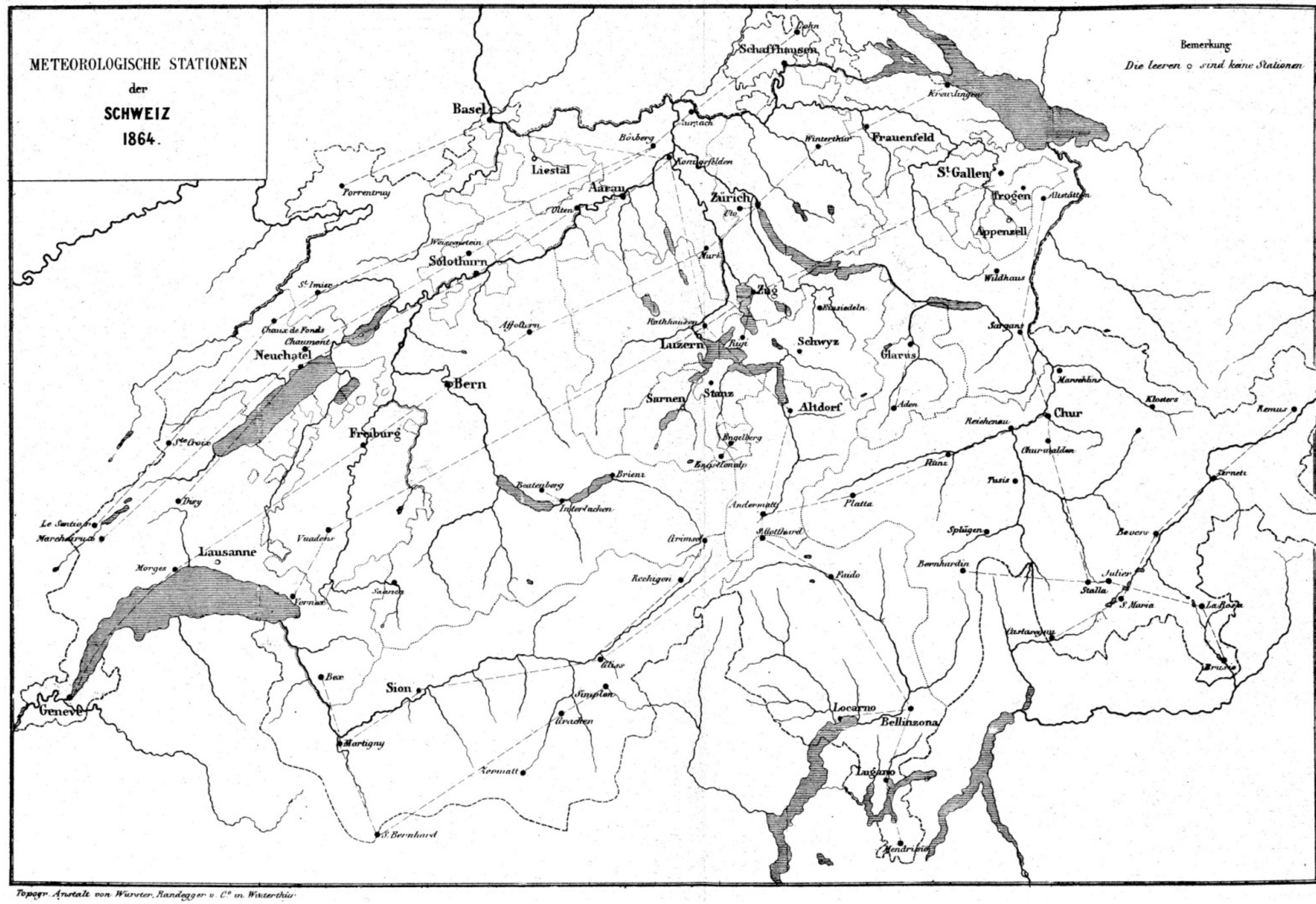

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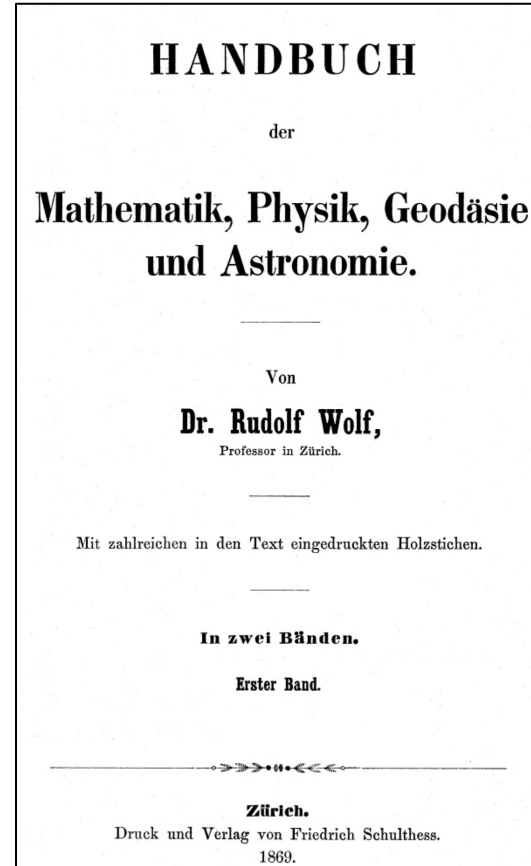
HANDBUCH

der

Mathematik, Physik, Geodäsie und Astronomie.

Von

Dr. Rudolf Wolf,
Professor in Zürich.

Mit zahlreichen in den Text eingedruckten Holzstichen.

In zwei Bänden.

Erster Band.

Zürich.
Druck und Verlag von Friedrich Schulthess.
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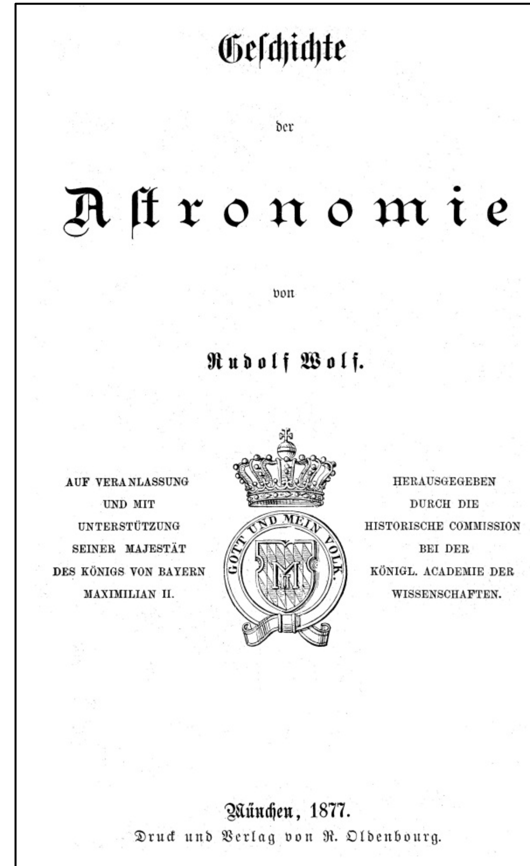
Geschichte

der

Astronomie

von

Rudolf Wolf.

AUF VERANLASSUNG UND MIT UNTERSTÜTZUNG SEINER MAJESTÄT DES KÖNIGS VON BAYERN MAXIMILIAN II.

GOTT UND MEIN VOLK.

HERAUSGEGEBEN DURCH DIE HISTORISCHE COMMISSION BEI DER KÖNIGL. ACADEMIE DER WISSENSCHAFTEN.

München, 1877.
Druck und Verlag von R. Oldenbourg.

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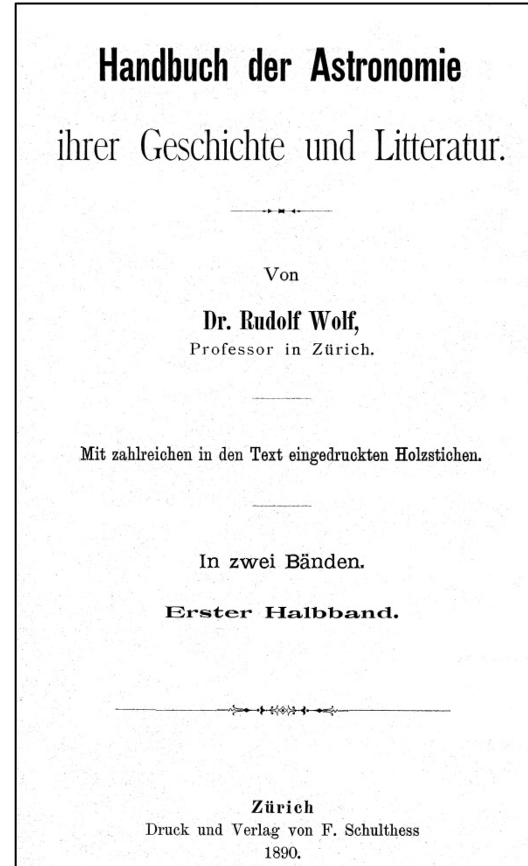
Handbuch der Astronomie

ihrer Geschichte und Litteratur.

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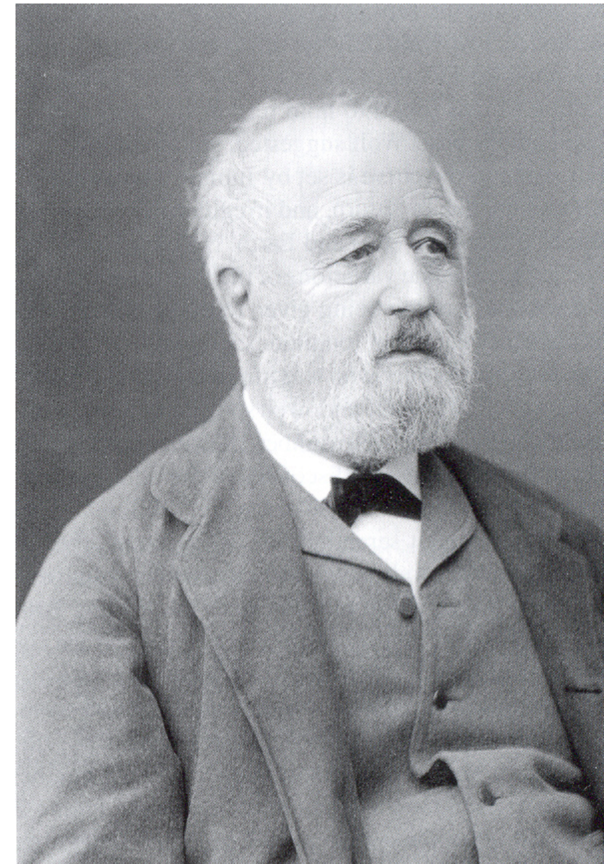
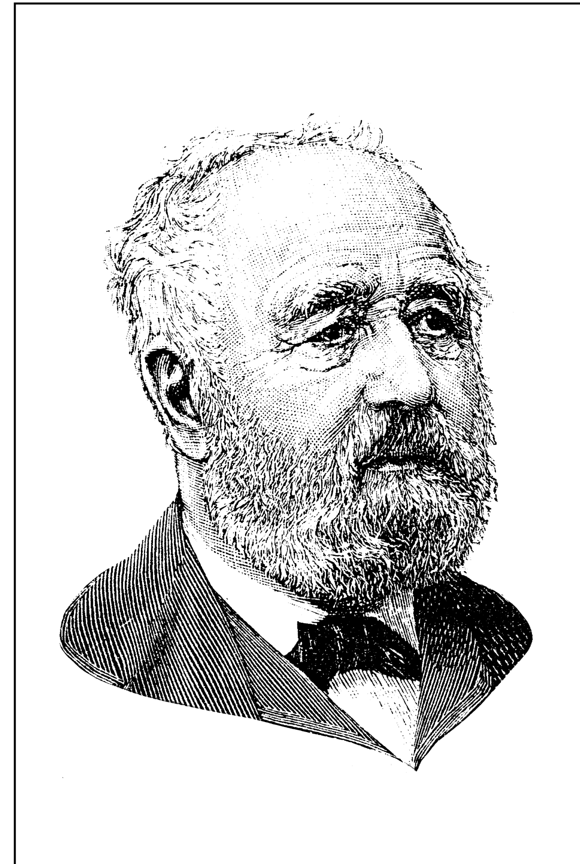


Contents

- Rudolf Wolf (1816 – 1893)
- **Zurich Sunspot Number**
- Wolf Series



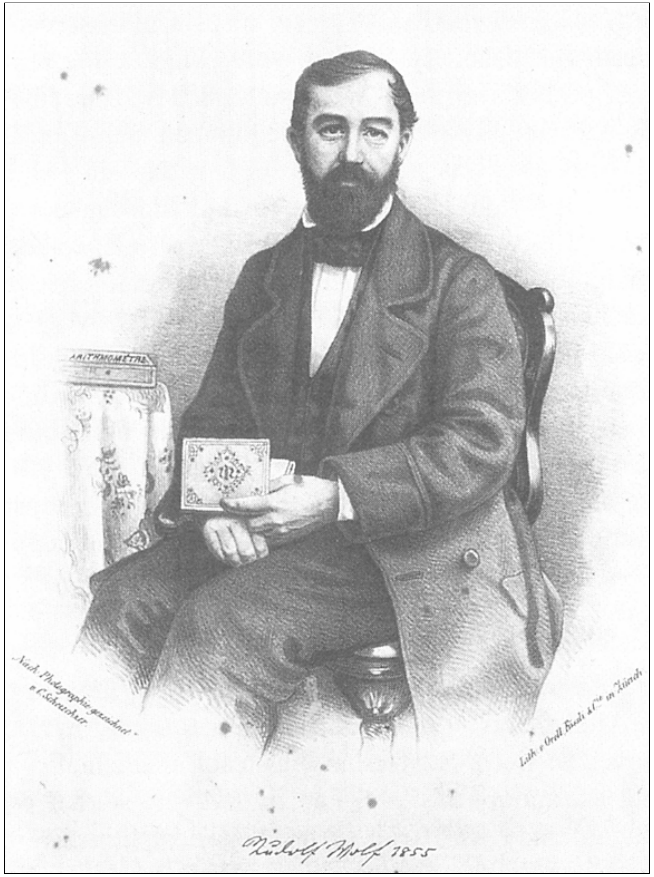
Zurich Sunspot Number

Rudolf Wolf

1847 4. December: First Observation with a 4 feet tube

1849 Start of systematic countings of groups and spots

- Equatorially mounted Fraunhofer refractor with 37``` (Parisian lines; 83 mm) aperture and 48`` (Parisian inches; 1320 mm) focal length with magnification 64 and sunglass
- Handheld 40/440 mm "Parisian" refractor with magnification 20 and sunglass



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1850 Invention of the sunspot relative number (published in 1851)

$$r := g + f / 10$$

calculated for complete observations of the Fraunhofer refractor; monthly means only

— 94 —

von Innen heraus spricht, gewissermassen wie wenn aus dem Innern heraus Gase an die Oberfläche dringen und da Blasen bilden würden, welche dann bei hinlänglichem Anschwellen platzen.

8) Stelle ich meine Sonnenfleckenbeobachtungen von 1849 und 1850 (die von 1848 machte ich leider noch nicht nach demselben Systeme) in der Weise zusammen, dass ich für jeden Tag, an dem ich bei reiner Sonne und mit dem grössern Fernrohre beobachten konnte, die erhaltene Gruppenzahl um $\frac{1}{10}$ der entsprechenden Fleckenzahl vermehre [1]), und aus diesen Zahlen die jedem Monat zugehörende Mittelzahl suche, so erhalte ich folgende Uebersicht des Fleckenstandes in diesen zwei Jahren [2]):

1849	Januar . .	17		
	Februar. .	14	41	
	März . . .	10		
	April . . .	11		
	Mai	10	31	
	Juni	10		129 : 12 = 10,8
	Juli	9		
	August . .	7	26	
	September	10		
	October. .	9		
	November	12	31	
	December	10		

[1]) Nach meiner Meinung würde eigentlich die Flächensumme sämmtlicher Flecken das beste Maass für den Fleckenstand geben; da mir aber bis jetzt die Zeit nicht erlaubte, regelmässig die dafür nothwendigen Abmessungen und Schätzungen vorzunehmen, so glaube ich durch die oben vorgenommene Weise ein möglichst gutes Surrogat dafür zu erhalten.

[2]) Die Anzahl aller Beobachtungstage in diesen zwei Jahren betrug 552, — aber nur an 258 dieser Tage konnte ich die reine Sonne mit dem grössern Fernrohr beobachten, und es wurden daher nur diese der Uebersicht zu Grunde gelegt.

Zurich Sunspot Number

Rudolf Wolf

1855 Call to Swiss Federal Institute of Technology in Zürich

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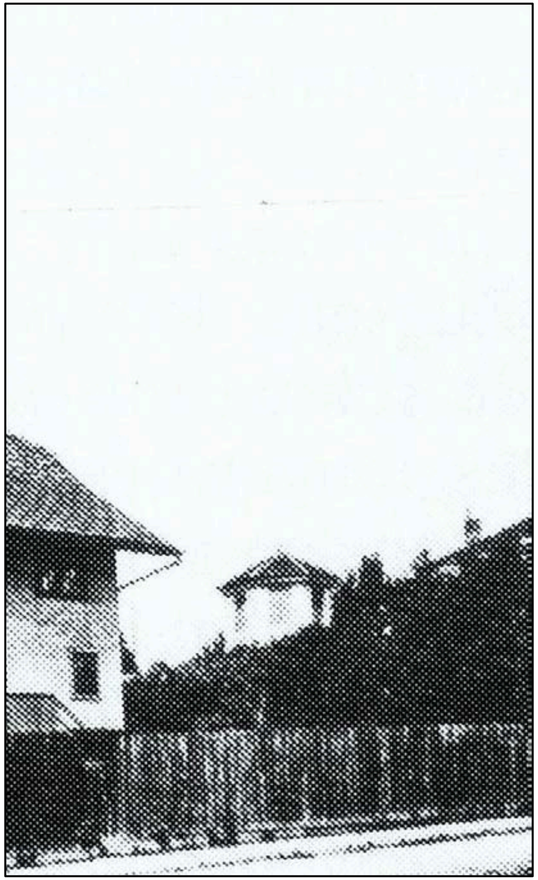

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1856 Redefinition of the sunspot relative number

$r := 10\ g + f$

calculated for complete observations of the Fraunhofer refractor, augmented by observations of H.S. Schwabe; monthly means only

1859 Introduction of the k-factor for each combination instr / mag / obs

$r := k\ (10\ g + f)$

The Fraunhofer is set as standard or normal refractor with k := 1

1860 – 1862: Parallel observations with Parisian instrument k := 1.5

1863 October 25: last observation with the standard refractor

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1863 October 25: last observation with the standard refractor

1890 Jan. 3: first obs. with Fraunhofer 43/550 mm refractor with mag 29

Zurich Sunspot Number

Rudolf Wolf

- No sketches or drawings
  - No diary, even no notes !
  - ▶ Bernese observations all published, but the Zurich ones from 1870 on only! From the others we know only from those used in the Wolf series.
- Wolf counted globally: first the groups and afterwards the spots
  - Advantage: Days could be used where only very short observation time was available due to weather constraints or other duties
  - Disadvantage: High probability of counting errors; seeing demands high concentration and good memory
- ▶ Perhaps Wolf changed to the Parisian refractor because fewer spots are seen and the seeing disturbances are much smaller ?
  - But how was the small refractor supported ?

Sonnenflecken–Beobachtungen A. 1849.

	Januar.					Februar.					März.				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
1	3	-	-	-	-	3	-	-	-	-	2	2	4	-	-
2	3	-	-	-	-	1	1	7	40	1	2	2	5	-	-
3	1	1	15	-	1	1	2	2	-	-	1	1	6	12	2
4	3	-	-	-	-	1	1	7	27	2	1	1	7	15	2
5	3	-	-	-	-	1	1	9	22	2	1	2	2	-	-
6	3	-	-	-	-	1	1	10	34	2	1	1	7	24	2
7	3	-	-	-	-	2	2	3	-	-	1	2	3	-	-
8	3	-	-	-	-	1	1	10	21	2	1	2	4	-	-
9	3	-	-	-	-	1	1	10	35	2	1	2	3	-	-
10	3	-	-	-	-	3	-	-	-	-	2	2	2	-	-
11	3	-	-	-	-	1	2	8	20	-	1	1	5	20	2
12	3	-	-	-	-	1	1	9	56	1	1	1	7	30	2
13	3	-	-	-	-	1	1	11	64	1	3	-	-	-	-
14	3	-	-	-	-	1	2	7	-	-	3	-	-	-	-
15	2	2	4	-	-	3	-	-	-	-	3	-	-	-	-
16	1	2	5	-	-	2	2	6	-	-	3	-	-	-	-
17	1	2	9	25	-	1	1	15	40	1	1	2	4	14	2
18	1	1	11	60	1	1	2	8	-	-	1	1	7	30	2
19	1	2	10	25	-	1	1	11	36	2	1	2	4	-	-
20	1	2	11	-	-	1	1	13	60	1	1	1	5	30	2
21	1	1	12	75	1	2	1	12	-	1	1	1	5	30	2
22	1	1	9	46	1	3	-	-	-	-	1	1	6	35	2
23	2	2	10	-	2	1	1	11	58	1	3	-	-	-	-
24	1	2	10	-	-	1	1	11	40	1	3	-	-	-	-
25	1	1	10	65	1	1	1	10	68	2	1	2	3	-	-
26	1	1	10	76	1	2	1	10	-	2	3	-	-	-	-
27	1	1	10	95	2	2	2	2	-	-	1	2	4	-	-
28	2	1	9	63	1	1	1	7	36	1	1	1	12	50	1
29	3	-	-	-	-						2	2	2	-	-
30	2	1	9	-	-						3	-	-	-	-
31	3	-	-	-	-						1	1	11	58	1

Zurich Sunspot Number

Rudolf Wolf

- Are the observations with the Parisian refractor good enough to serve as (secondary) standard series ?
  - This is the key question concerning the homogeneity of the Wolf series during the years 1863 and 1894.
  - Wolfer made sunspot observations with the Parisian instrument between 1894 and 1925 and found a mean k-factor of 1.20 with a secular drift.

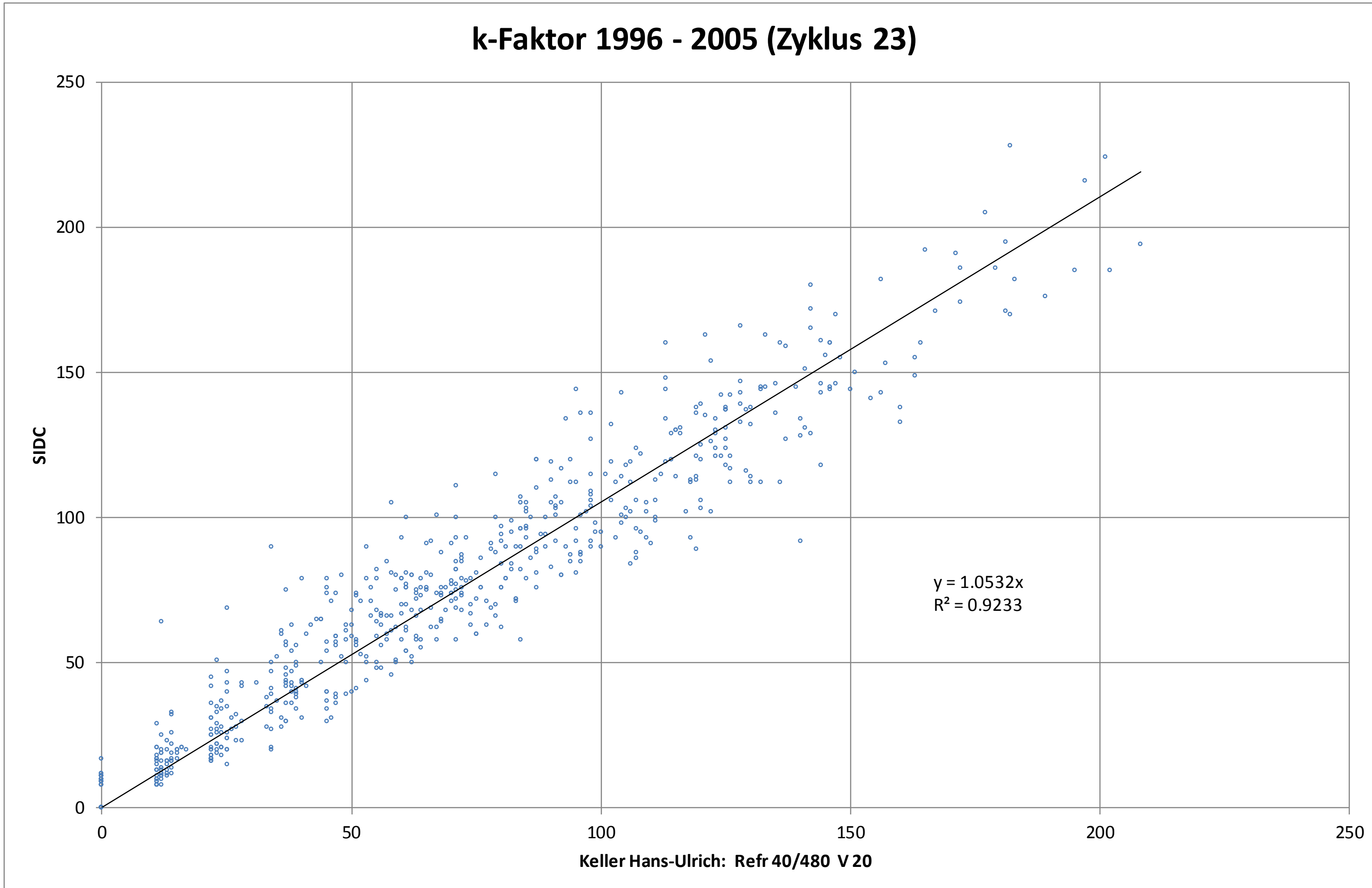
	K_1 I Sem.	K_1 II Sem.	K_1 Mittel	H_2 I Sem.	H_2 II Sem.	H_2 Mittel
1894	1.04	1.03	1.035	1.12	1.09	1.105
95	1.08	1.04	1.060	1.16	1.10	1.130
96	1.04	1.07	1.055	1.19	1.25	1.220
97	0.91	0.96	0.935	1.00	1.03	1.015
98	1.03	0.97	1.000	1.19	1.10	1.145
99	1.02	1.01	1.015	1.18	1.14	1.160
1900	0.99	1.05	1.020	1.00	1.23	1.115
1	1.09	1.09	1.090	1.21	1.15	1.180
2	0.97	1.01	0.990	1.11	1.16	1.135
3	0.95	1.11	1.030	1.16	1.28	1.220
4	1.09	1.08	1.085	1.19	1.22	1.205
5	0.98	1.16	1.070	1.14	1.36	1.250
6	1.08	1.13	1.105	1.18	1.24	1.210
7	1.07	1.04	1.055	1.21	1.18	1.195
8	0.97	1.12	1.045	1.09	1.31	1.200
9	1.02	0.97	0.995	1.17	1.07	1.120
10	1.00	0.82	0.910	1.21	0.95	1.080
11	0.78	0.83	0.805	0.90	1.13	1.015
12	0.98		0.980	1.05		1.050
13	1.11		1.110	1.24		1.240
14	1.10	0.99	1.045	1.36	1.09	1.225
15	1.05	1.16	1.105	1.21	1.31	1.260
16	1.10	1.01	1.055	1.33	1.23	1.280
17	1.10	1.16	1.130	1.24	1.33	1.285
18	1.11	1.17	1.140	1.28	1.40	1.340
19	1.08	1.16	1.120	1.23	1.29	1.260
20	1.03	1.00	1.015	1.22	1.07	1.145
21	1.14	1.15	1.145	1.34	1.33	1.335
22	1.24	1.01	1.125	1.44	1.10	1.270
23	1.03	1.02	1.025	1.21	1.23	1.220
24	1.30	1.09	1.195	1.54	1.23	1.385
25	1.23	1.25	1.240	1.38	1.63	1.505
n = 32						
Σ	33.71	33.75	33.730	38.48	38.52	38.50
Mittel	1.054	1.055	1.054	1.202	1.204	1.203

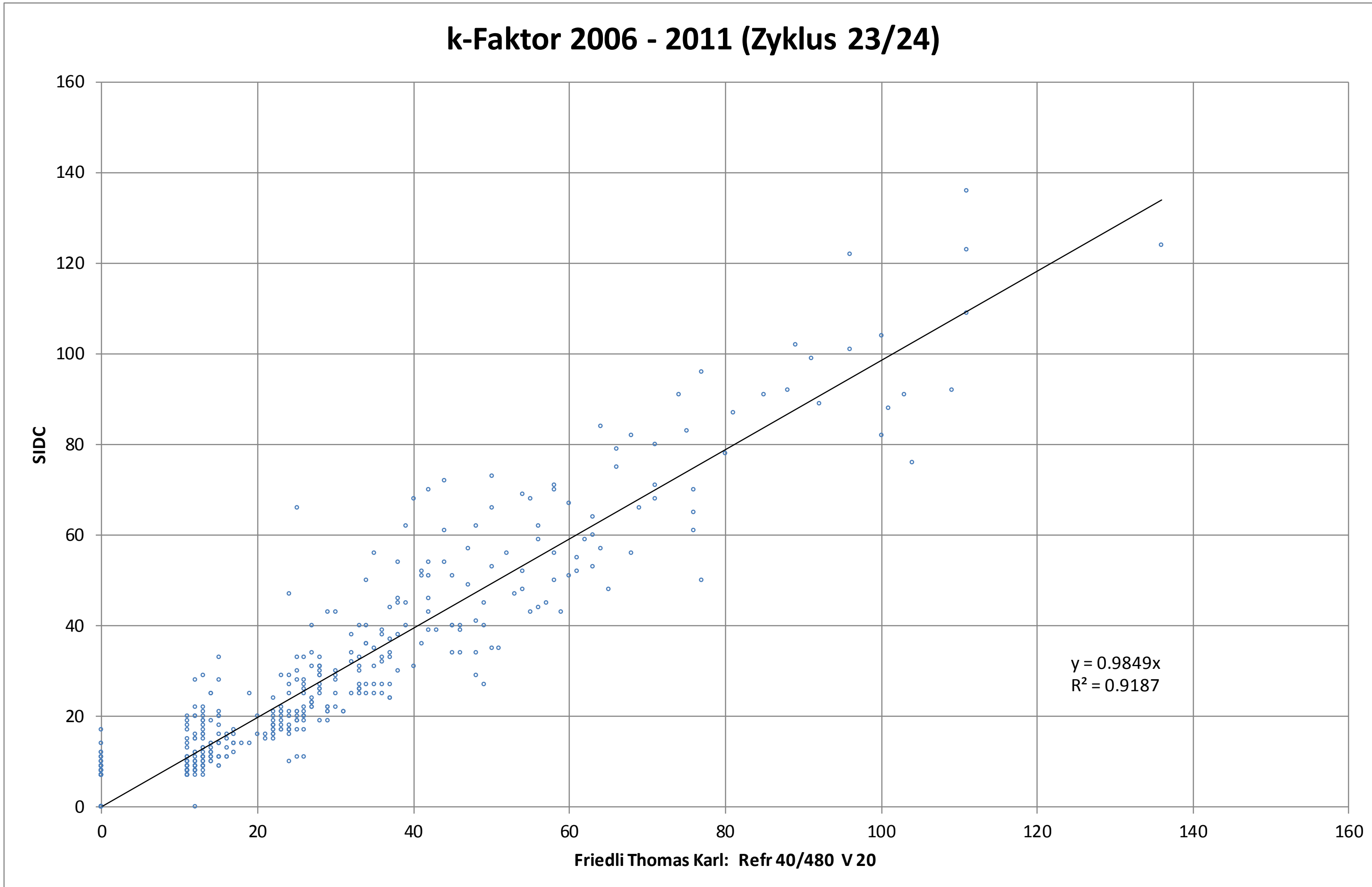
Source: ETHBIB HS 135: 14[10]

Zurich Sunspot Number

Rudolf Wolf

- Are the observations with the Parisian refractor good enough to serve as (secondary) standard series ?
  - This is the key question concerning the homogeneity of the Wolf series during the years 1863 and 1894.
  - Wolfer made sunspot observations with the Parisian instrument between 1894 and 1925 and found a mean k-factor of 1.20 with a secular drift.
  - In 1993 the Rudolf Wolf Society started a re-evaluation campaign with the Parisian Instrument used by Wolf.
  - From 1996 to 2005 H.U. Keller (staff-observer at Zurich Observatory from 1975 - 1995) was using the instrument and since 2006 I've been using it myself.


k-Faktor 1996 - 2005 (Zyklus 23)
SIDC
Keller Hans-Ulrich: Refr 40/480 V 20
y = 1.0532x
R² = 0.9233
0
50
100
150
200
250
0
50
100
150
200
250

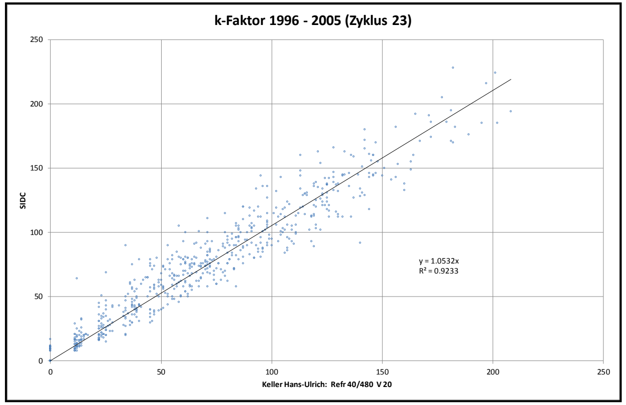

k-Faktor 2006 - 2011 (Zyklus 23/24)
SIDC
Friedli Thomas Karl: Refr 40/480 V 20
y = 0.9849x
R² = 0.9187
0
20
40
60
80
100
120
140
160

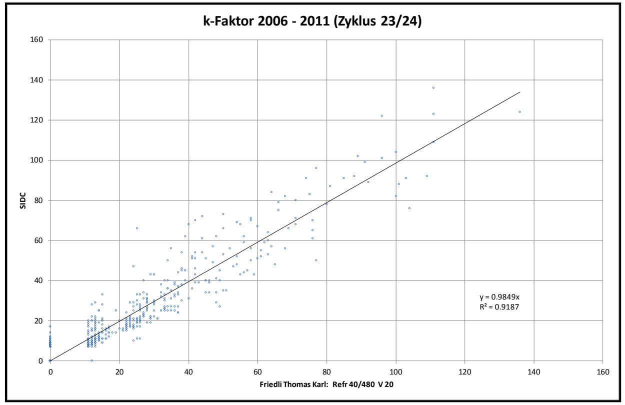
Zurich Sunspot Number

Rudolf Wolf

- Are the observations with the Parisian refractor good enough to serve as (secondary) standard series ?
  - This is the key question concerning the homogeneity of the Wolf series during the years 1863 and 1894.
  - Wolfer made with the Parisian instrument sunspot observations from 1894 to 1925 and found a mean k-factor of 1.20 with a secular drift.
  - In 1993 the Rudolf Wolf Society started a re-evaluation campaign with the Parisian Instrument used by Wolf.
  - From 1996 to 2005 H.U. Keller (from 1975 - 1995 staff-observer at Zurich Observatory) used the instrument and from 2006 on I used it for myself.
  - The calibration plots show stable linear regression lines with vanishing intercepts, thus a stable proportionality of the observations with the Parisian instrument against the official series with a coefficient of determination of 92%.

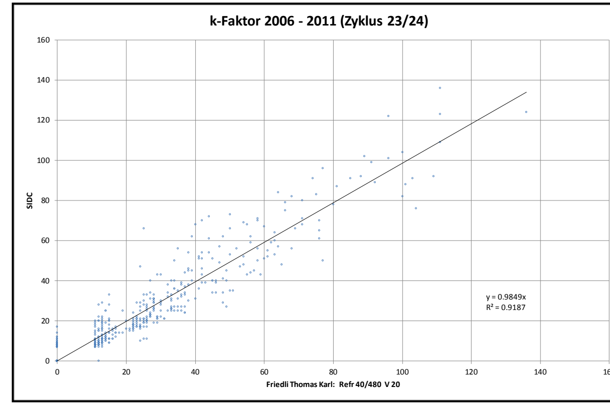
- The observations with the Parisian instrument are good enough to serve as (secondary) standard series!

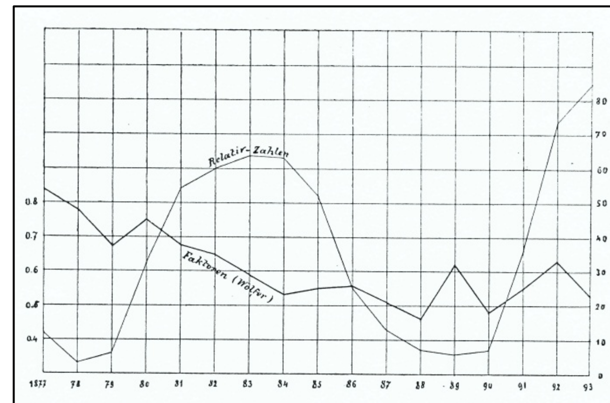




Rudolf Wolf

- Conclusions
  - o We agree with Wolfer that the weakening of Wolf’s vision was the main reason for the dampening of the observed k-factors from 1877 on of the four main auxiliary series since we observe a stable calibration function not depending on the sunspot number itself.
  - ▶ Thus, in 1894 the k-factor of Wolfer of 0.6 should have been chosen significantly higher! The correct solution would have been to construct with the best available long term auxiliary series a (tertiary) standard to bridge between Wolf and Wolfer. Unfortunately, Wolfer announced such a task, but never did it!
  - o We calculate for my observations a k-factor of 1.73 from the Parisian refractor to the Standard Fraunhofer refractor. The difference to 1.5 as calculated by Wolf may be attributed to the installation of the polarisation helioscope in 1864.
  - ▶ Thus, the k-factor of 1.5 assigned in 1864 by Wolf for the Parisian instrument is probably correct, but has to be validated very carefully.

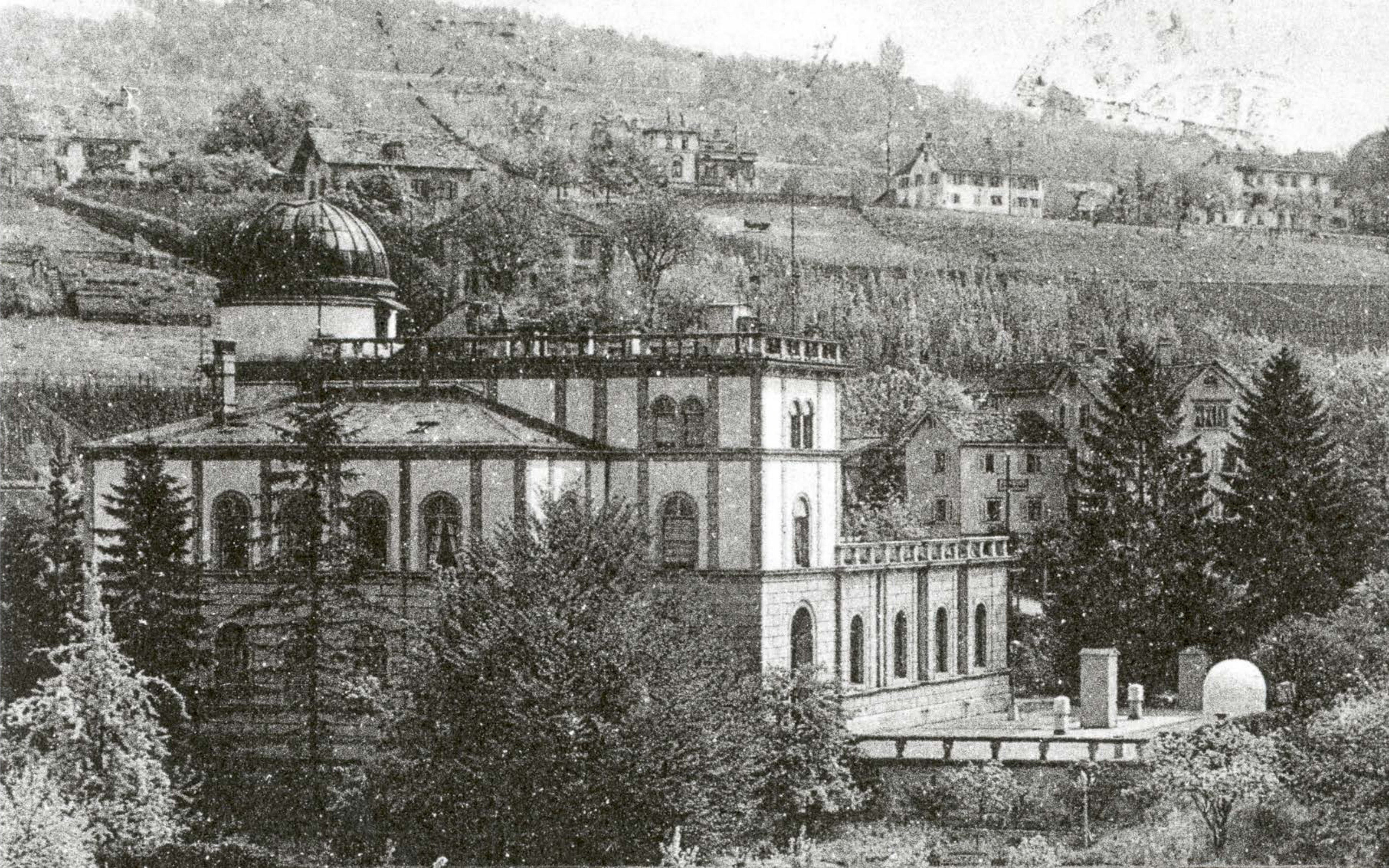




Zurich Sunspot Number

Alfred Wolfer

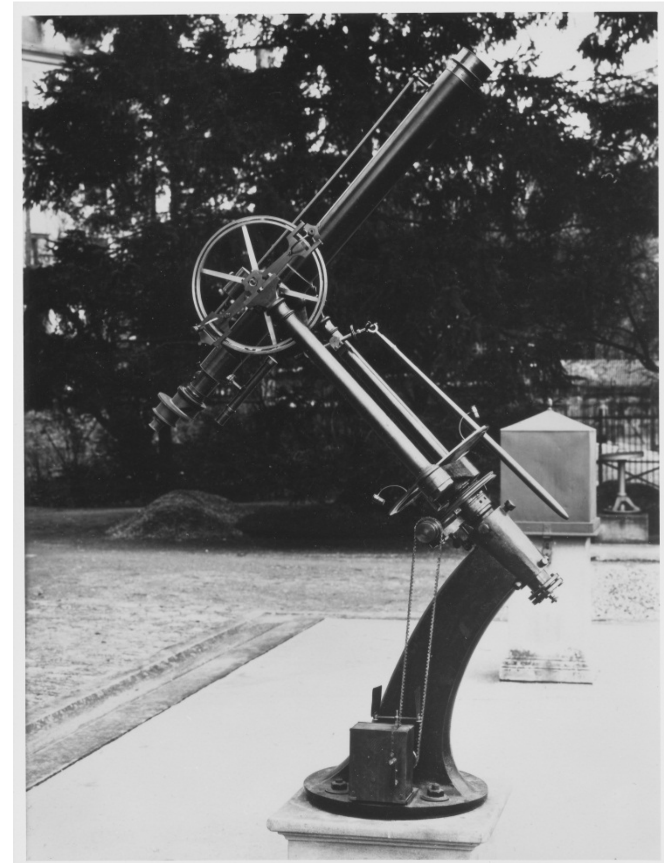
- 1864: New Swiss Federal Observatory
  - Fraunhofer telescope now on the terrace south of the building



Zurich Sunspot Number

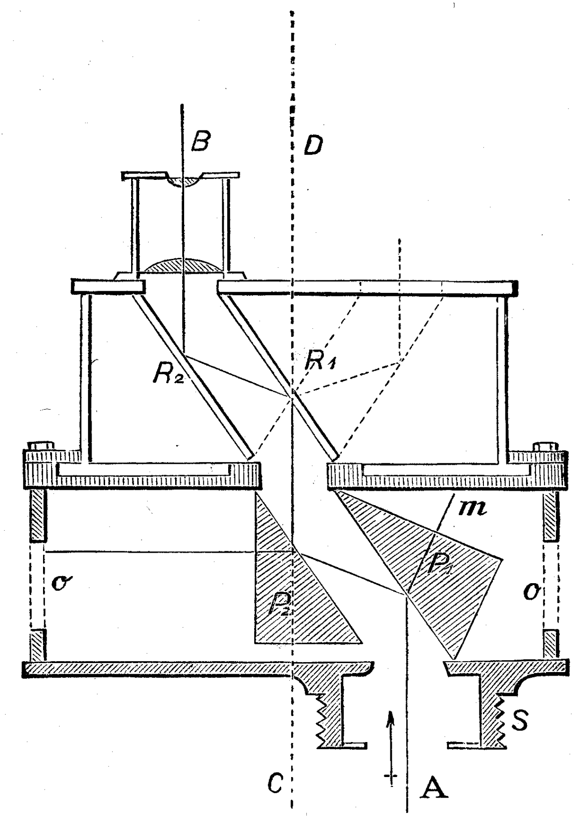
Alfred Wolfer

- 1864: New Swiss Federal Observatory
  - Fraunhofer telescope now on the terrace south of the building
  - With new polarization helioscope by G. & S. Merz in Munich



Alfred Wolfer

- 1864: New Swiss Federal Observatory
  - Fraunhofer telescope now on the terrace south of the building
  - With new polarization helioscope by G. & S. Merz in Munich
  - ▶ Sustainable upgrade to the instrument (which Wolf never used!)



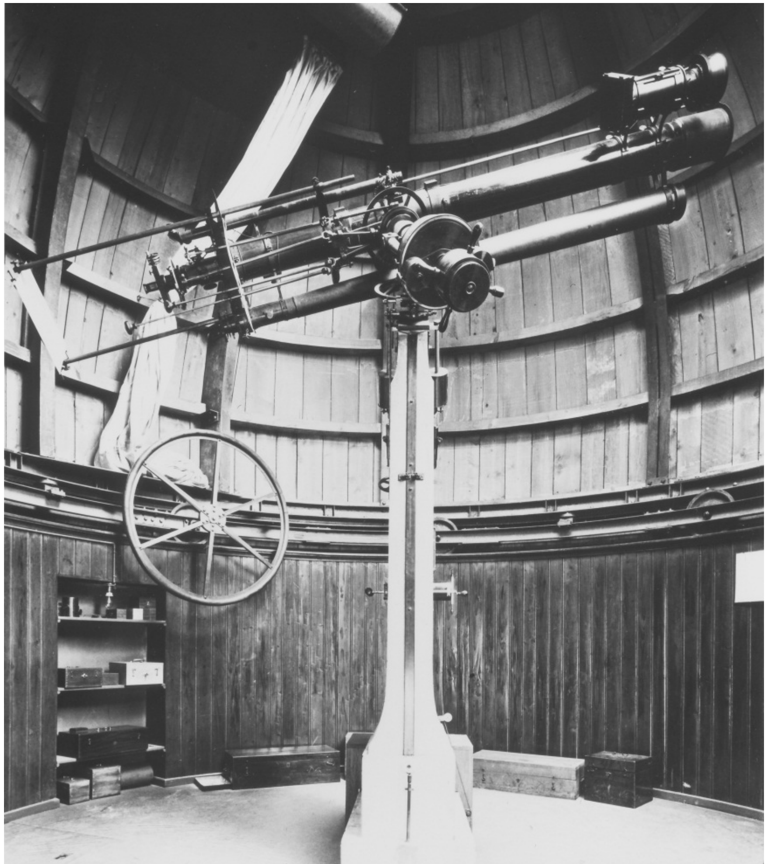
Merz's Helioscope.

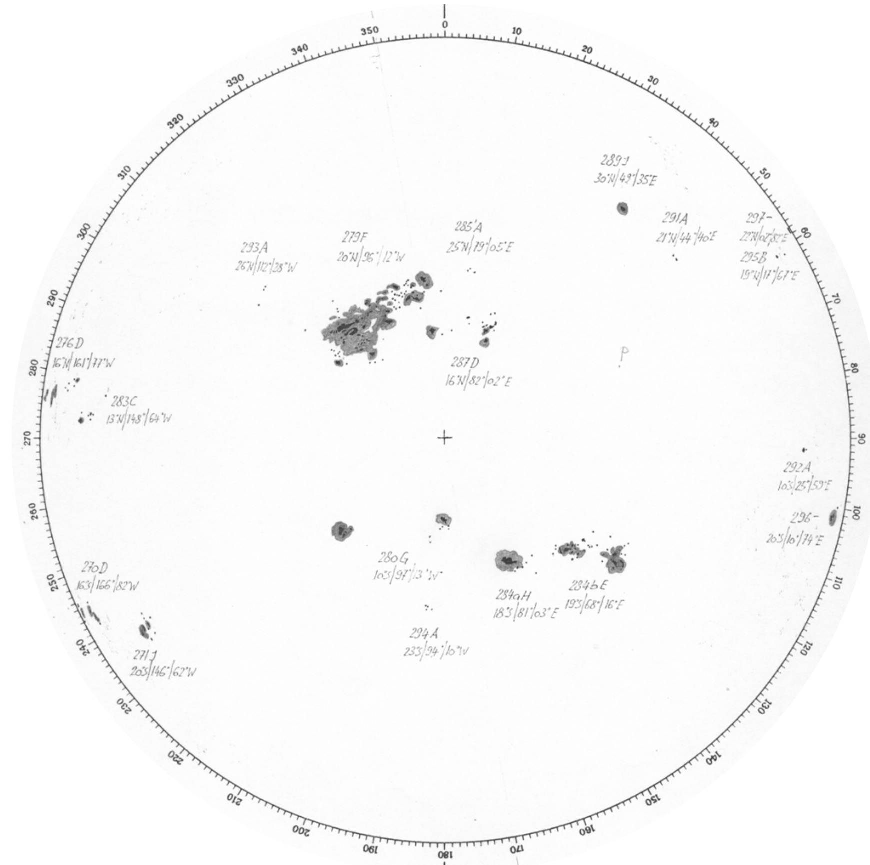
Zurich Sunspot Number

Alfred Wolfer

- 1864: New Swiss Federal Observatory
  - Fraunhofer telescope now on the terrace south of the building
  - With new polarization helioscope by G. & S. Merz in Munich
  - ▶ Sustainable upgrade to the instrument (which Wolf never used!)
- 1864: New Assistant (for meteorology)
  - A. Weilenmann 1864 – 1867
  - A. Fretz 1866
  - G.A. Meyer 1867 – 1871
  - R. Billwiller 1871 – 1878
  - A. Wolfer 1877 - 1893
  - ▶ Alfred Wolfer was the first “true” assistant for astronomy!
- New observing program
  - 1879: Measurements of positions of spots, faculae and protuberances
  - 1883: Daily drawings on 25 cm projection image of spots and faculae

Zurich Sunspot Number





Zurich Sunspot Number

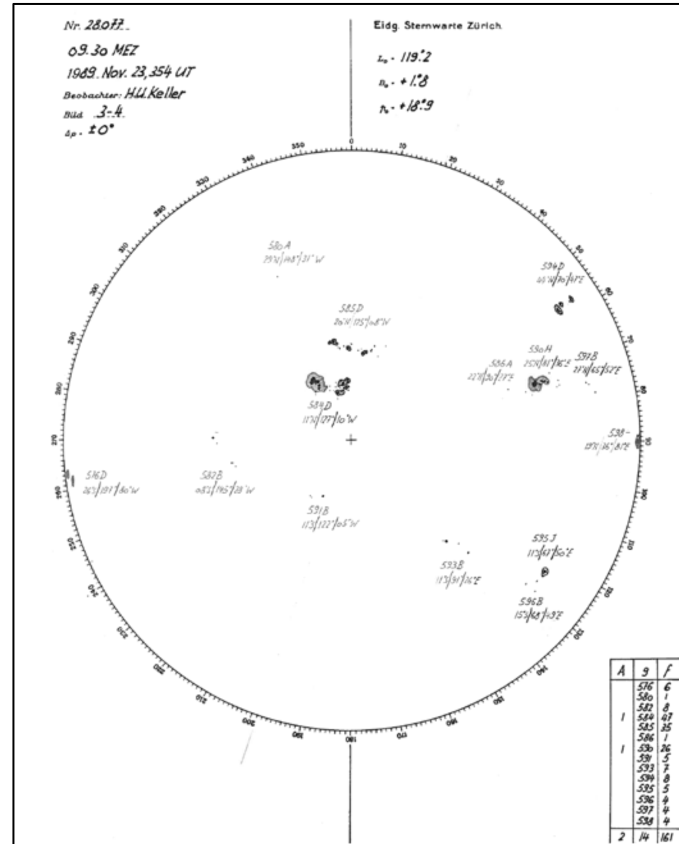
Alfred Wolfer

- Impact on the observing method of the sunspot number
  - On the projection screen a much more systematic search for small groups is possible than through the limited field of view of the standard refractor
  - Once detected on the projection screen spots are much easier to locate at the ocular of the standard refractor
  - Once detected at the standard refractor generally more fine detail is seen in umbrae and penumbrae
  - Thus, the drawing program forced the observer at the standard refractor routinely to a painstaking search of all detectable spots which pushed this instrument to a performance level well beyond of all others with similar aperture and magnification.
  - This fruitful coexistence remained unchanged up to 1995 where the observing station at the Swiss Federal Observatory was closed.
- Thus, Wolfer quasi re-invented and improved the counting program at the standard refractor!

Zurich Sunspot Number

Alfred Wolfer

- Long term impact on the definition of sunspot groups
  - o The daily drawings of the photosphere showed the evolution of the active regions in full detail. Thus, studies of growth and dissolution of the groups soon revealed, that all spots belonging to the same group form also a common evolutionary ensemble
  - Later, William Brunner and Max Waldmeier visualised and formalised these ideas in their famous Zurich Classification of sunspot groups
  - Thus, an implicit definition of a sunspot group was established: the classification scheme gave the visual appearance of outlines how a standard group had to look like
- We have evidence, that the Swiss Federal Observatory during the 1930ies asked the foreign contributors of the sunspot number program to send in their drawings, so that the staff in Zurich could make the necessary separation of groups according to their own rules!
- In examining the old heliographic maps we can find numerous examples of nowadays differently separated or combined sunspot groups. Thus, we have to be aware, that Wolf himself also had a slightly different practice in separating groups especially on the many historic series he has quantified!



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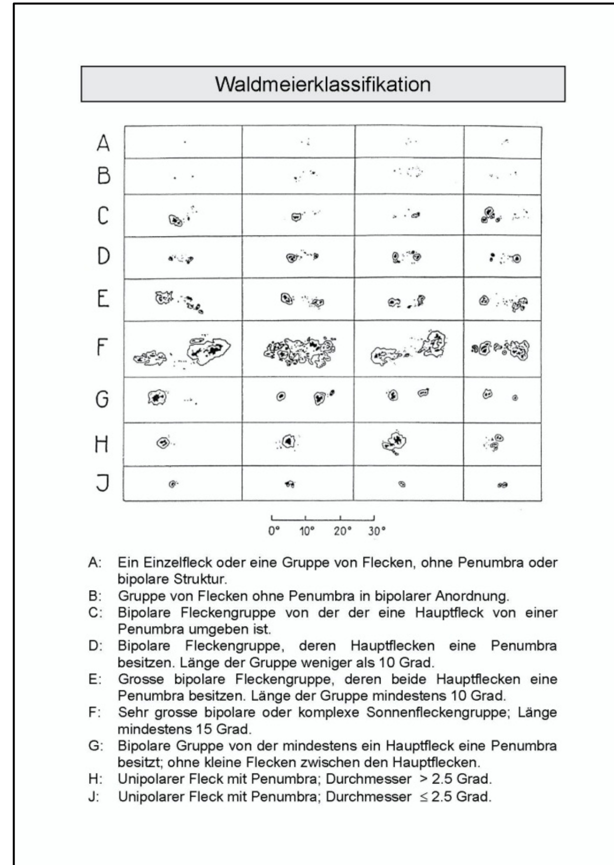
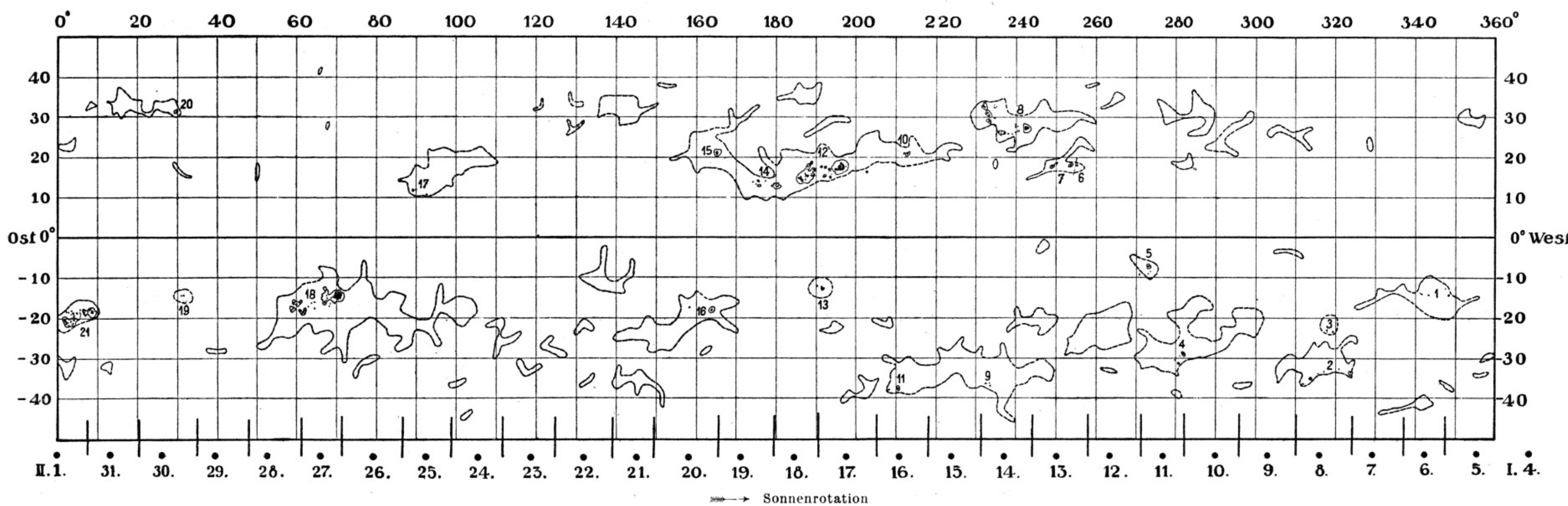


Zurich Sunspot Number



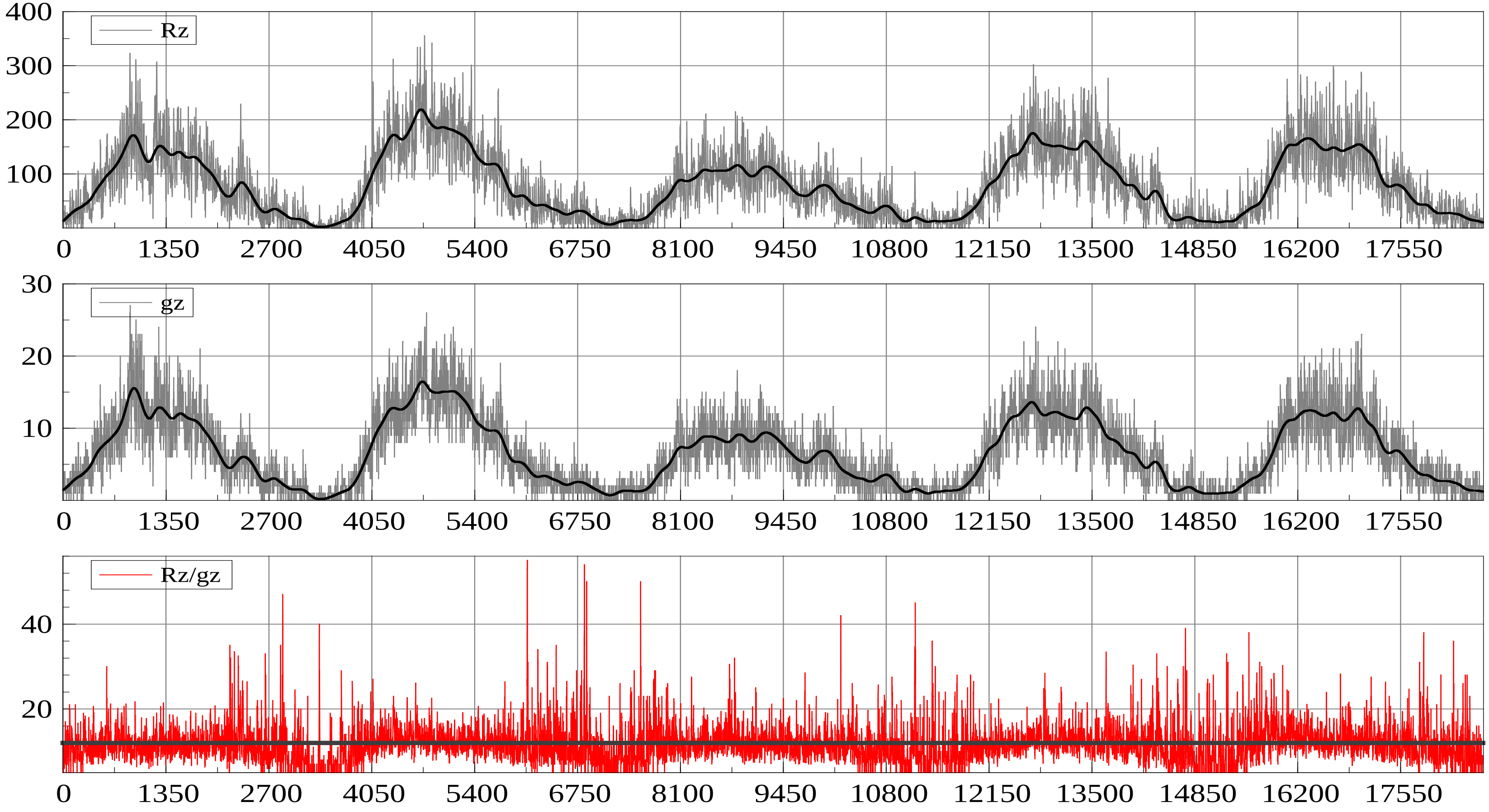
Zurich Sunspot Number

Alfred Wolfer

- Long term impact on the definition of sunspot groups

- Since the 1880ies the group number from the standard refractor and the number of groups on the drawings and maps were kept consistent, so we now have an objective archive for the group countings wherein possible inhomogeneities or changements could easily be detected. Thus, if one suspect, e.g., that Waldmeier started to separate the groups differently from his predecessors, he may consult these maps and evolutionary tables, which reach back to 1887. Furthermore, Max Waldmeier published beginning with 1945 in the yearly reports on sunspot activity an official series of Zurich sunspot group numbers which is available on request from the Wolf Institute of the Rudolf Wolf Society.

Zurich Sunspot Number



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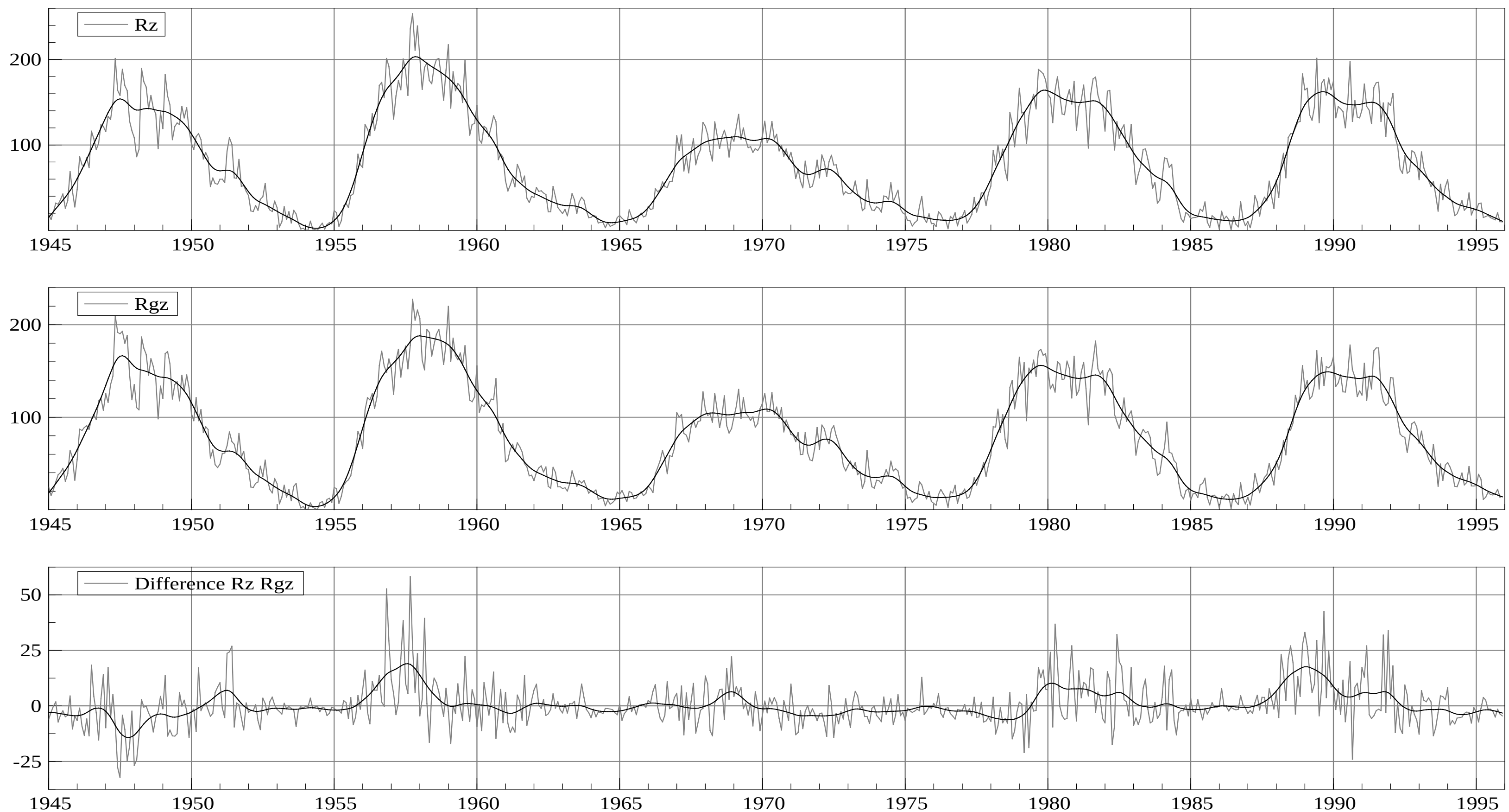
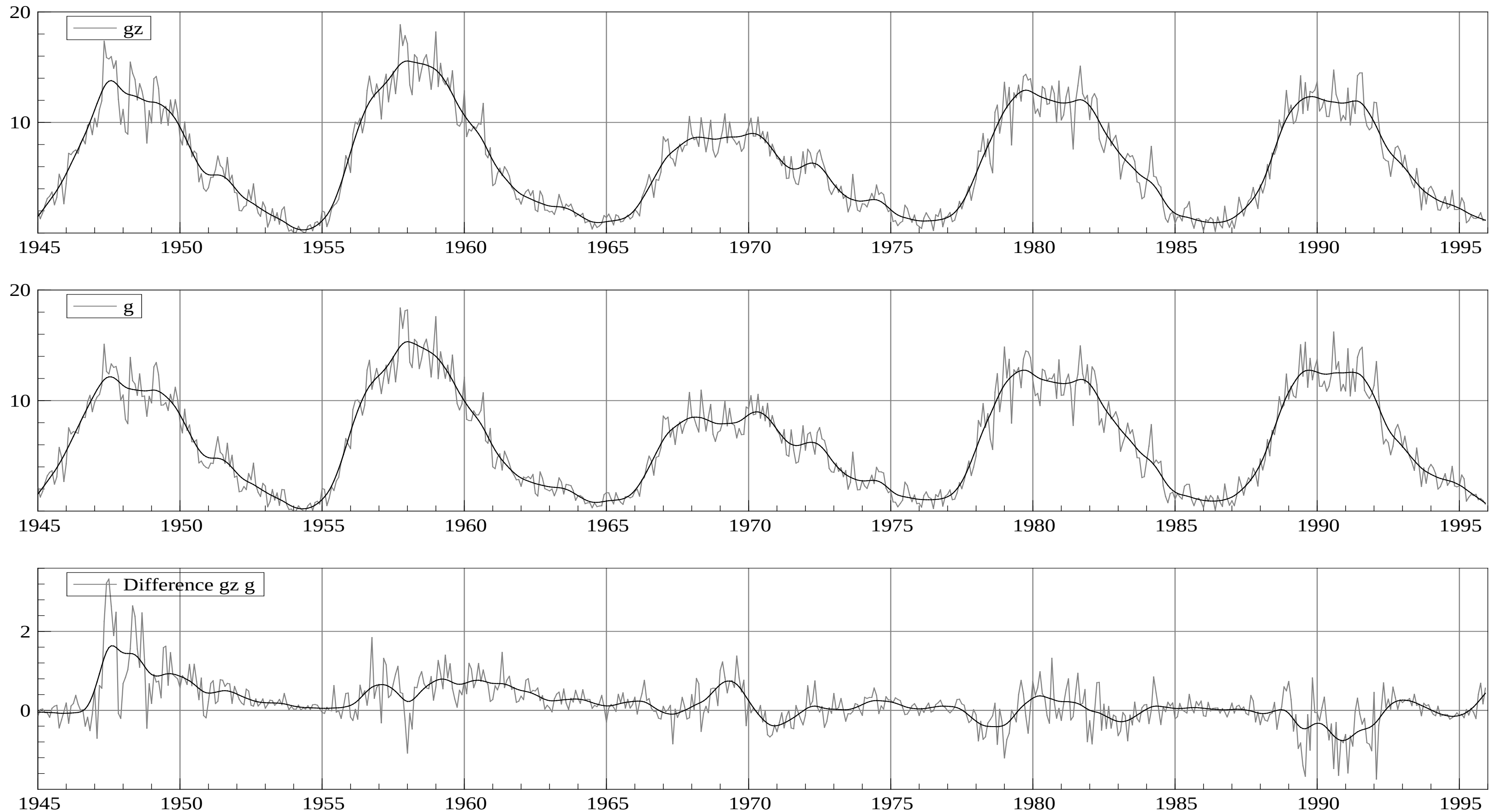
- In my dissertation on homogeneity testing of the sunspot number I analysed the relationship between the grouped sunspot number and the Zurich sunspot number and the relationship between the Zurich grouped sunspot number and the grouped sunspot number provided by Hoyt and Schatten.

Zurich Sunspot Number



Zurich Sunspot Number



Zurich Sunspot Number

Thomas K. Friedli

- Codification of the implicit Zurich definitions and practices
  - Zurich standard observing conditions
    - Observing devices have to perform similar to standard refractor
    - Observation method
    - Counting method for sunspots
    - Group separation rules
  - Formal definition of the Wolf number
    - Explicit definitions of sunspots and groups
  - Included in a tutorial for sunspot observers available from the Rudolf Wolf Society
- Suggestions
  - We should name the unity of the sunspot number "Wolf" in honor of the achievements of Rudolf Wolf
  - To ease the calibration calculations and to linearize the relationship of the Wolf number to better suited indices of very low solar activity (e.g. Ca II *K* plage indices) we should assign an index of 10 Wolf to a spottless ("zero") activity level

$$\begin{aligned} r_t : \Gamma_t \times \Phi_t &\longrightarrow \mathbb{N}_0 \\ (\gamma_t\,, \varphi_t) &\longmapsto 10 \cdot \Bbbk_1(\gamma_t) + \Bbbk_2(\varphi_t) \end{aligned}$$

$\Phi_t := \{\varphi \in \mathbb{N}_0 \mid \varphi = \text{card } F_t\}$

$F := \{f \mid f \text{ is a sunspot}\}$

A domain of the solar photosphere is called a sunspot $f \in F$, if

S1: its color is black, not just greyish,
S2: its lifetime is at least 30 minutes,
S3: its aera covers more than 1 Millionth Hemisphere (MH) and
S4: its aera is connected.

$\Gamma_t := \{\gamma \in \mathbb{N}_0 \mid \gamma = \text{card } G_t\}$

$G := \{g \mid g \text{ is a sunspot group}\}$

A cluster of sunspots $f \in F$ is called a sunspot group $g \in G$, if

C1: it is spatially isolated,
C2: it develops independently and if
C3: it belongs to the same magnetic activity center.

t := epoch of observation
$\mathbb{N}_0$:= $\{n \mid n \in \mathbb{N} \vee n = 0\}$
card X := number of elements of X
$\Bbbk_1, \Bbbk_2$:= solarstatistical calibration models

Zurich Sunspot Number

Alfred Wolfer and William Brunner

- Preservation of scale

  - To secure the long term homogeneity of the scale, Wolfer involved his assistant, Max Broger, in the daily determination of the sunspot numbers
  - After his retirement in 1925 William Brunner was appointed as new director of the Swiss Federal Observatory. But he was a complete beginner in practical observing. Thus Wolfer continued his sunspot countings at the standard refractor until 1928. And his former assistant Max Broger rested for another cycle until 1935 at the institute (totally for 38 years!)
  - Already in 1829 William Brunner installed his nephew William Brunner-Hagger as second assistant. After the retirement of Max Broger in 1835 Dr. Max Waldmeier became assistant

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Zurich Sunspot Number

Max Waldmeier

- Preservation of scale
    - After the retirement of William Brunner in 1944 Max Waldmeier had some problems in establishing his own observing crew: both Brunners did not continue with their observations. Thus Waldmeier had to rely on PhD students and external post-docs for the rapidly growing daily routine work. In 1957 the Specola Solare in Locarno Monti began with daily observations on a projection image with 25 cm diameter. Finally, in 1959, Waldmeier managed to establish in Zurich a fulltime staff-observer, responsible for the daily drawings and the countings at the standard refractor
    - In 1961 the standard refractor was moved on top of the roof terrace of the Swiss Federal Observatory in the direct vicinity of the newly errected Zeiss-Coudé refractor in the main dome of the observatory for the daily drawings and cinematographic monitoring of the chromosphere in H-alpha
    - Nevertheless, Waldmeier made always the bulk of the daily countings at the standard refractor. Up to this own retirement in 1979 all his observations made under good seeing conditions entered directly in the final statistic. The missing days were filled first by the observations of the auxiliary observers in Zurich or Locarno and the remaining few by the external contributors.

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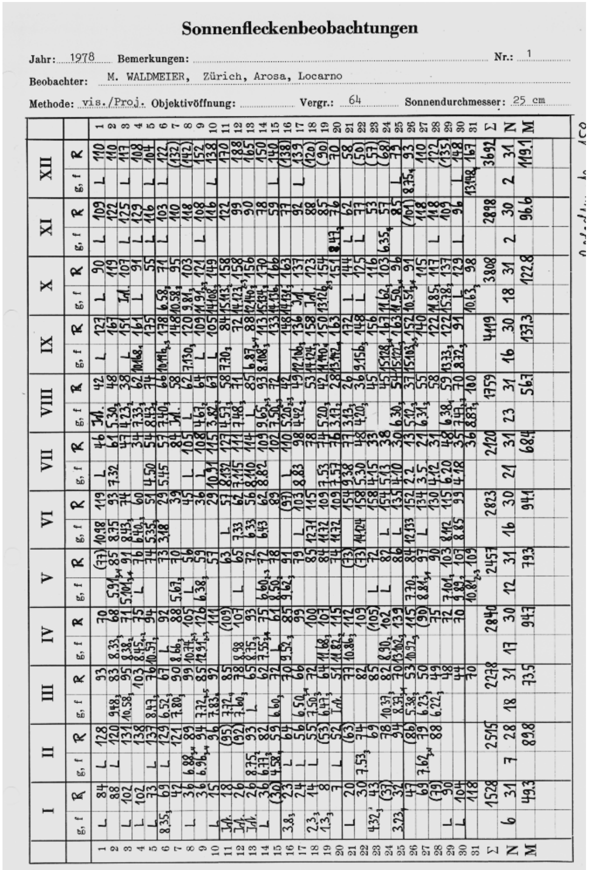
Sonnenfleckenbeobachtungen

Jahr: 1978 Bemerkungen: Nr.: 1

Beobachter: M. WALDMEIER, Zürich, Arosa, Locarno

Methode: vis./Proj. Objektivöffnung: Vergr.: 64 Sonnendurchmesser: 25 cm

Zurich Sunspot Number

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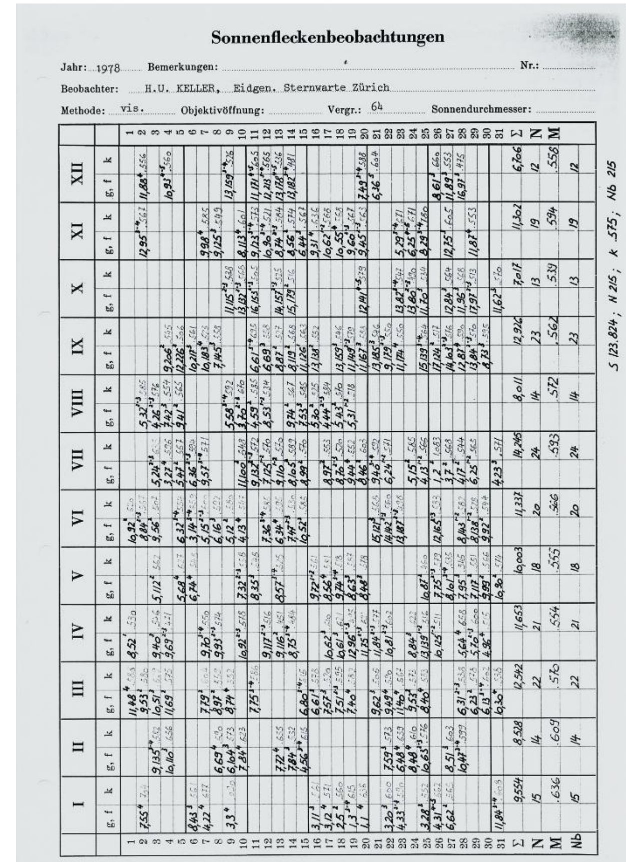

Zurich Sunspot Number

H.U. Keller

- Closure of the Swiss Federal Observatory 1980

  - Shortly after the retirement of Max Waldmeier his successor Jan Olof Stenflo announced the end of the daily routine programs and the closure of the Swiss Federal Observatory. The responsibility for the production and publication of the Wolf series was transferred to the newly established Sunspot Index Data Center in Brussels with the Locarno station as principle observer and grantee for a continuous preservation of the original Zurich scale.

  - In Zurich a minimal observing program could be preserved since the Swiss Department of Defence needed forecasts of the solar activity for shortwave propagation purposes to secure their military and diplomatic shortwave communication lines. Thus H.U. Keller continued the daily drawings at the Zeiss-Coudé refractor and the countings at the Fraunhofer standard refractor.

H.U. Keller and Thomas K. Friedli

- Closure of the former Swiss Federal Observatory 1995
  - In 1992 we founded the Rudolf Wolf Society to secure the long term observations at the standard refractor and to secure and exploit the scientific heritage of the Wolf series.

Zurich Sunspot Number

H.U. Keller and Thomas K. Friedli

- Closure of the former Swiss Federal Observatory 1995
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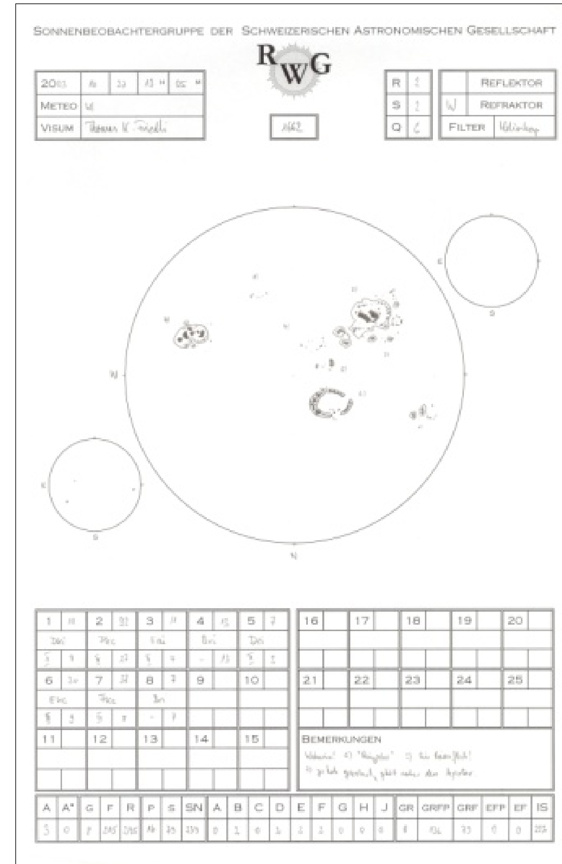
  - In 1995 the observing station at the former Swiss Federal Observatory was closed and the historic Fraunhofer refractor came to my disposal.
  - In 1996 I started my daily observations with this instrument – more than 150 years after Rudolf Wolf made the first sunspot observations with it!

Zurich Sunspot Number

Thomas K. Friedli

▸ Adapted observing program

- Daily sketch with outlines and positions of all sunspot groups
- I register my countings for each group separately
- To secure the scale we invited the Swiss solar observer group to participate on a common observing program. Later, this group was incorporated into the Rudolf Wolf Society and provided the necessary long term observation series needed to study possible deviations from scale and to bridge between H. U. Keller and me.



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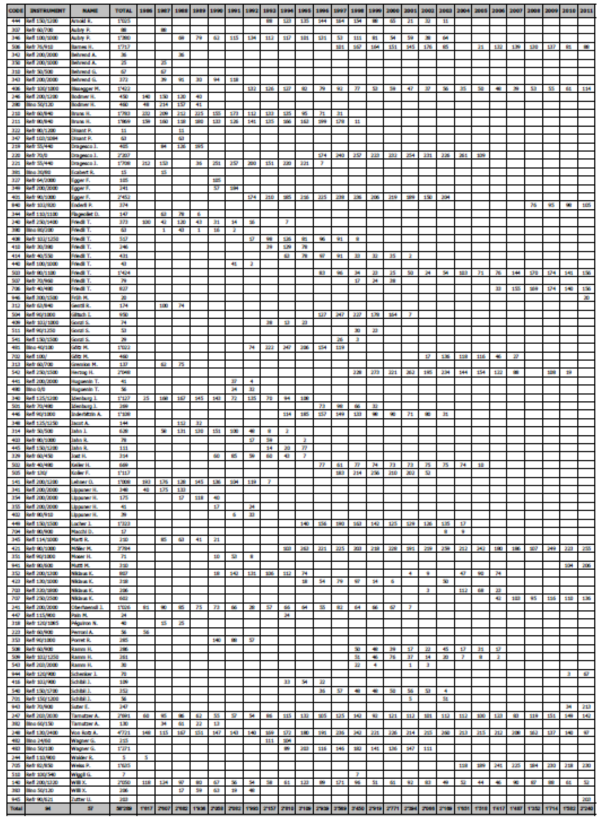
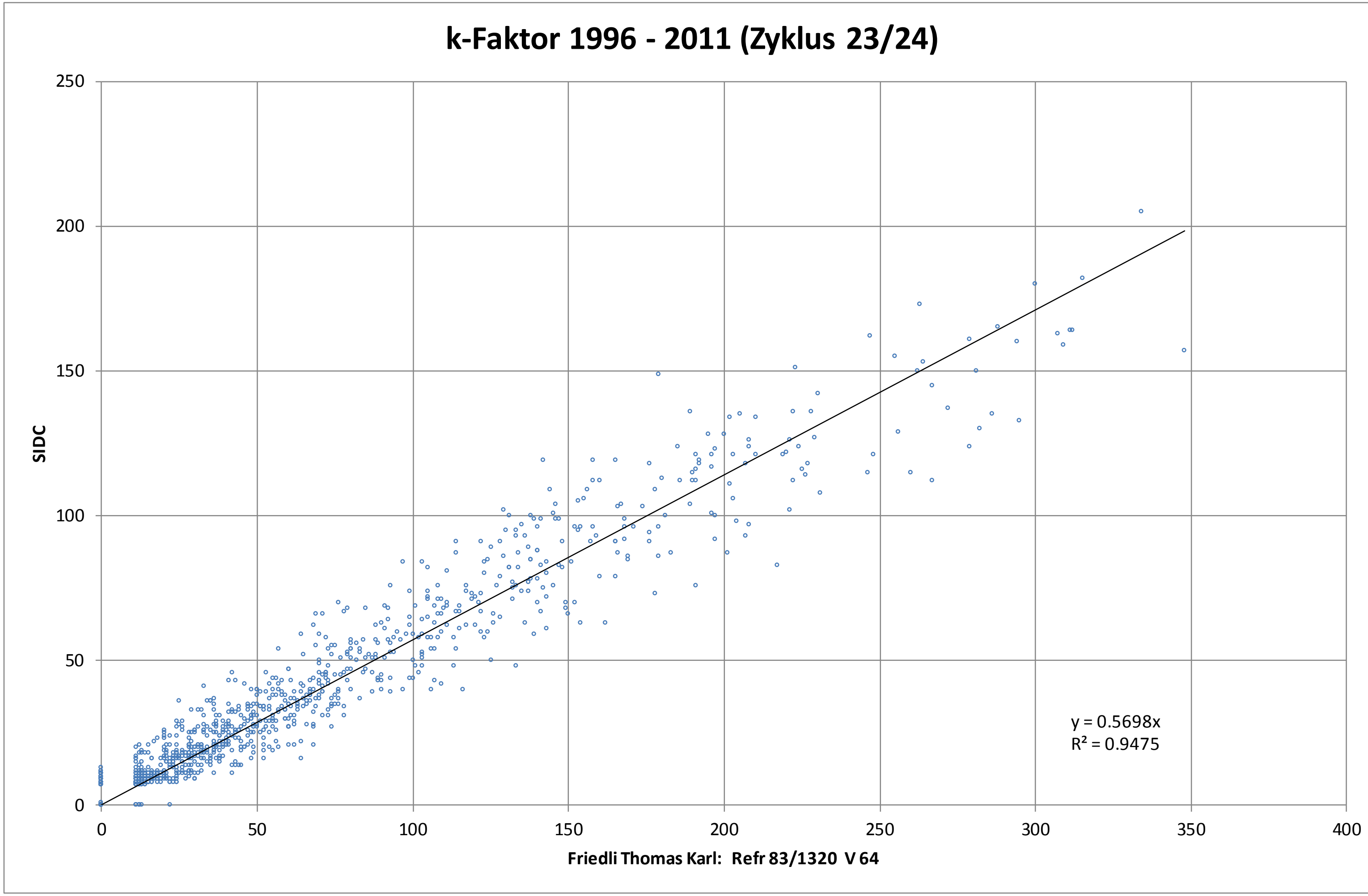
  - o Since 1986 I gave much effort in a careful education of these observers on Zurich standards and meaning while we dispose on several good series covering at least one or two cycles.
- The calibration plot of my observations on the Fraunhofer standard refractor show a linear regression line with vanishing intercept, thus a stable proportionality against the official series with a coefficient of determination of 95% and a k-factor of 0.57.

Number of Observations 1986 - 2011




k-Faktor 1996 - 2011 (Zyklus 23/24)
SIDC
250
200
150
100
50
0
0
50
100
150
200
250
300
350
400
Friedli Thomas Karl: Refr 83/1320 V 64
y = 0.5698x
R² = 0.9475

Zurich Sunspot Number

Weighting of individual sunspots

- Codification of last practice at Zurich observatory in 1988
  - Each umbra is weighted according to their area. The weights are estimated on a subjective scale.
  - There exist a different weighting scheme for spots within and outside penumbrae.
    - Spots outside of penumbrae are weighted between 1 and 3
    - Spots within penumbrae are weighted between 1 and 8
    - Penumbrae near the limb without visible umbra are weighted as 2

(Z6) Ein einzelner Sonnenfleck **ohne** Penumbra wird mit:

1 gewichtet, wenn keine sichtbare Ausdehnung festgestellt werden kann, der Fleck also als schwarzer Punkt erscheint

2 gewichtet, wenn eine Ausdehnung festgestellt werden kann

3 gewichtet, wenn seine Ausdehnung überdurchschnittlich gross ist oder gar eine kleine Penumbra nicht ausgeschlossen, aber nicht beobachtet werden kann

(Z7) Ein einzelner Sonnenfleck **innerhalb einer *einkernigen* Penumbra** wird mit:

2 gewichtet, wenn eine **Rand**penumbra ohne Umbra sichtbar wird, letztere aber vermutlich vorhanden ist (Wilson-Effekt! Vgl. auch zweite Anmerkung zu Regel Z1)

3 gewichtet, wenn der Kern kleiner ist als 10 MH

4 gewichtet, wenn der Kern kleiner ist als 24 MH

5 gewichtet, wenn der Kern kleiner ist als 44 MH

6 gewichtet, wenn der Kern kleiner ist als 69 MH

7 gewichtet, wenn der Kern kleiner ist als 99 MH

8 gewichtet, wenn der Kern grösser ist als 99 MH

(Z8) Ein einzelner Sonnenfleck **innerhalb einer *mehrkernigen* Penumbra** wird mit:

1 gewichtet, wenn der Fleck als schwarzer Punkt erscheint

2 gewichtet,wenn eine Ausdehnung festgestellt werden kann

3 gewichtet, wenn der Kern grösser ist als 2 MH

4 gewichtet, wenn der Kern grösser ist als 10 MH

5 gewichtet, wenn der Kern grösser ist als 24 MH

6 gewichtet, wenn der Kern grösser ist als 44 MH

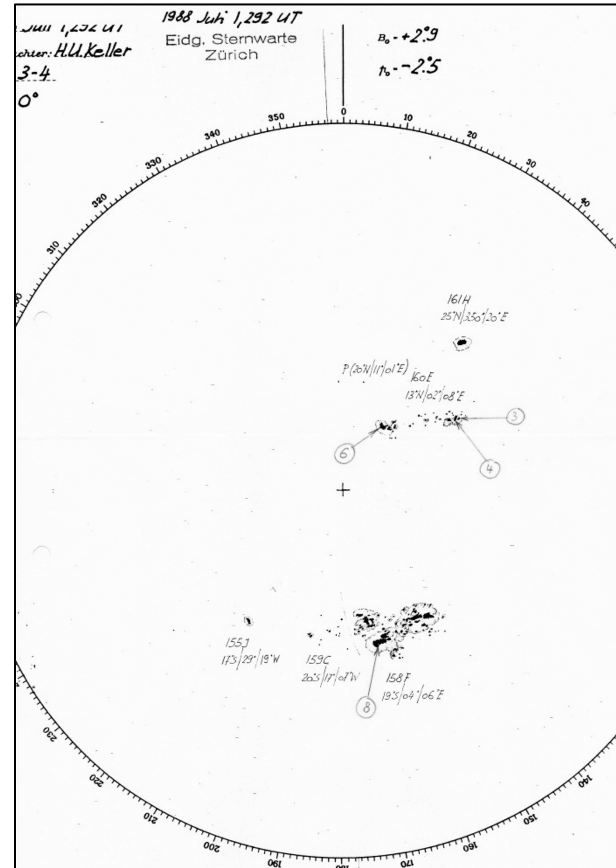
7 gewichtet, wenn der Kern grösser ist als 69 MH

8 gewichtet, wenn der Kern grösser ist als 99 MH

Zurich Sunspot Number

Weighting of individual sunspots

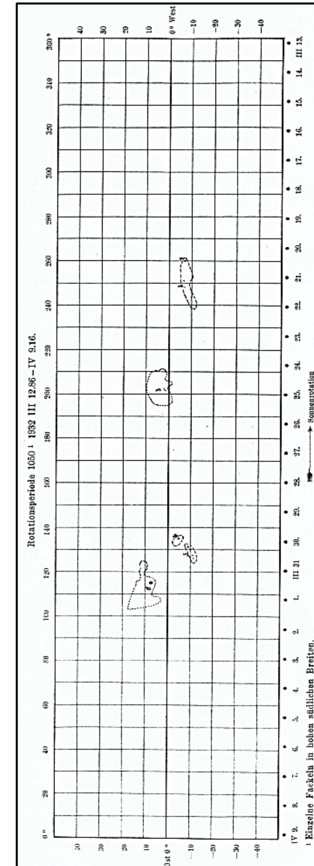
- Codification of last practice at Zurich observatory in 1988
  - Each umbra is weighted according to their area. The weights are estimated on a subjective scale.
  - There exist a different weighting scheme for spots within and outside penumbrae.
    - Spots outside of penumbrae are weighted between 1 and 3
    - Spots within penumbrae are weighted between 1 and 8
    - Penumbrae near the limb without visible umbra are weighted as 2
  - H.U. Keller identified on the Zurich drawings for each weighting class several spots outside and inside of penumbrae. From all these spots I measured the area in millionth of the hemisphere. A nonlinear regression thru the observed data points gave the estimated area equivalents and their class borders.
    - Published in Friedli, T.K.: Grundlagen der Solarstatistik. Bern. 1988



Zurich Sunspot Number

Weighting of individual sunspots

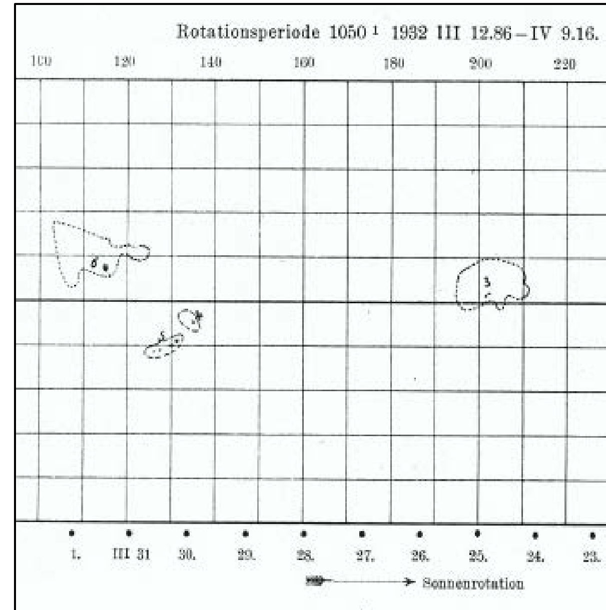
- Back tracing of the weighting practice at Zurich observatory
    - The heliographic maps and evolutionary tables are consistent with corresponding countings at the standard refractor



Zurich Sunspot Number

Weighting of individual sunspots

- Back tracing of the weighting practice at Zurich observatory
  - The heliographic maps and evolutionary tables are consistent with corresponding countings at the standard refractor
  - During sunspot minima there exist some days where only one single spot is seen. Thus, we can check the published raw countings of the early Zurich standard observers back to Wolfer if they have weighted or not.
  - The study is not finished yet, but up to now I identified during
    - 1930 – 1935: 7 A1 groups on 11 days and 6 J1 groups on 35 days
    - 1889 – 1891: 2 A1 groups on 3 days and 4 J1 groups on 11 days



Rotationsperiode 1050 1932 III 12.86—IV 9.16.

1.	260	—7	Ein unbeständiger kleiner Fleck.	III 21. 22.*
2.	251—248	—7	Unbeständige kleine Flecken; III 18. auf der Ostseite entstanden; III 21. aufgelöst.	III 18. 19.* 20.
3.	202—201	+2	Kleines Grüppchen kleiner Flecken.	III 24.
4.	135	—5	Kleine unbeständige Flecken.	III 27.* 28.
5.	131—126	(—9)—(—11)	Gruppe kleiner Flecken; IV 3. auf der Westseite entstanden. IV. 5./6. ausgetreten.	IV 3. 4.*
6.	115	+7	Kleiner abnehmender Hoffleck; III 25./26. eingetreten. IV 4. aufgelöst.	III 26. 27. 28. 29.* 30. 31. IV 1. 2. 3.

Zurich Sunspot Number

Weighting of individual sunspots

- Back tracing of the weighting practice at Zurich observatory
    - The heliographic maps and evolutionary tables are consistent with corresponding countings at the standard refractor
    - During sunspot minima there exist some days where only one single spot is seen. Thus, we can check the published raw countings of the early Zurich standard observers back to Wolfer if they have weighted or not.
    - The study is not finished yet, but up to now I identified during
        - 1930 – 1935: 7 A1 groups on 11 days and 6 J1 groups on 35 days
        - 1889 – 1891: 2 A1 groups on 3 days and 4 J1 groups on 11 days
- We have evidence that Waldmeier, Prof. Brunner, Assistant Brunner, Buser and Broger did weight the spots but that Wolfer did NOT!
- We observed individual weights up to 8 and probably individual the weighting scheme was open to the upper end. Thus, Waldmeier (again!) unveiled in 1979 only parts of the truth!

Zurich Sunspot Number

Weighting of individual sunspots

- Conclusions
  - I don’t believe that the weighting is an invention of Wolfer: It’s true that he argued in 1894 that weighting could be helpful (since an additional weighting of bigger spots would reduce the effects of aperture, magnitude and seeing on the variability of the counts of individual spots) but as far as I know, he never weighted himself (at least in the early 1890ies) .
  - In fact the weighting was a reaction of his successors and assistants, especially of Max Broger! They tried to reproduce more or less the same number of groups and spots as Wolfer did. There exists a remark from Brunner, that “now I’ve adapted my counting method exactly to that of Wolfer”.
  - Later generations adopted this “tradition”. As if several observers at the same instrument would *ever* see the same number of spots!

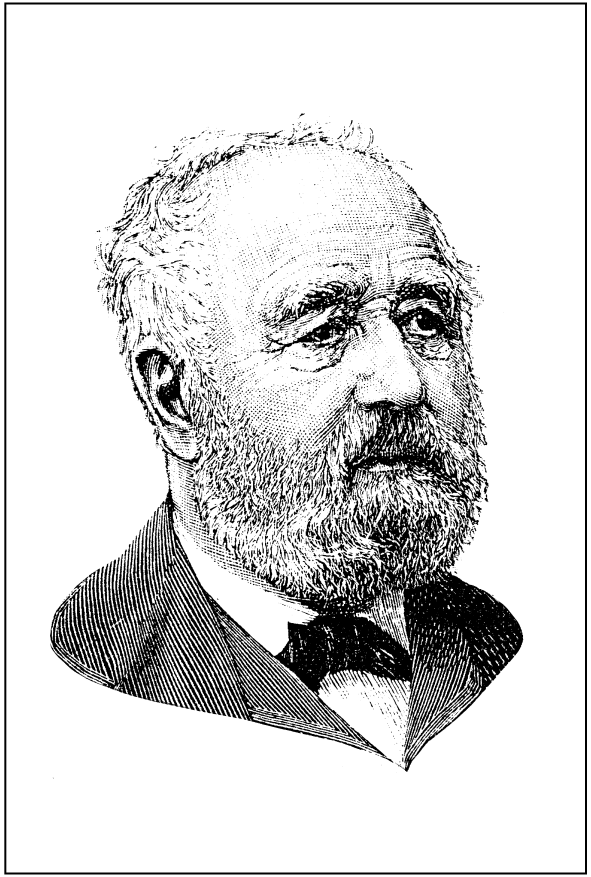
Zurich Sunspot Number

Weighting of individual sunspots

- Significance
  - As long as the individual weighting scheme and its application remain constant, the weighting is completely absorbed by the individual k-factor! Its effect can not be separated from other instrumental influences from aperture, magnification or filtering method.
  - The crucial point is not the sophistication but the long term stability of the counting method: Thus, develop your own working practice in counting individual spots (preferably similar to the classic, unweighted, one) and keep it constant “for ever”!
- Open issue
  - We have to check if Wolfer in his later years began to weight since such a slow drift will affect the long term homogeneity of the series (Wolfer’s k-factor remained unchanged at 0.6)

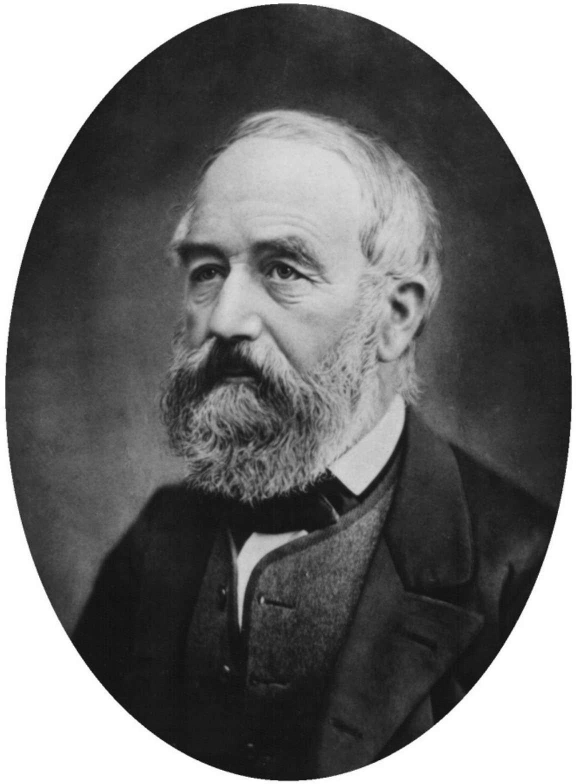
Contents

- Rudolf Wolf (1816 – 1893)
- Zurich Sunspot Number
- **Wolf Series**



Reconstruction of the Wolf series

- Wolf's final release
  - The definitive edition of the Wolf series is Waldmeier (1960)
  - The corresponding reconstructions and calculations were finished in mid 1877 and published in 1877 (smoothed monthly means) and in 1880 (observed monthly means)
  - Wolf did never publish the corresponding daily values! But there exists a source book with all raw data, k-factors and computed daily values from the beginnings in 1610 up to 1877
  - Wolf considered only one observation per day, usually the most reliable one. He started with his own observations and extended the series backwards with the observations from Schwabe, Flaugerques, Tevel, Bode and Staudacher as fiducial backbone
  - The necessary k-factors were estimated with corresponding observations. Gaps were filled with one observation each from the available auxiliary series. Remaining gaps were filled by graphical interpolation.
- We are currently working on the edition of this crucial source book



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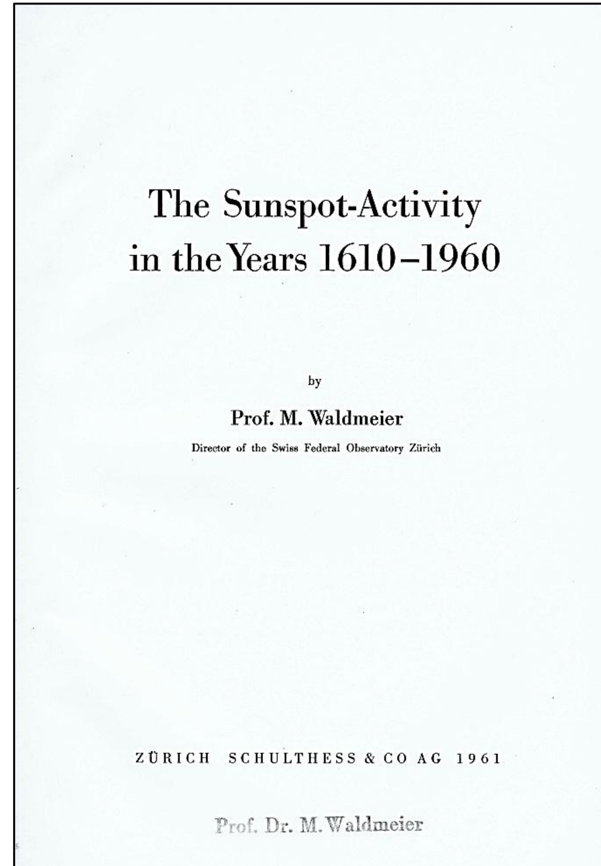
The Sunspot-Activity in the Years 1610–1960

by

Prof. M. Waldmeier

Director of the Swiss Federal Observatory Zürich

ZÜRICH SCHULTHESS & CO AG 1961

Prof. Dr. M. Waldmeier

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Beobachtungen

der

Sonnenflecken

Von der Zeit ihrer Entdeckung bis auf die Gegenwart.

Gesammelt

von

Rudolf Wolf.

Wolf Series

1849 Sonnenflecken-Beobachtungen.

	I.			II.			III.			IV.			V.			VI.			
1	s	9.31	151	s	3.6	45	sh	6.?	92	w	10.70	170	w	9.30	120	w	8.48	128	1
2	s	9.34	155	w	7.40	110	K	5.?	82	K	7.?	170	w	9.40	130	w	9.64	154	2
3	w	15.?	180	sh	5.?	65	w	6.12	72	s	10.38	172	K	5.12	93	w	8.50	130	3
4	s	9.31	151	w	7.27	97	w	7.15	85	w	12.58	178	w	7.45	115	w	10.50	150	4
5	s	9.?	147	w	9.22	112	sh	7.?	90	K	8.20	150	w	8.50	130	w	8.45	125	5
6	s	8.?	143	w	10.34	134	w	7.24	94	w	10.60	160	w	7.38	108	w	7.45	115	6
7	sh	12.?	139	sh	8.?	110	sh	8.?	100	K	8.24	156	w	6.?	90	K	5.?	100	7
8	s	8.28	135	w	10.21	121	K	4.?	70	K	6.20	120	w	6.20	80	K	5.12	93	8
9	s	8.30	137	w	10.35	135	sh	5.?	50	w	9.45	135	w	6.25	85	sh	5.?	70	9
10	s	8.?	132	w	10.?	140	sh	6.?	60	w	7.?	100	w	6.?	80	sh	4.?	50	10
11	s	7.?	127	K	8.20	150	w	5.20	70	w	6.24	84	K	4.10	75	sh	5.?	60	11
12	s	7.28	122	w	9.56	146	w	7.30	100	w	6.?	74	K	1.2	18	w	5.12	62	12
13	s	7.?	132	w	11.64	174	w	7.?	107	w	5.14	64	K	0.0	0	s	5.14	80	13
14	s	8.?	142	K	7.?	115	s	7.22	115	s	5.16	82	w	5.16	66	s	6.14	92	14
15	sh	9.?	152	s	1.2	27	s	6.23	104	w	5.10	60	s	4.?	65	K	4.8	72	15
16	sh	9.?	102	K	6.?	100	K	4.?	40	s	2.2	27	w	4.25	65	K	3.4	51	16
17	K	9.25	172	w	15.40	190	K	4.24	81	K	2.2	33	w	4.?	65	w	4.8	48	17
18	w	11.60	170	K	8.?	160	w	7.30	100	K	5.?	81	w	4.30	70	w	5.35	85	18
19	K	10.25	187	w	11.36	146	K	4.?	90	w	6.25	85	w	4.?	70	w	5.35	85	19
20	s	11.74	230	w	13.60	190	w	5.30	80	K	6.11	106	w	3.42	72	K	2.5	37	20
21	w	12.75	195	w	12.?	170	w	5.30	80	K	6.?	120	s	3.22	65	w	4.42	82	21
22	w	9.46	136	s	10.21	151	w	6.35	95	K	6.36	144	w	3.28	58	w	6.56	116	22
23	K	10.?	146	w	11.58	168	w	6.?	90	K	3.12	63	w	4.25	65	w	5.38	88	23
24	K	10.?	156	w	11.40	150	w	5.?	80	K	2.10	45	K	3.8	57	sh	4.?	80	24
25	w	10.65	165	w	10.68	168	K	3.?	70	w	5.30	80	w	6.25	85	w	5.30	80	25
26	w	10.76	176	s	10.35	169	K	4.?	85	K	4.10	75	w	5.12	62	w	4.25	65	26
27	w	10.95	195	sh	8.?	120	K	4.?	100	w	6.44	104	w	6.20	80	w	2.15	35	27
28	w	9.63	153	w	7.36	106	w	12.50	170	K	3.?	85	w	8.30	110	w	2.10	30	28
29	s	9.62	190		.		sh	9.?	160	K	3.20	75	K	6.10	105	w	4.6	46	29
30	w	9.?	160		.		s	9.31	151	K	3.20	75	w	7.40	110	w	5.?	55	30
31	w	8.?	130		.		w	11.58	168		.		K	6.10	105		.		31
M.			156,7			131,7			96,5			102,5			80,6			81,2	M.

Bemerkungen:

w Wolf mit 4' = 1,00 angenommen als Einheit
K — — 2' = 1,50 aus zahlreichen in diesem und folg. Jahren mit w angest. Vergl.
s Schwabe = 1,25 — — — —
c Colla fällt nicht in Berechnung
sh Schmidt " "

Sonnenflecken-Beobachtungen. 95.

	VII.			VIII.			IX.			X.			XI.			XII.			
1	s	4.13	66	w	4.15	55	w	7.64	134	w	8.10	90	K	5.16	99	w	10.?	145	1
2	K	3.3	49	w	6.18	78	w	5.35	85	K	7.10	120	w	7.41	111	K	8.9	133	2
3	K	3.6	54	w	6.15	75	w	4.27	67	K	3.4	51	w	3.10	40	w	8.17	97	3
4	K	3.10	60	w	4.12	52	w	5.41	91	K	2.3	34	w	4.31	71	sh	5.?	117	4
5	sh	5.?	70	w	5.20	70	sh	7.?	100	K	1.2	18	w	4.?	74	w	9.47	137	5
6	K	4.8	72	w	4.18	58	w	6.25	85	K	4.6	69	w	5.?	78	sh	4.?	107	6
7	K	5.10	90	w	3.20	50	w	7.48	118	K	4.?	68	w	6.22	82	w	7.?	100	7
8	K	6.15	112	w	3.15	45	w	5.38	88	w	5.16	66	w	7.35	105	w	6.?	92	8
9	K	7.20	135	w	4.14	54	w	7.50	120	w	5.26	76	w	6.20	80	w	5.?	84	9
10	K	3.6	54	w	5.27	77	w	9.26	116	sh	3.?	40	sh	6.?	70	w	5.?	76	10
11	K	2.4	36	w	5.32	82	w	7.25	95	w	2.5	25	sh	5.?	60	w	4.?	68	11
12	K	3.8	57	w	7.25	95	s	6.?	65	w	3.?	40	sh	3.?	45	w	4.?	60	12
13	K	4.10	75	w	7.24	94	w	4.40	80	w	4.26	66	w	5.11	61	w	3.22	52	13
14	*K	3.12	63	w	6.15	75	K	5.15	77	sh	4.?	60	w	6.22	82	w	3.12	42	14
15	K	3.12	63	w	6.14	74	w	9.59	149	sh	3.?	40	w	5.20	70	w	4.19	59	15
16	w	7.45	115	w	7.21	91	w	7.54	124	w	3.5	35	w	4.?	60	K	3.5	52	16
17	w	8.40	120	s	6.?	90	w	6.32	92	w	4.21	61	sh	3.?	50	w	5.22	72	17
18	w	9.30	120	w	6.30	90	w	5.19	69	w	4.25	65	w	2.22	42	w	7.37	107	18
19	w	7.22	92	w	5.26	76	w	3.9	39	w	6.56	116	w	5.25	75	K	6.10	105	19
20	w	7.22	92	K	3.5	52	w	4.26	66	w	6.41	101	w	7.47	117	K	4.5	67	20
21	w	7.15	85	w	5.10	60	w	6.24	84	w	8.36	116	K	6.16	114	sh	10.?	100	21
22	w	6.8	68	w	4.4	44	w	7.28	98	sh	8.?	110	sh	9.?	121	sh	9.?	115	22
23	w	5.12	62	w	4.7	47	w	7.34	104	w	7.46	116	sh	9.?	129	sh	9.?	130	23
24	w	5.9	59	w	3.4	34	w	7.23	93	K	5.8	87	c	9.?	136	w	10.?	140	24
25	w	7.14	84	w	3.10	40	w	5.22	72	K	4.4	66	w	9.?	143	w	11.43	153	25
26	w	4.8	48	w	5.20	70	w	5.15	65	c	4.?	60	w	9.?	150	K	6.13	109	26
27	w	5.7	57	w	5.21	71	w	8.15	95	c	3.?	55	w	9.68	158	K	5.?	95	27
28	w	7.20	90	w	3.15	45	w	9.16	106	K	3.4	51	w	11.72	182	K	5.7	85	28
29	w	7.24	94	w	4.24	64	w	8.17	97	K	5.11	91	w	13.74	204	w	8.52	132	29
30	w	8.20	100	w	5.36	86	w	8.17	97	w	7.48	118	w	11.52	162	K	4.11	76	30
31	w	6.16	76	w	6.45	105		.		K	5.16	99		.		c	5.?	100	31
M.			78,0			61,3			93,7			71,5			99,7			97,0	M.

Bemerkungen:

RWG

Wolf Series

1803 Sonnenflecken-Beobachtungen. Sonnenflecken-Beobachtungen. 71

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
1	i . 66	i . 67	.	hs x.	i . 71	i . 72	id 3.11 ~~73~~ 56	di 3.14 ~~74~~ 60	i . 75	i . ~~76~~ 60	i . 77	i . 77
2	.	.	.	st x.	.	.	d 2.9 39	d 3.14 60	.	.	.	.
3	.	.	hd 54.13 ~~67~~ 72	di 2.3 ~~69~~ 31	.	.	d 2.8 38	d 3.8 52	d 4.5 61	.	.	.
4	.	.	hs x.	hs x.	.	.	d 2.9 39	.	.	.	.	.
5	.	d 3.11 56	hs x.	d 1.5 20	.	.	d 2.83 38	.	.	.	.	.
6	.	d 3.12 57	.	d 1.6 20	.	.	d 2.8 38	d 1.1 15	.	.	.	.
7	.	.	.	hd x1.4 19	.	d 2.5 34	.	.	.	.	.	.
8	.	.	.	hd x3.4 46	.	.	.	.	.	.	.	.
9	.	.	hs x.	hd x3.4 46	.	.	.	d 1.3 18	.	.	.	.
10	.	.	.	.	.	.	.	d 1.6 22	.	.	.	.
11	.	d 3.3 45	hs x.	hd x2.4 33	.	.	.	.	.	.	.	.
12	.	d 3.3 45	hs x.	hs x.	d 2.2 30	.	.	d 2.2 30	.	.	.	.
13	.	hs x.	hs x.	.	.	.	.	.	.	.	.	.
14	.	hs x.	hs x.	d 1.1 15	.	.	.	.	.	.	.	.
15	. 50	.	i . 68	d 1.1 15	d 3.10 54	.	.	.	.	.	.	.
16	i . ~~66~~	hs x.	hs x.	id 1.1 ~~69~~ 15	i . 71	i . 72	.	f 2.3. 44	.	.	.	.
17	.	i . 67	hs x.	d 1.1 15	.	.	f . 73	. 2	i . ~~75~~ 60	i . ~~76~~ 60	i . ~~77~~ 57	i . ~~77~~ 48
18	.	.	hd x1.1 16	.	.	.	d 2.2 30	.	.	.	.	.
19	.	.	h x.	.	.	.	d 3.3 45	.	.	.	.	.
20	.	.	d 1.1 15	.	.	.	d 3.3 45	.	.	.	.	.
21	.	.	d 1.1 15	.	.	.	d 3.3 45	.	.	.	.	.
22	.	.	.	.	.	.	.	.	.	.	.	.
23	.	.	d 2.3 31	.	d 3.6 49	.	d 2.3 31	.	.	.	.	.
24	.	.	d 1.3 18	.	.	.	d 3.5 48	.	.	.	.	.
25	.	.	.	.	.	.	d 3.5 48	.	.	.	.	.
26	.	.	d 1.2 16	.	.	.	.	.	.	.	.	.
27	.	.	d 1.2 16	.	.	.	d 3.9 53	.	d 1.1 15	d 2.7 37	.	.
28	.	i . 67	d 3.6 49	.	.	.	d 4.12 71	.	.	.	.	.
29	.	.	d 3.5 48	.	.	d 2.6 35	d 4.11 69	d 1.5 20	.	.	.	.
30	.	.	i . 69	.	.	id 2.9 ~~72~~ 39	d 4.10 68	id 1.5 ~~74~~ 20	i . 75	.	.	i . 77
31	i . 66	.	.	i . 69	i . 71	.	id 4.11 ~~73~~ 69	d 2.5 34	.	i . ~~76~~ 60	i . ~~77~~	.
M.	0+3 ... 66,0 50,6	~~0+3 ... 67,0~~ 56.8	0+3 ... 68,0 29.6	0+3 ... 69,0 25.0	0+3 ... 71,0 44.3	0+3 ... 72,0 36.0	0+3 ... 73,0 48.3	7+1 ... 64,0 34.1	0+3 ... 75,0 43.3	0+3 ... 76,0 54.3	0+3 ... ~~77~~,0 57	0+3 ... 77,0 48.0

Bemerkungen:

f Flaugergues = 1,92 bis 1788
hs Herschel
h Heinrich = 1,21 bis 1781
st Stürmer
hu Huber
b Bode
d Dorfflinger – 1.36

Bemerkungen:

Flaugergues sagt 1803 [illegible] Sonnenflecke [illegible]

1766 Sonnenflecken-Beobachtungen. 11,4

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	
1													1
2	i . 12	i . 11	i . 10	i . 9	St 1.5 62	i . 9	i . 0	i . 0	i . 0	i . 0	i . 0	i . 0	2
3													3
4													4
5													5
6			i . 10										6
7					St 1.1 27								7
8					St 1.1 27							St 0.0 0	8
9												St 1.6 40	9
10												St 1.4 35	10
11			St 1.3 32										11
12			St 1.2 30										12
13			St 2.4 60	i . 9									13
14			St 3.4 85										14
15			St 3.3 62			St 0.0 0	i . 10	i . 12	i . 13	i . 15	i . 14		15
16													16
17	i . 12	i . 11											17
18					i . 9							i . 20	18
19													19
20													20
21													21
22			i . 10										22
23				St 0.0 0									23
24													24
25													25
26													26
27													27
28		i . 11											28
29	i . 12		i . 10			i . 0	i . 0	i . 0	i . 0	i . 0	i . 0	i . 20	29
30					i . 9								30
31													31
M.	0+3 ... 12,0	0+3 ... 11,0	5+4 ... 36,6	1+2 ... 6,0	3+2 ... 26,8	1+2 ... 3,0	0+3 ... 3,3	0+3 ... 4,0	0+3 ... 4,3	0+3 ... 5,0	0+3 ... 5,7	3+3 ... 19,2	M.

Bemerkungen:

St Staudacher = 2,50 [illegible] 1749
L Lalande

Bemerkungen:

Staudacher sagt: „Ende Juni nichts und ferner bis [illegible] December."

Wolf Series

1872 Sonnenflecken-Beobachtungen.

	I.			II.			III.			IV.			V.			VI.			
1	K	2.5	37	K	6.29	113	K	6.26	129	K	7.21	136	K	5.19	107	wb	13.178	157	1
2	K	4.10	75	K	7.39	163	wb	9.132	113	K	6.13	109	K	4.13	79	wb	14.193	170	2
3	wb	5.44	48	K	7.31	151	K	6.25	127	K	6.8	102	K	4.16	87	K	7.21	136	3
4	K	4.15	82	K	8.28	162	K	6.11	106	K	5.10	90	K	7.24	141	wb	9.85	89	4
5	K	4.14	81	K	7.22	138	K	5.11	91	sh	6.?	97	wb	9.203	149	wb	7.65	69	5
6	wb	9.109	101	K	7.29	148	K	3.7	55	sh	6.?	97	wb	10.158	130	K	3.9	58	6
7	K	3.9	58	w	9.239	169	K	3.4	51	K	5.11	91	K	8.18	147	K	4.13	79	7
8	wb	6.105	84	K	7.29	148	K	3.5	52	K	5.11	91	K	5.12	93	K	6.22	123	8
9	K	4.9	73	K	7.33	154	K	2.4	36	K	5.7	85	wb	8.120	102	K	6.25	127	9
10	wb	5.95	74	K	7.27	145	wb	4.40	41	wb	6.80	71	wb	5.110	81	K	5.15	97	10
11	K	4.15	82	wb	7.193	134	wb	2.23	22	K	4.20	90	K	4.9	73	K	8.36	124	11
12	wb	7.115	94	K	6.24	126	K	2.4	36	K	4.13	79	wb	7.86	80	K	7.25	142	12
13	K	5.21	106	t	8.50	96	K	3.3	49	K	6.16	114	K	3.6	54	K	7.23	139	13
14	wb	7.125	99	K	5.15	97	K	2.2	33	K	5.14	96	K	4.10	75	K	6.27	130	14
15	K	4.17	85	wb	7.110	92	K	2.2	33	K	6.21	121	K	3.9	58	K	5.21	106	15
16	wb	7.125	99	wb	5.52	52	K	2.2	33	K	5.18	102	K	4.9	73	K	5.21	106	16
17	wb	7.120	97	K	4.17	85	K	2.3	34	K	6.26	129	K	4.11	76	K	4.17	85	17
18	K	4.10	75	K	3.12	63	K	4.7	70	sh	9.?	136	K	4.12	78	K	5.15	97	18
19	K	3.17	70	K	4.6	69	wb	10.76	90	sh	9.?	136	K	4.19	88	K	6.11	106	19
20	K	4.19	88	K	3.5	52	K	6.11	106	wb	10.200	153	K	6.23	124	wb	7.56	64	20
21	K	4.24	96	K	4.11	76	K	7.13	124	K	4.11	76	sh	7.?	110	K	6.11	106	21
22	K	3.14	66	K	5.13	94	wb	14.175	161	K	6.17	115	wb	8.231	159	K	7.10	120	22
23	K	3.16	69	K	5.17	100	K	8.22	153	K	6.17	115	K	7.29	148	K	6.11	106	23
24	wb	6.89	76	wb	7.160	117	K	6.14	111	K	5.23	109	K	7.27	145	K	6.8	102	24
25	K	3.7	55	wb	7.190	133	sh	8.?	123	K	4.27	100	wb	9.122	108	K	6.10	105	25
26	K	3.7	55	wb	8.?	148	K	6.19	118	K	4.17	85	K	6.13	109	wb	7.71	72	26
27	K	3.7	55	wb	8.240	163	K	7.24	141	K	4.17	85	K	5.15	97	K	6.10	105	27
28	K	3.8	57	K	6.35	142	K	6.25	127	K	4.15	82	K	7.18	132	w	7.50	107	28
29	wb	6.116	90	K	7.33	154	K	6.25	127	K	5.12	93	K	8.25	157	K	5.21	106	29
30	K	4.29	103		.		wb	9.165	140	K	4.13	79	w	10.80	160	K	5.26	114	30
31	K	6.30	135		.		K	6.13	109				K	9.23	169		.		31
M.			79,5			120,1			88,4			102,1			107,6			109,9	M.

Bemerkungen:

K Wolf mit 2' = 1,50 angenommen wie
w Billwiller = 0,89 aus 46 Vergl. mit K
wb Weber = 0,51 " "
h Meis = 1,05 " "
t Tacchini = 0,74 " "
sh Schmidt vergl. 293 Liter.

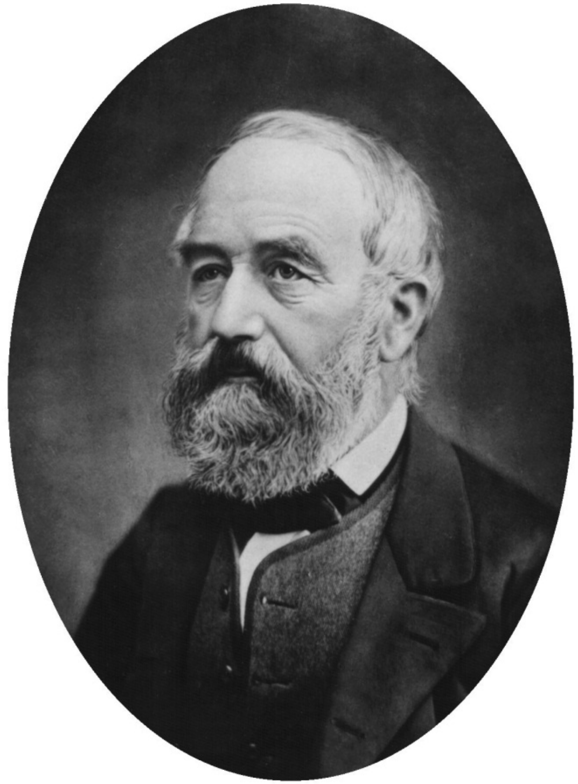
Sonnenflecken-Beobachtungen. 101

	VII.			VIII.			IX.			X.			XI.			XII.			
1	K	6.23	124	K	4.13	79	K	4.9	73	K	9.27	125	K	4.5	67	wb	2.206	120	1
2	K	5.16	99	K	4.25	97	K	4.14	81	K	8.28	162	K	3.5	52	K	4.19	88	2
3	K	5.17	100	wb	8.196	141	K	4.16	84	wb	10.173	139	K	4.4	66	K	4.17	85	3
4	K	6.18	117	K	6.27	130	K	3.13	64	sh	9.?	136	K	5.9	88	wb	6.235	150	4
5	K	5.14	96	K	7.26	144	K	4.23	94	sh	8.?	123	sh	6.?	97	sh	8.?	123	5
6	K	5.12	93	K	7.25	142	K	4.21	91	wb	11.155	135	K	4.22	93	wb	7.145	110	6
7	K	5.17	100	K	7.25	142	K	6.26	129	wb	11.146	131	K	4.25	97	K	5.11	91	7
8	K	6.23	124	K	6.24	126	K	6.23	124	K	4.13	79	K	5.26	117	K	7.21	136	8
9	wb	9.165	130	K	7.27	145	K	7.16	144	wb	6.72	67	K	6.29	133	wb	9.125	110	9
10	K	8.51	196	K	7.29	148	K	9.19	163	K	4.13	79	sh	9.?	136	K	5.10	90	10
11	K	7.45	172	h	4.23	66	sh	9.?	136	K	6.13	109	wb	7.241	124	sh	6.?	97	11
12	K	7.46	174	K	7.19	133	K	5.20	105	wb	7.111	92	wb	4.285	106	wb	6.153	109	12
13	K	7.43	169	K	7.17	130	K	7.24	141	K	5.14	103	wb	8.261	174	K	5.10	90	13
14	K	6.28	132	K	5.13	94	K	6.19	118	sh	5.?	83	K	6.18	117	K	5.7	85	14
15	K	5.22	108	K	4.11	76	K	6.20	120	sh	4.?	69	K	4.13	79	K	5.8	87	15
16	K	4.15	82	K	4.8	72	K	6.26	129	w	6.58	105	K	6.23	124	K	4.5	67	16
17	K	4.12	78	K	3.12	63	K	5.29	118	wb	6.160	112	K	6.15	112	sh	6.?	97	17
18	K	5.16	99	K	3.14	66	K	4.24	96	wb	9.179	137	wb	9.185	140	K	3.5	52	18
19	K	5.12	93	K	3.10	60	wb	14.153	149	K	5.15	97	K	6.29	133	K	4.13	79	19
20	K	5.8	87	K	3.7	55	K	5.22	109	K	5.11	91	wb	7.226	151	K	3.10	60	20
21	K	5.6	84	K	4.13	79	K	5.11	91	K	5.8	87	K	5.28	117	wb	4.64	57	21
22	K	4.5	67	wb	7.116	94	K	5.11	91	K	4.7	70	K	4.33	109	K	3.7	55	22
23	K	5.11	91	K	3.14	66	K	5.7	85	K	4.8	72	K	5.30	120	wb	3.27	29	23
24	K	4.5	67	wb	8.116	97	K	5.9	88	K	4.9	73	K	5.31	121	wb	3.16	23	24
25	K	4.6	69	K	5.15	97	K	5.9	88	wb	6.70	66	K	4.27	100	sh	2.?	38	25
26	K	4.7	70	K	4.13	79	K	8.23	154	K	7.15	127	wb	5.120	112	K	4.5	67	26
27	K	4.6	69	K	4.12	78	K	8.20	150	K	6.13	109	K	4.11	76	K	4.7	70	27
28	K	5.9	88	K	2.6	39	K	8.22	153	wb	7.115	94	K	5.14	96	wb	6.60	61	28
29	K	4.10	75	K	2.2	33	K	7.18	132	K	5.11	91	K	5.14	96	wb	6.102	83	29
30	K	5.15	97	K	2.5	37	wb	12.151	138	K	5.14	96	K	5.14	96	K	4.16	84	30
31	K	6.18	117	K	4.7	70		.		K	4.8	72		.		K	5.24	111	31
M.			105,5			92,4			114,6			103,5			112,0			83,9	M.

Bemerkungen:

Reconstruction of the Wolf series

- Wolf's final release
  - The definitive edition of the Wolf series is Waldmeier (1960)
  - The corresponding reconstructions and calculations were finished in mid 1877 and published in 1877 (smoothed monthly means) and in 1880 (observed monthly means)
  - Wolf did never publish the corresponding daily values! But there exists a source book with all raw data, k-factors and computed daily values from the beginnings in 1610 up to 1877
  - Wolf considered only one observation per day, usually the most reliable one. He started with his own observations and extended the series backwards with the observations from Schwabe, Flaugerques, Tevel, Bode and Staudacher as fiducial backbone
  - The necessary k-factors were estimated with corresponding observations. Gaps were filled with one observation each from the available auxiliary series. Remaining gaps were filled by graphical interpolation.
- We are currently working on the edition of this crucial source book



Homogeneity Testing of Sunspot Numbers

Dissertationsvortrag

16. Juni 2005

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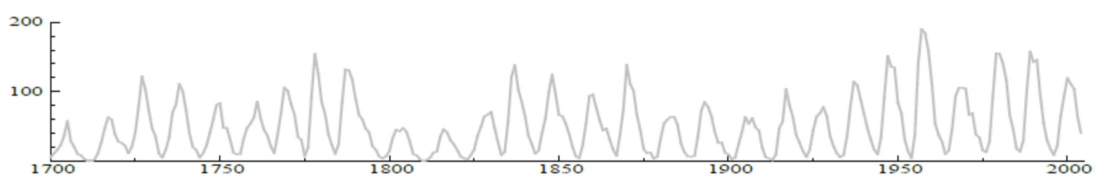
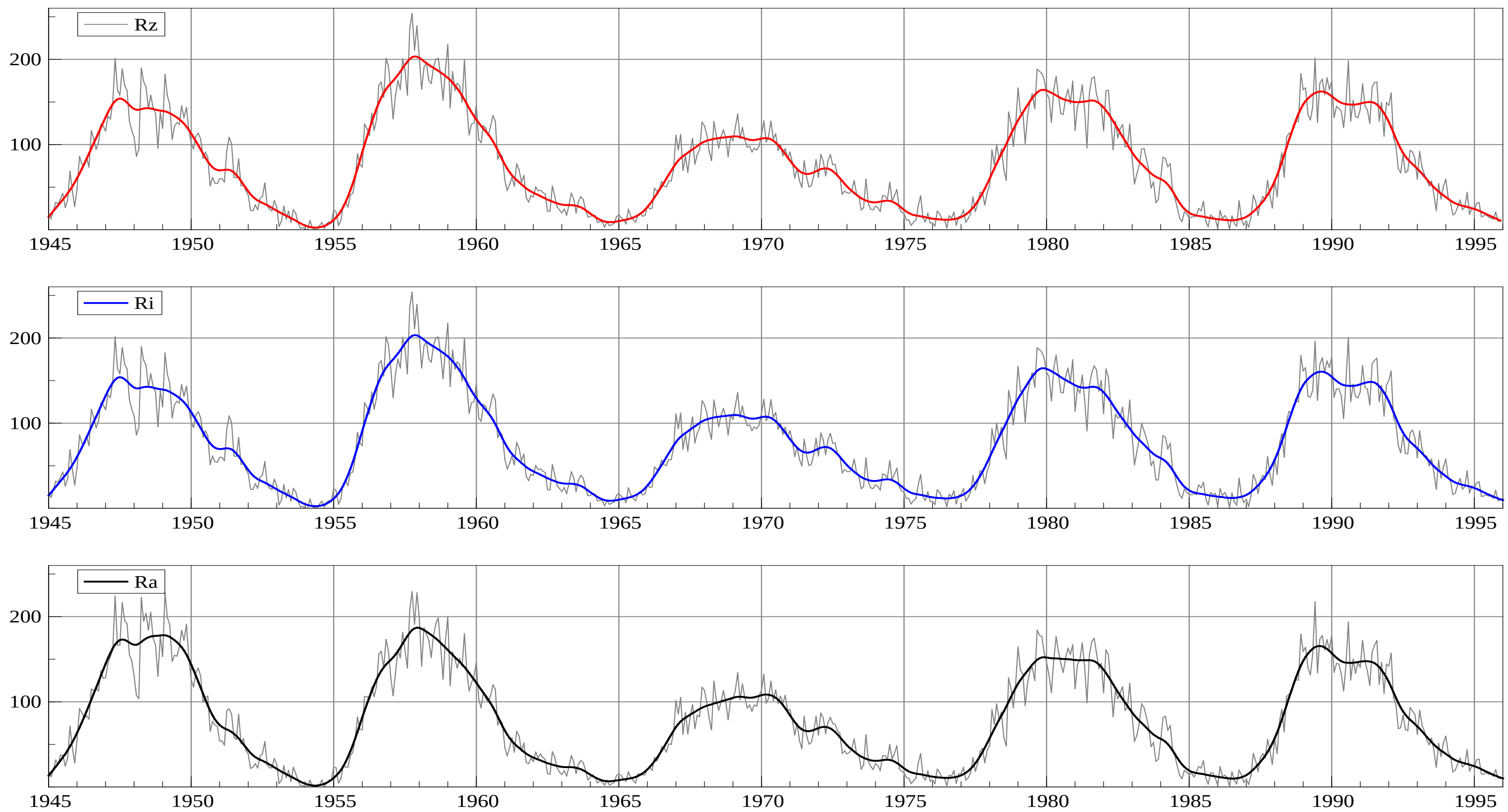
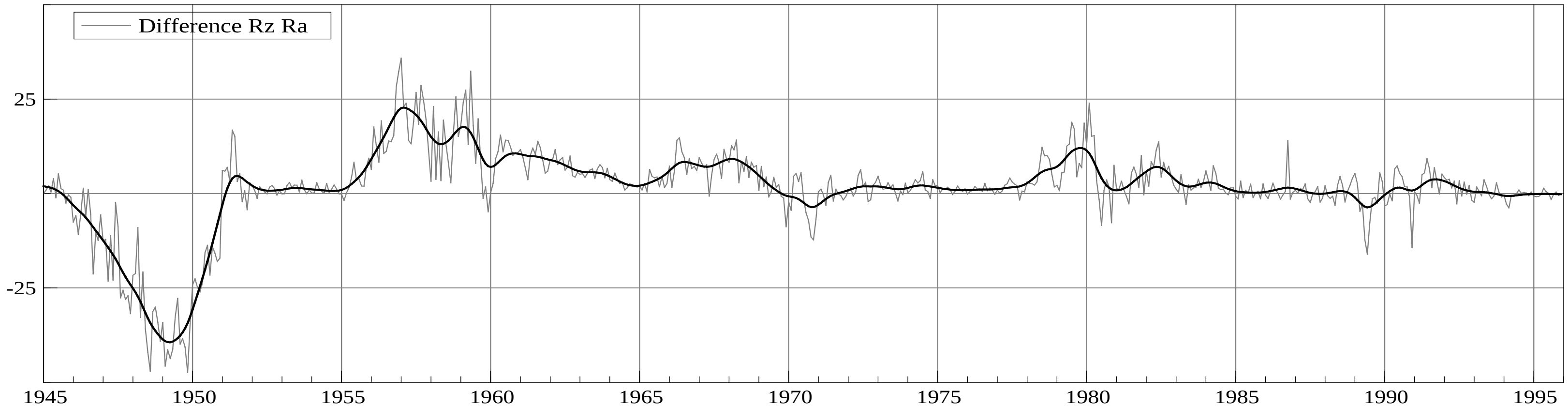
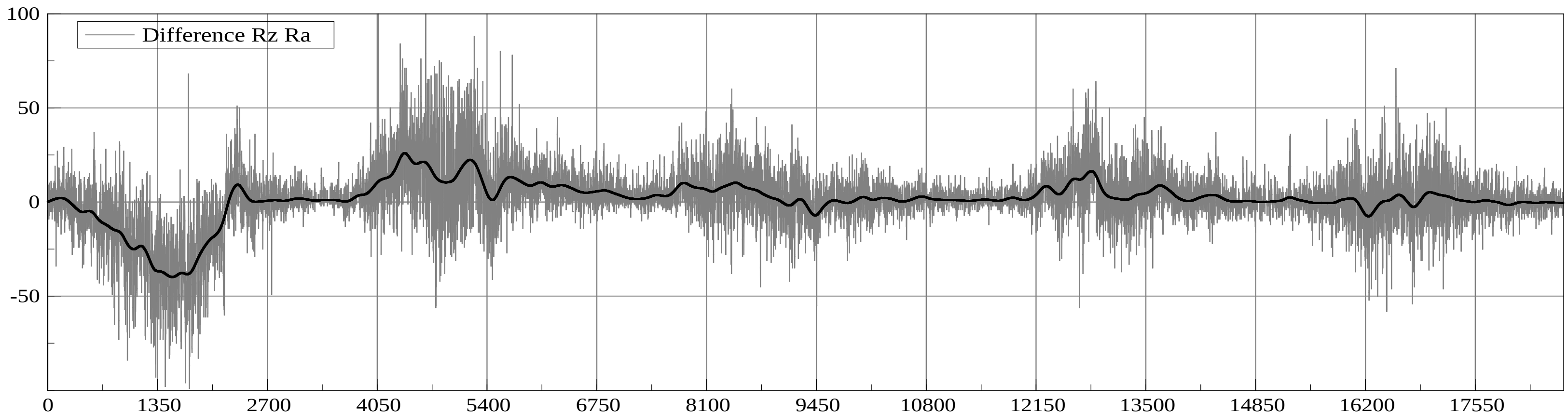


Vergleichsreihen 1945 - 2003

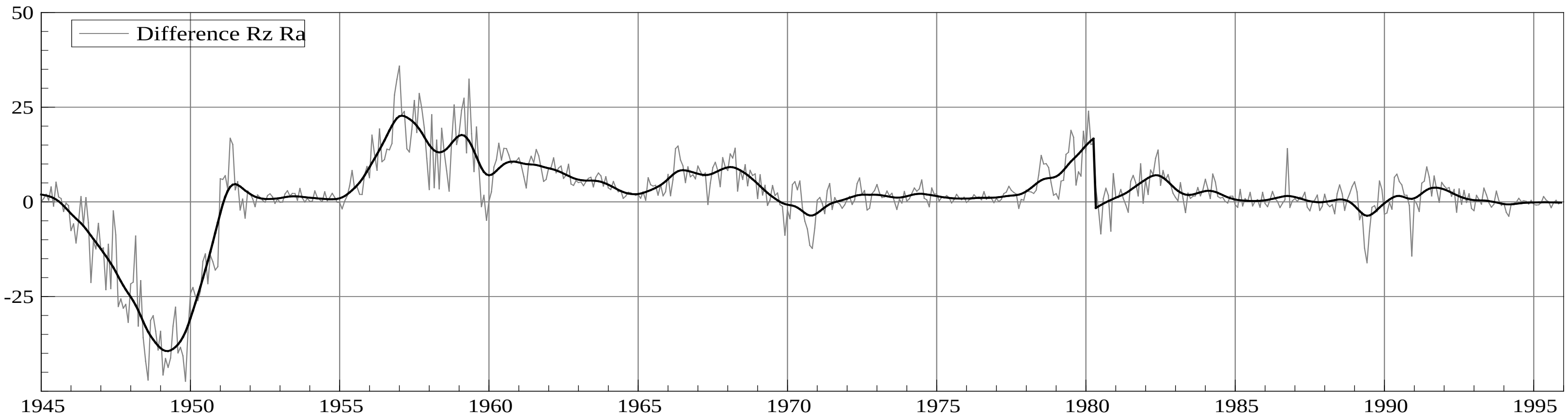


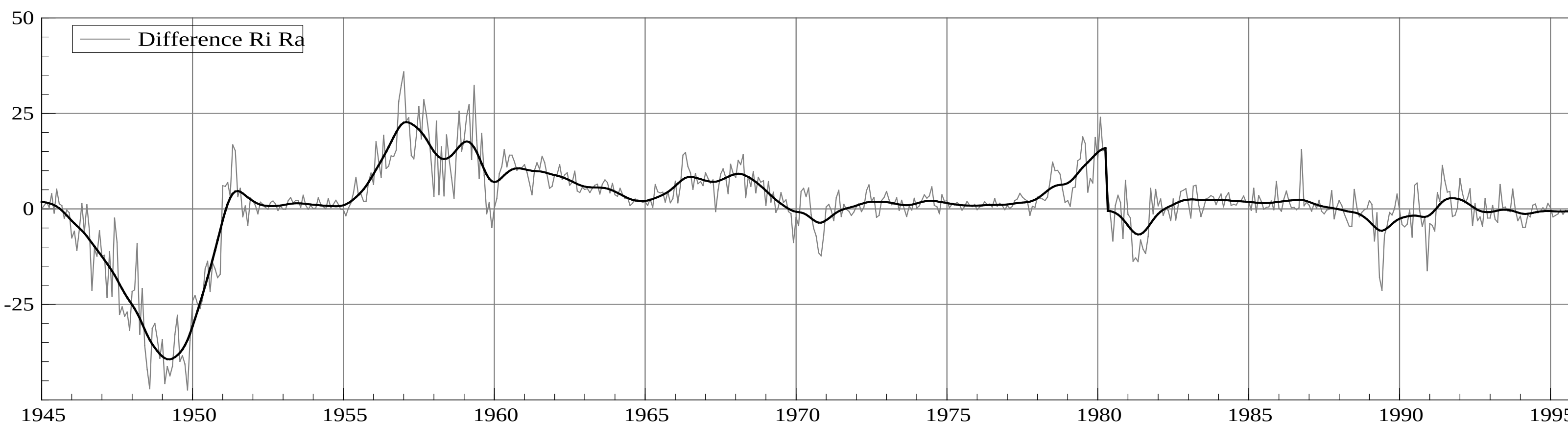
Differenzenreihen 1945 - 1995



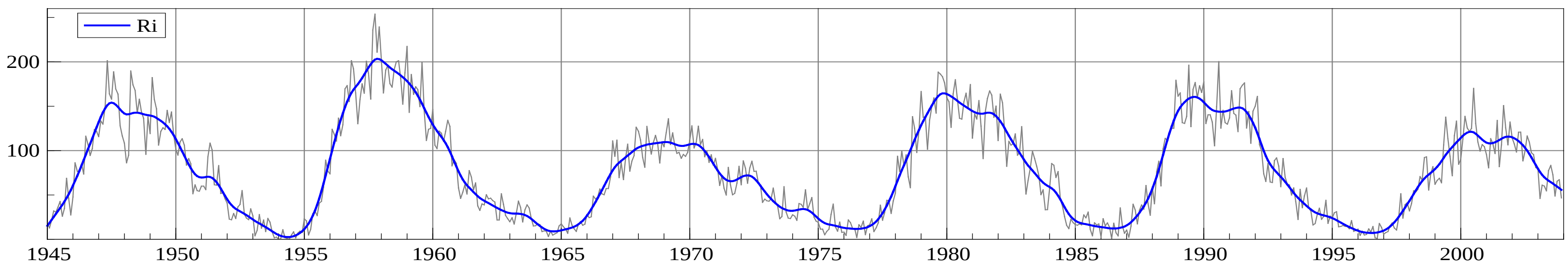


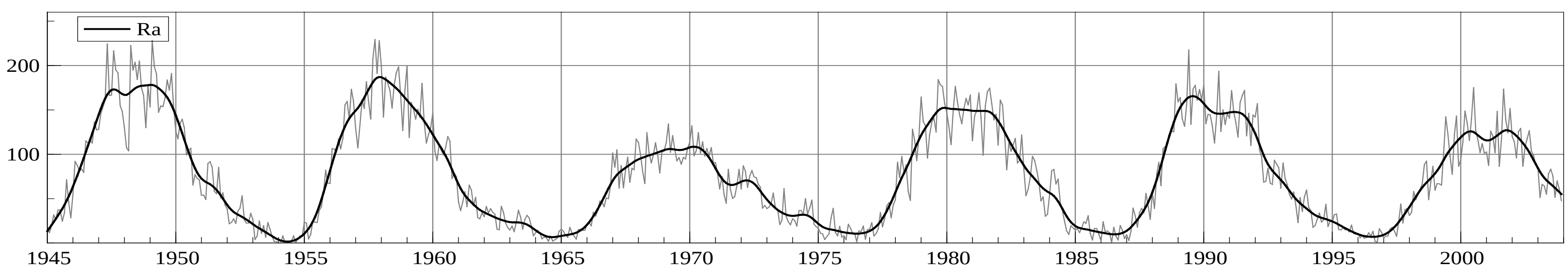
Homogenität 1945 - 1995

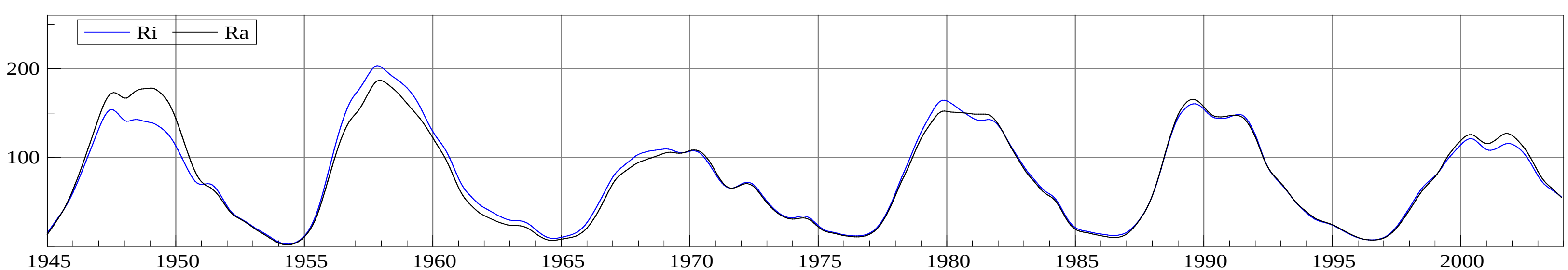




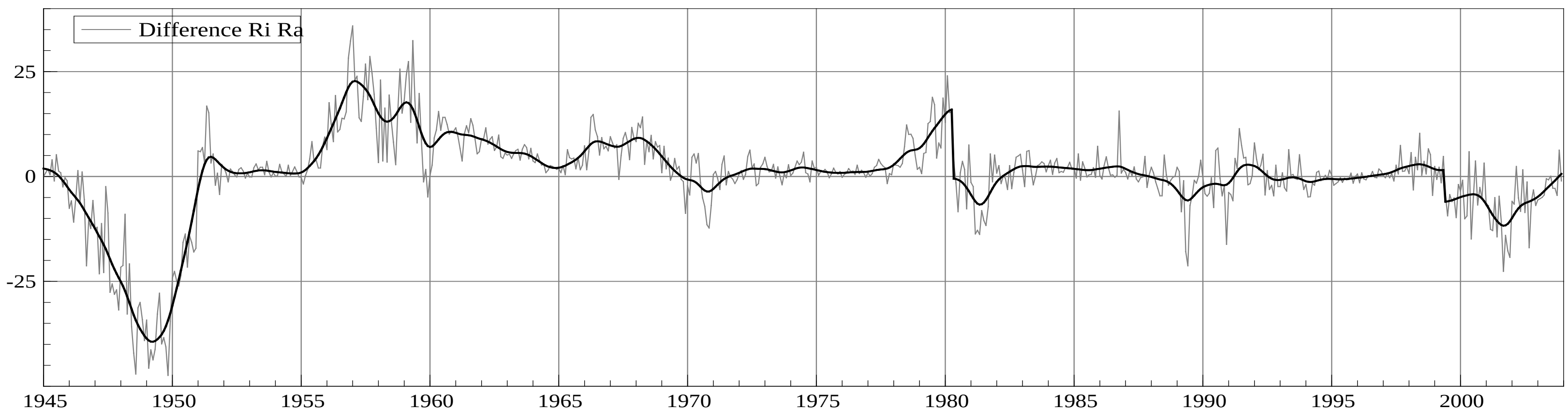
Vergleichsreihen 1945 - 2003

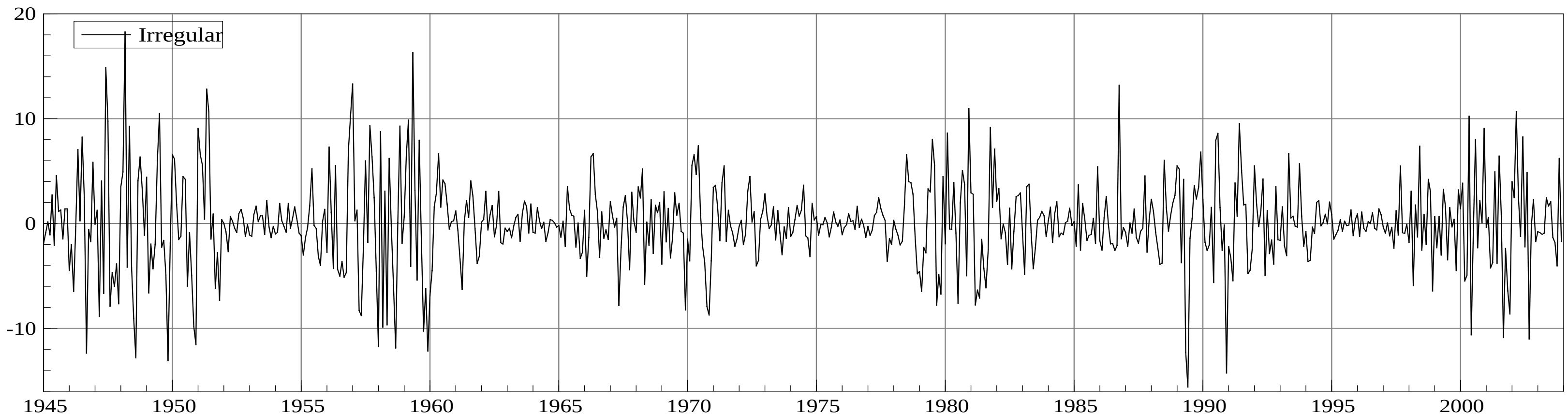




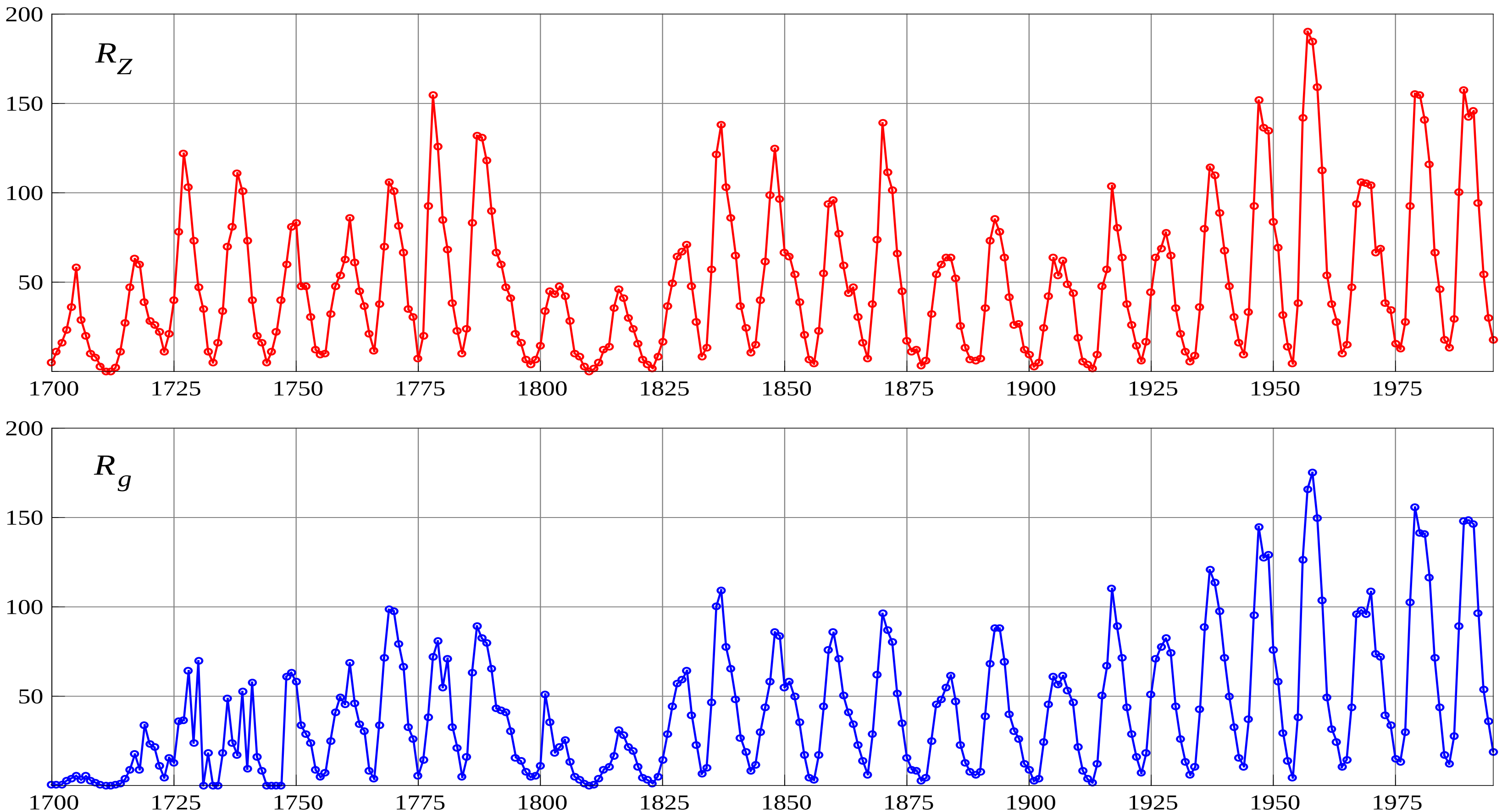


Homogenität 1945 - 2003





Vergleichsreihe 1700 - 1995



Relativzahldefinitionen

- Zürcher Sonnenfleckenrelativzahl

$$R_Z = k\,(10 \cdot g + f)$$

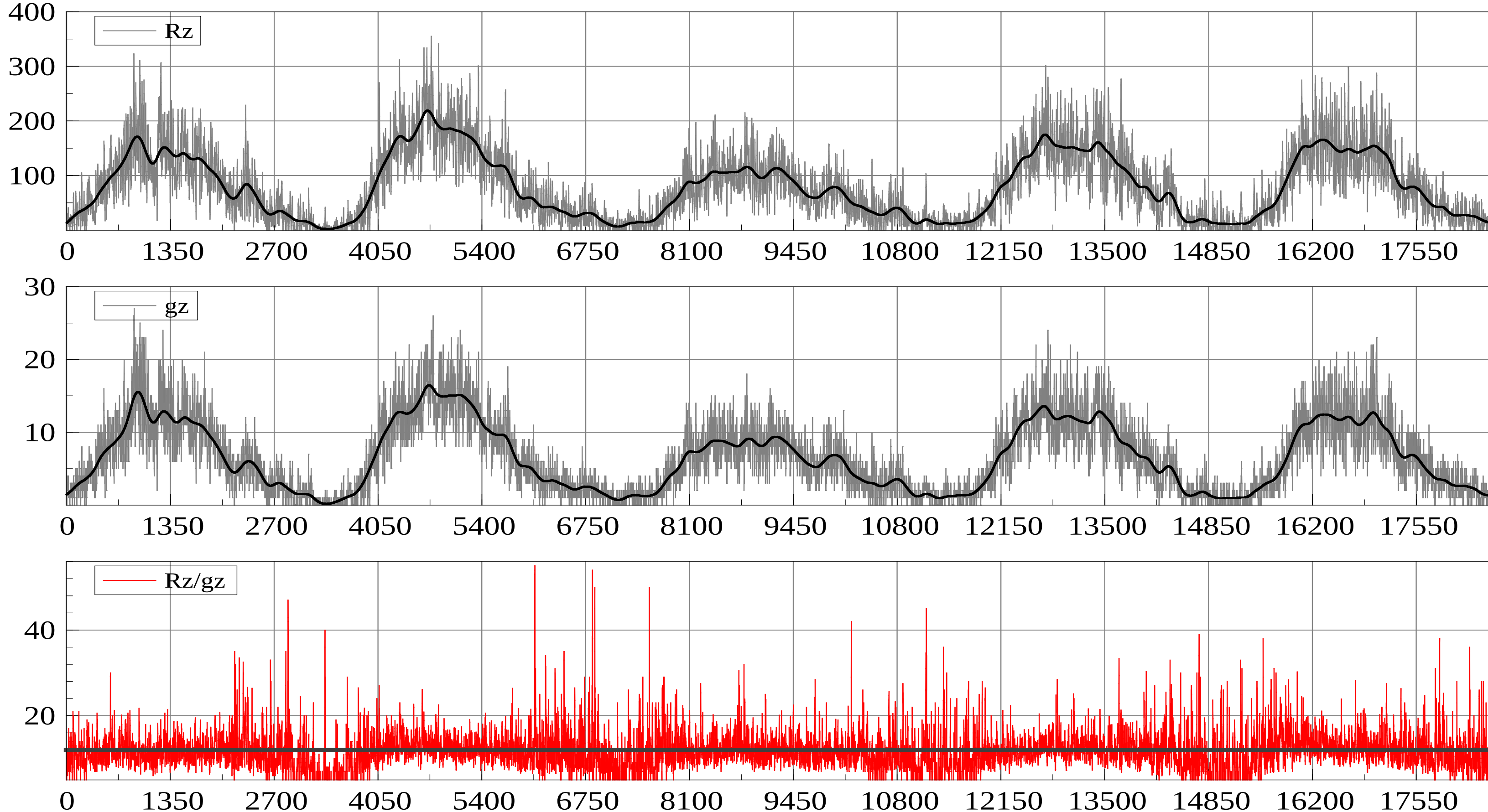
⇨ Gruppen- und Fleckenzahlen bestimmt am 83/1320 mm Fraunhoferrefraktor von Rudolf Wolf

- Gruppierte Sonnenfleckenrelativzahl

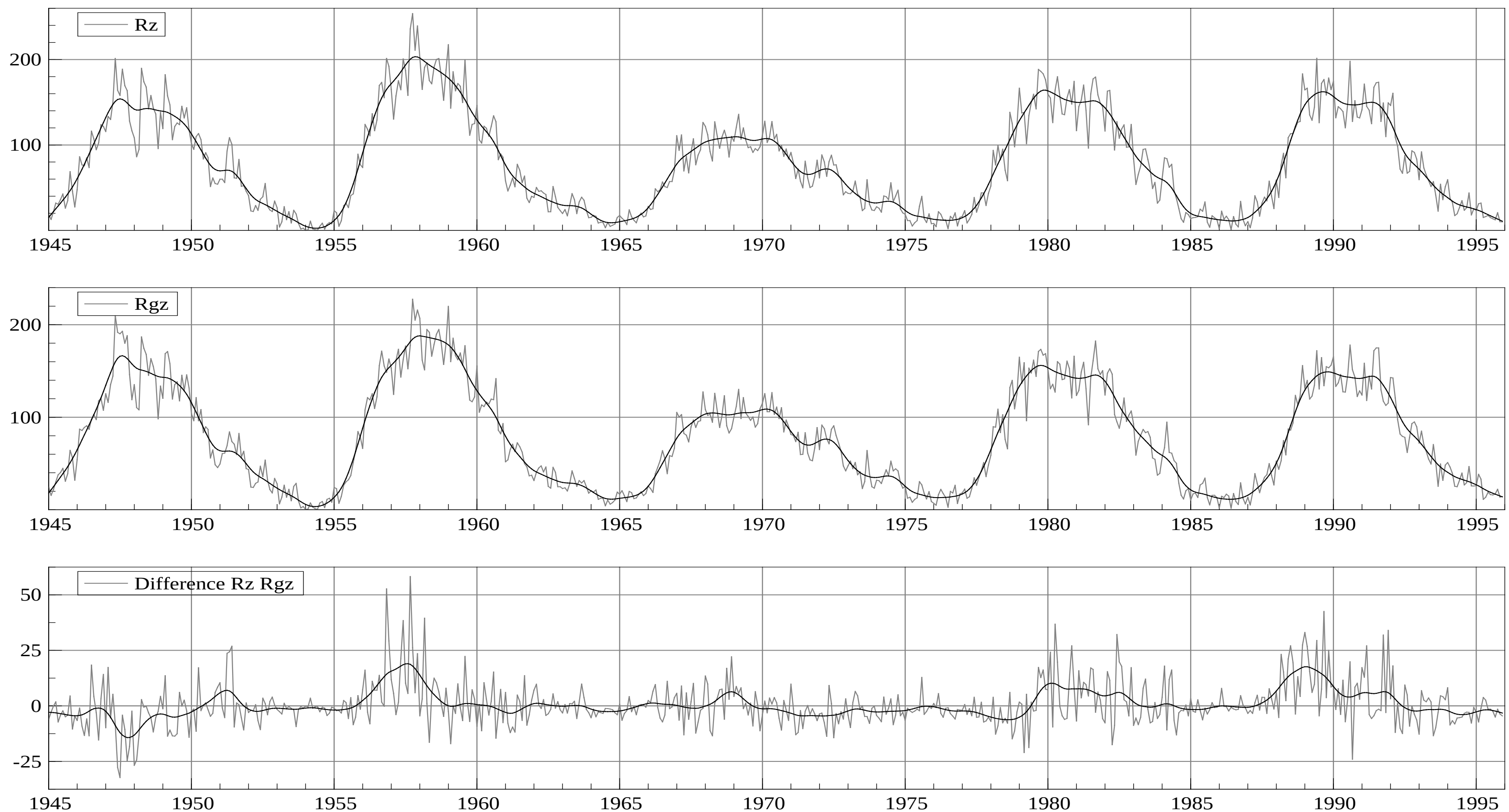
$$R_g = \frac{12.08}{N} \sum_{i=1}^{N} k_i\, g_i$$

⇨ Gruppenzahlen des Royal Greenwich Observatoriums (RGO) bestimmt ab Photoheliogrammen

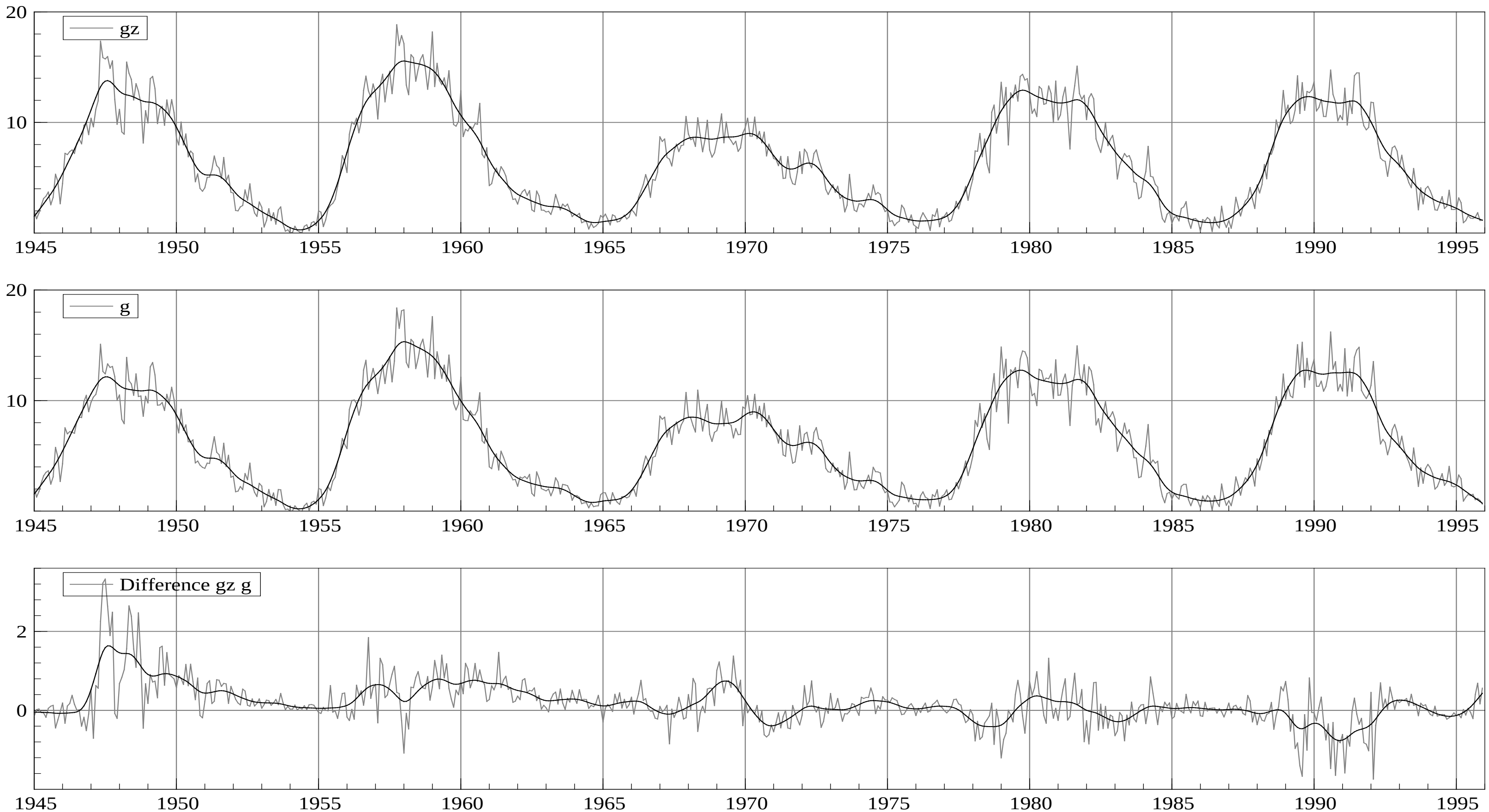
Verhältnis R_z / g_z 1945 - 1995



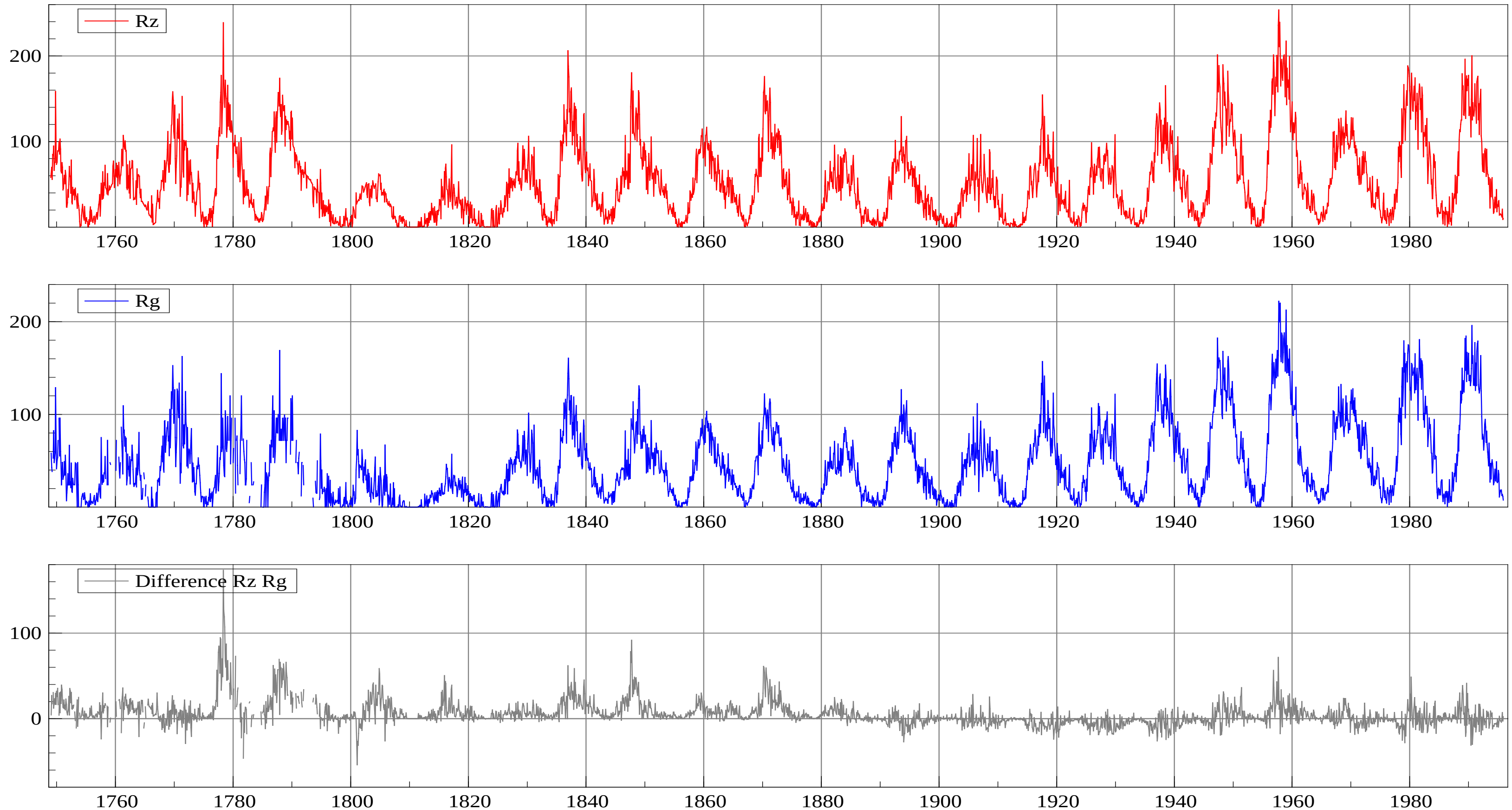
Definitionsunterschiede 1945 - 1995



Rekonstruktionsdifferenz 1945 - 1995



Langfristige Homogenität 1749 - 1995



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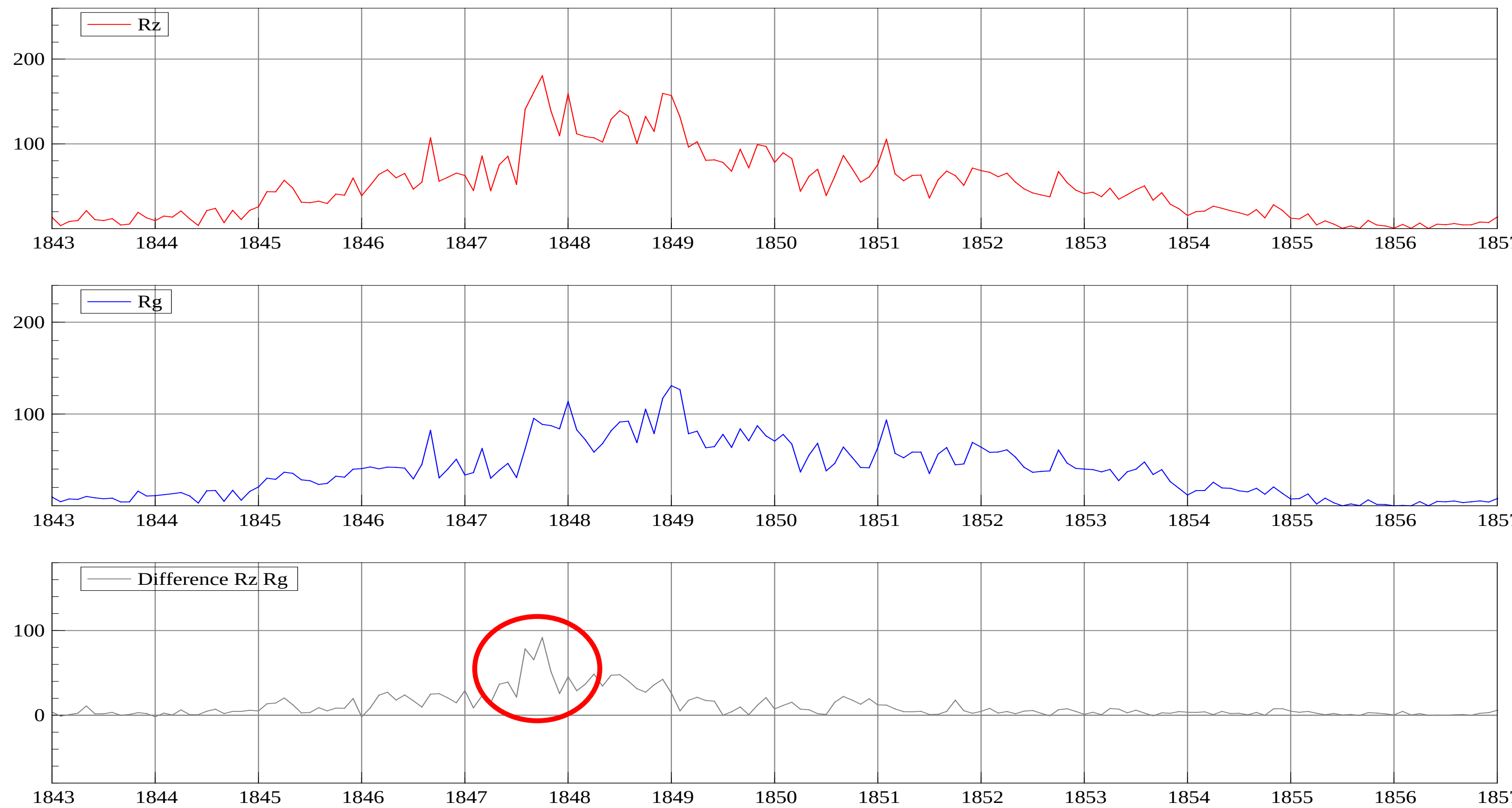
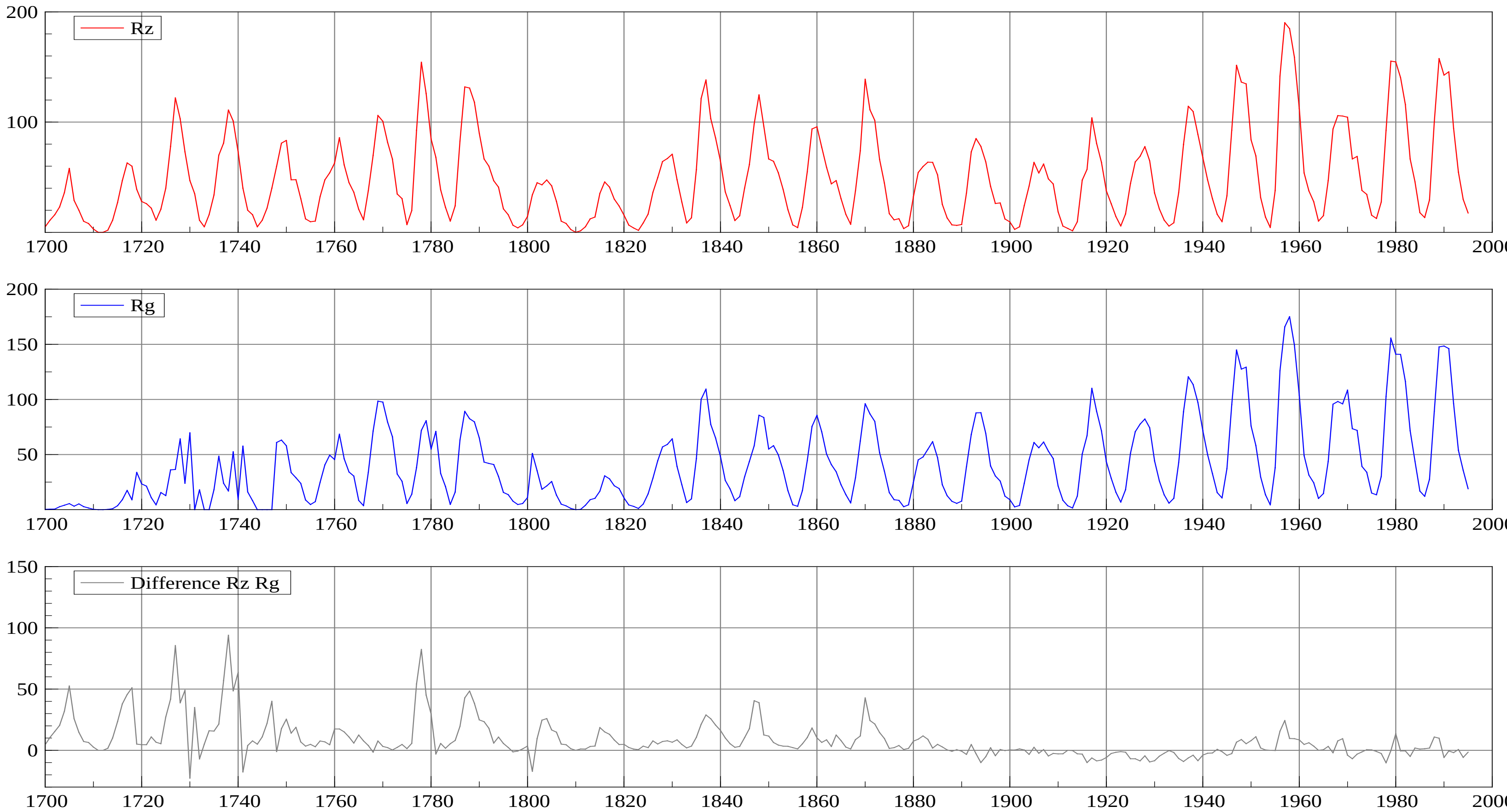
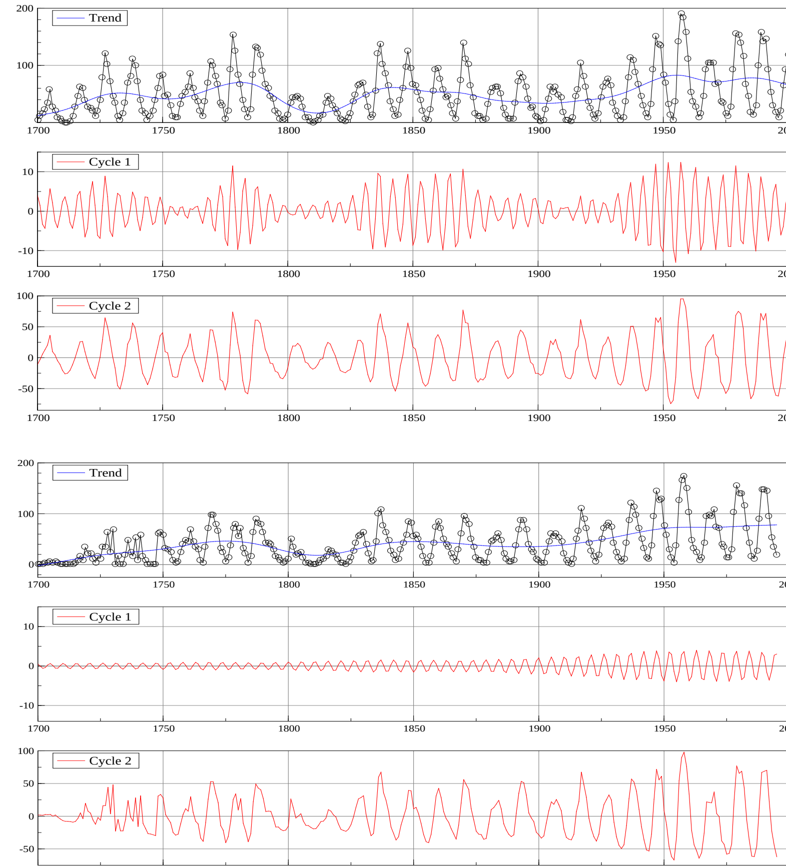


Langfristige Homogenität 1700 - 1995



“Do we have the right reconstruction of solar activity ?”



“Do we have the right reconstruction of solar activity ?”

- Die Wolfsche Reihe ist inhomogen, nicht nur in den rekonstruierten, sondern auch in den direkt beobachteten Teilen.
- Allerdings beruhen die gefundenen Differenzen weniger auf Inhomogenitäten denn auf Rekonstruktionsmängeln.
- Offensichtlich müsste die Wolfsche Reihe mit einer validen Auswertungsmethode, welche es erlaubt, die mehr oder weniger kurzen Beobachtungsserien zu einer gemeinsamen, homogenen Reihe zusammenzufassen, neu rekonstruiert werden.
- Hierzu wären allerdings die zahlreichen Originalbeobachtungen kritisch zu sichten und elektronisch zu erfassen.