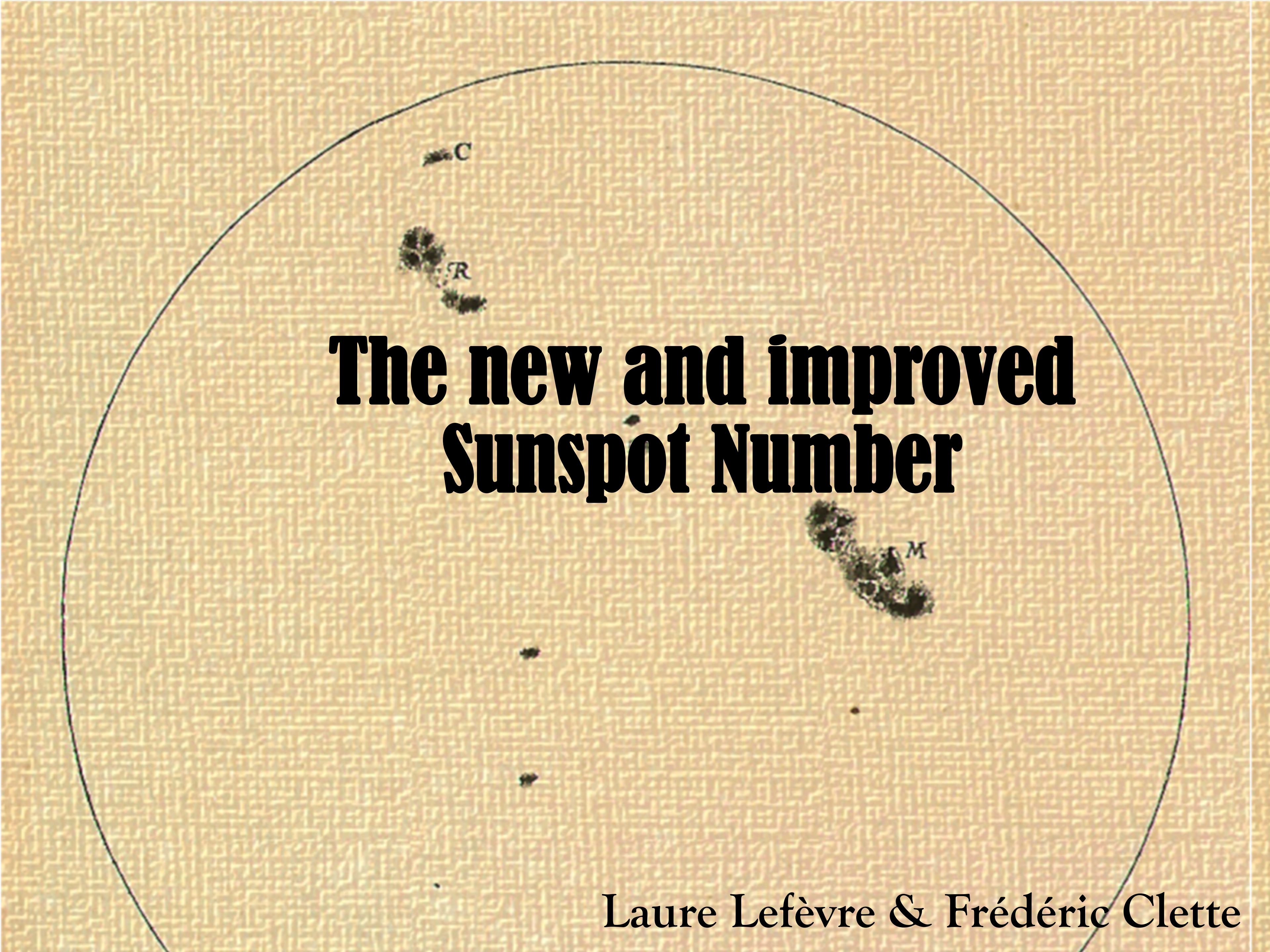

The new and improved Sunspot Number

Laure Lefèvre & Frédéric Clette

The 400-year sunspot record

- Only direct record of the evolution of the solar cycle over multiple centuries
- Longest scientific experiment still ongoing (*B.Owens, Nature, March 2013)*
- Multiple applications
- > 100 scientific publications / year
- Part of public culture and astronomy education
    - > 150 000 Google hits on “sunspot number”

The July 1st transition

- SILSO website :http://www.sidc.be/silso/

The July 1st transition

lefevre.laure@gmail.com – Gmail

Home | Data | FAQ | Observers | News-Archive | Contact | Subscribe

Sunspot Index and Long-term Solar Observations

World Data Center for the production, preservation and dissemination of the international sunspot number

Major change of data set on July 1st, 2015: key information

Menu

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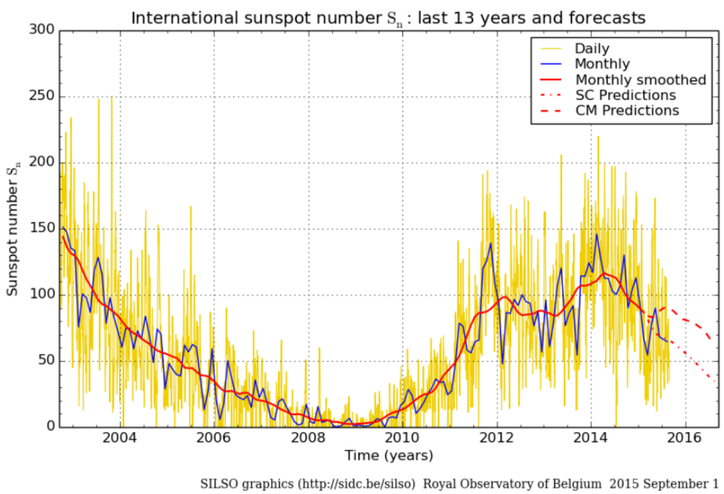
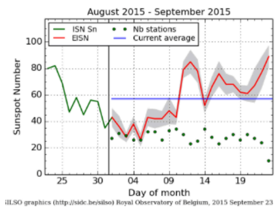
Sunspot number series: latest update



Latest Sunspot Bulletin

Daily estimated sunspot number



EISN DATA FILES

19 September : 62

20 September : 61

21 September : 67

The July 1st transition

- SILSO website : http://www.sidc.be/silso/
- Change of scale : 0.6 factor dropped
- Pilot station is still Locarno, but Locarno "unweighted" (additional factor 1.177)
- Error bars
- $S_N = R_i / (0.6 \times 1.177)$

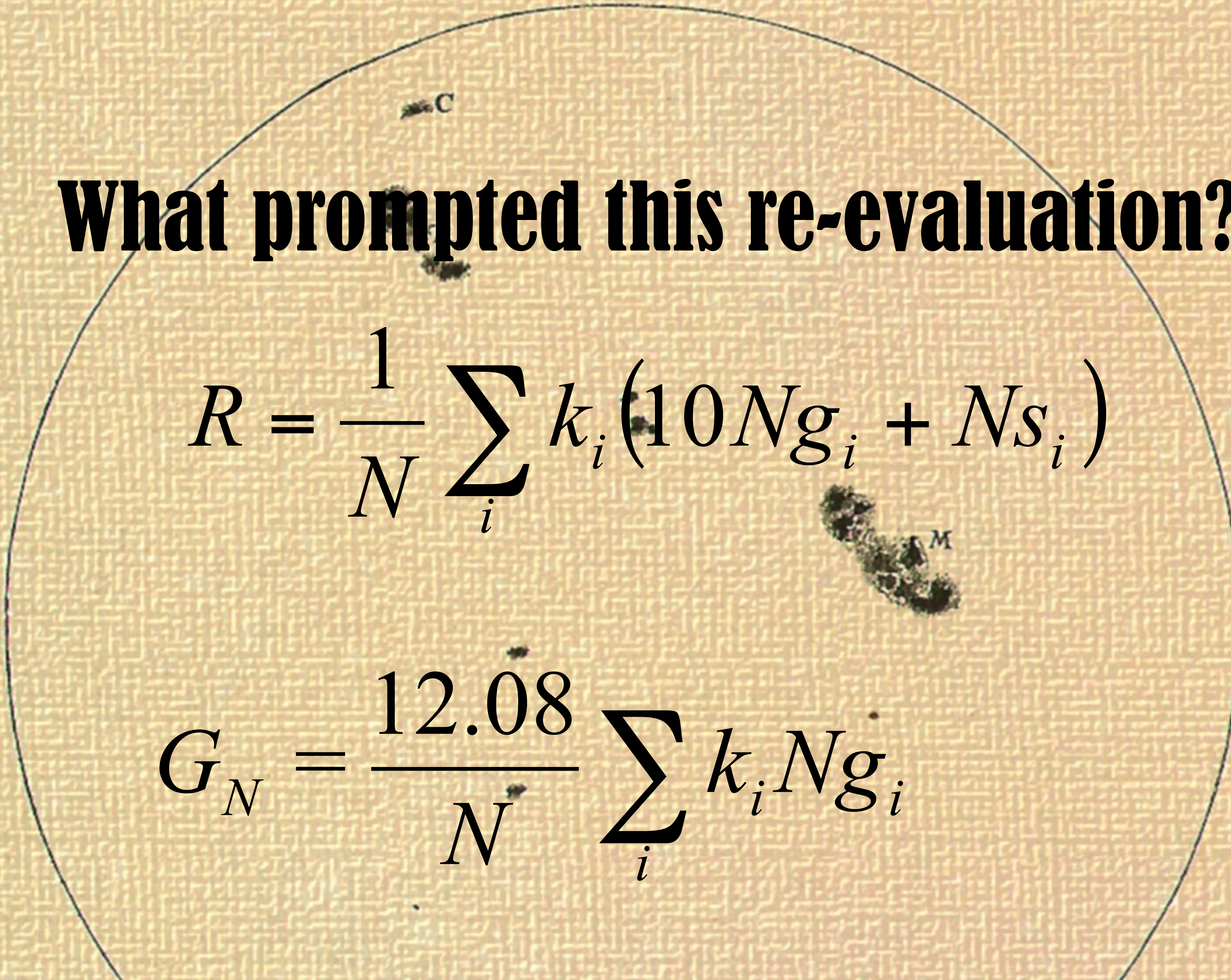
The July 1st transition

- New name / new implementation : V2.0 (old series: V1.0)
- Filenames with a **2-digit version number: Vn.i**
  - **n**: for each major change to the SN values
  - **i**: for minor changes (e.g. isolated typos) or side modifications (e.g. error estimates, file format).

What prompted this re-evaluation?

$$R = \frac{1}{N} \sum_i k_i \left(10 Ng_i + Ns_i \right)$$

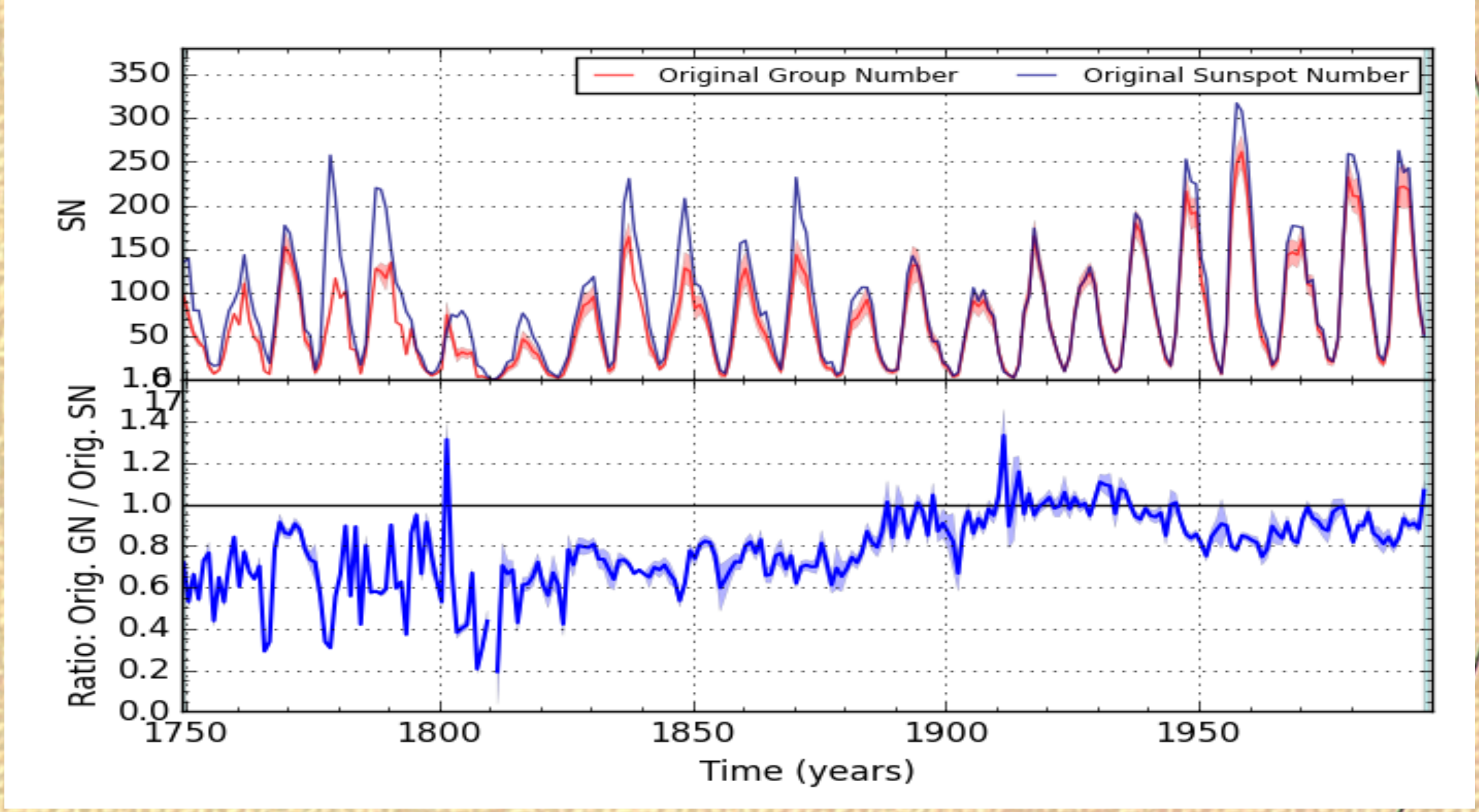
$$G_N = \frac{12.08}{N} \sum_i k_i Ng_i$$



$$R = \frac{1}{N}\sum_i k_i\left(10Ng_i + Ns_i\right)$$

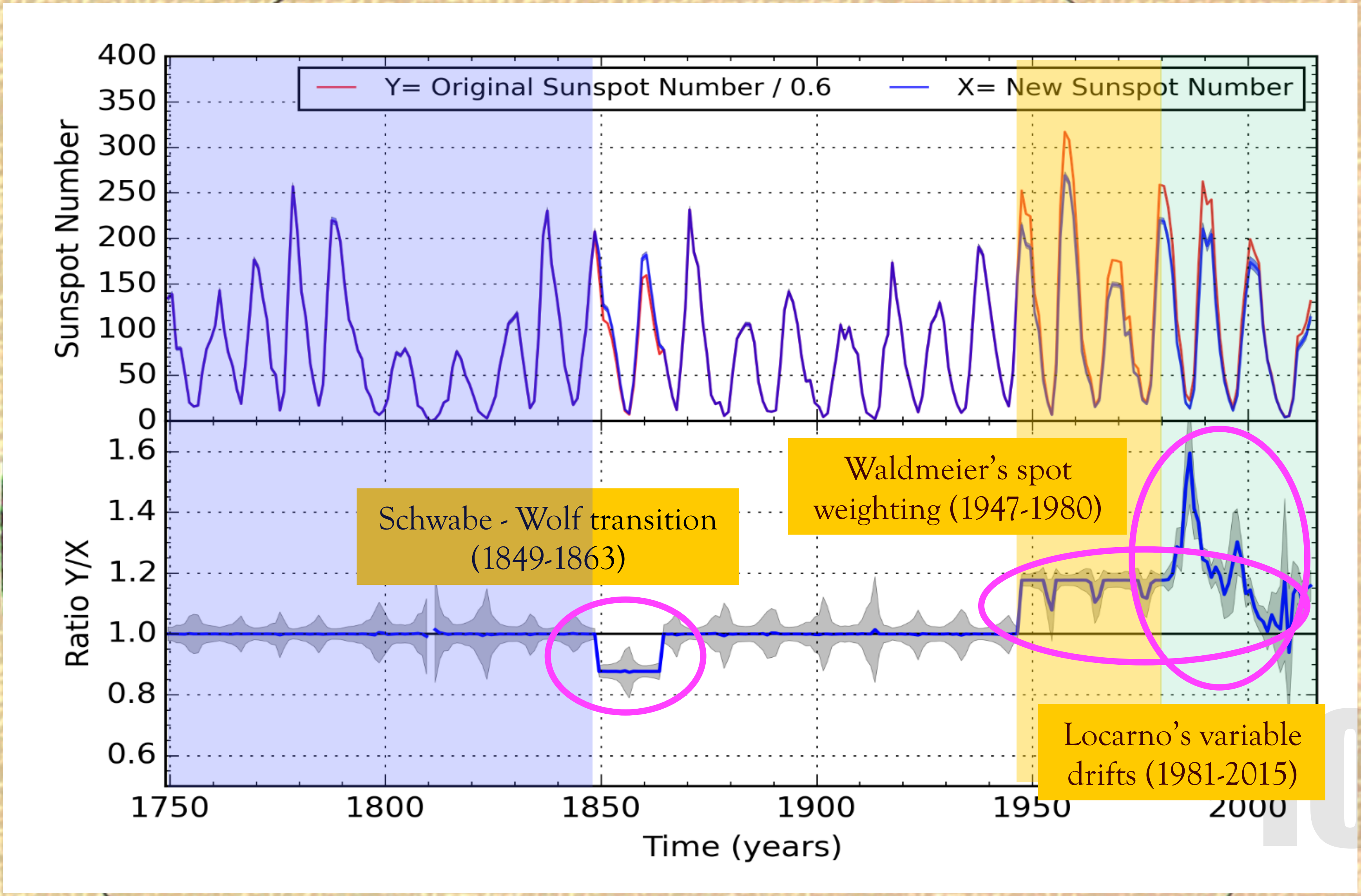
$$G_N = \frac{12.08}{N}\sum_i k_i Ng_i$$

What prompted this re-evaluation?

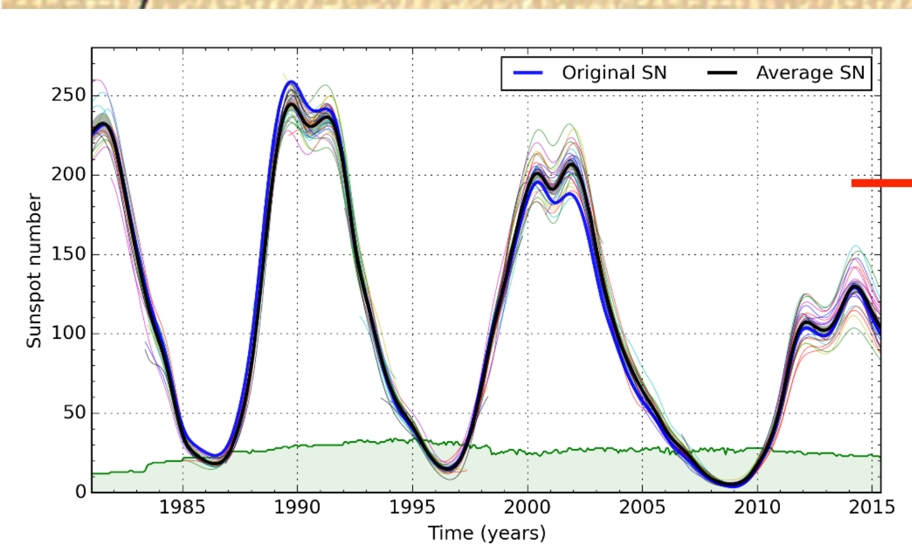


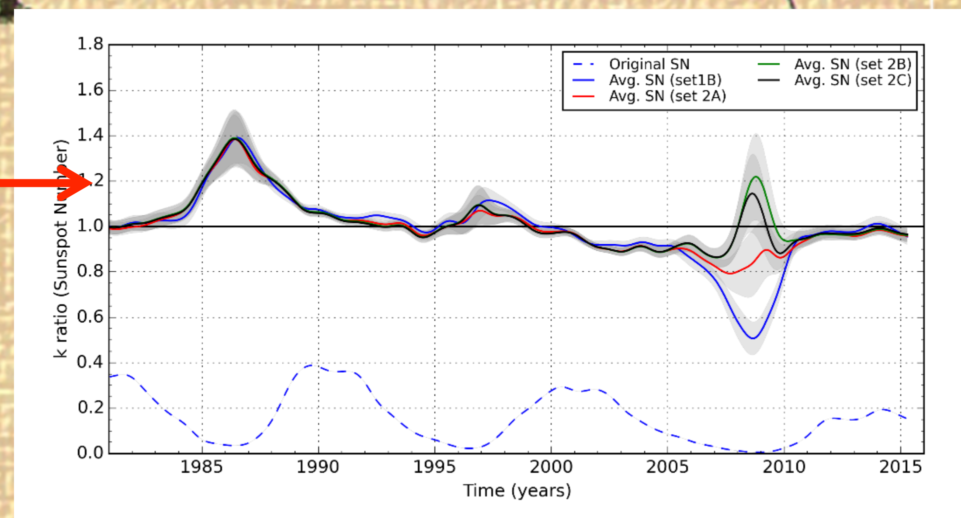
A new impulse: Sunspot Number Workshops

Sunspot Number corrections: overview

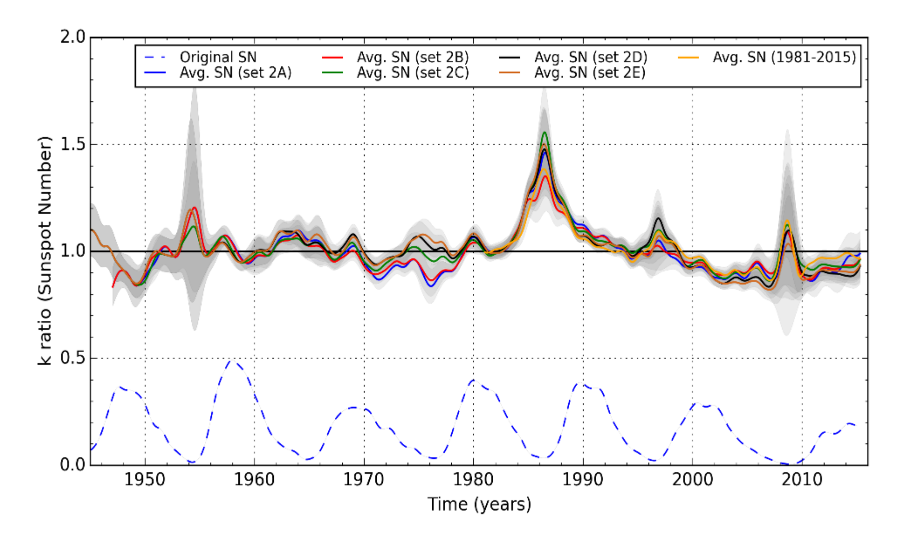


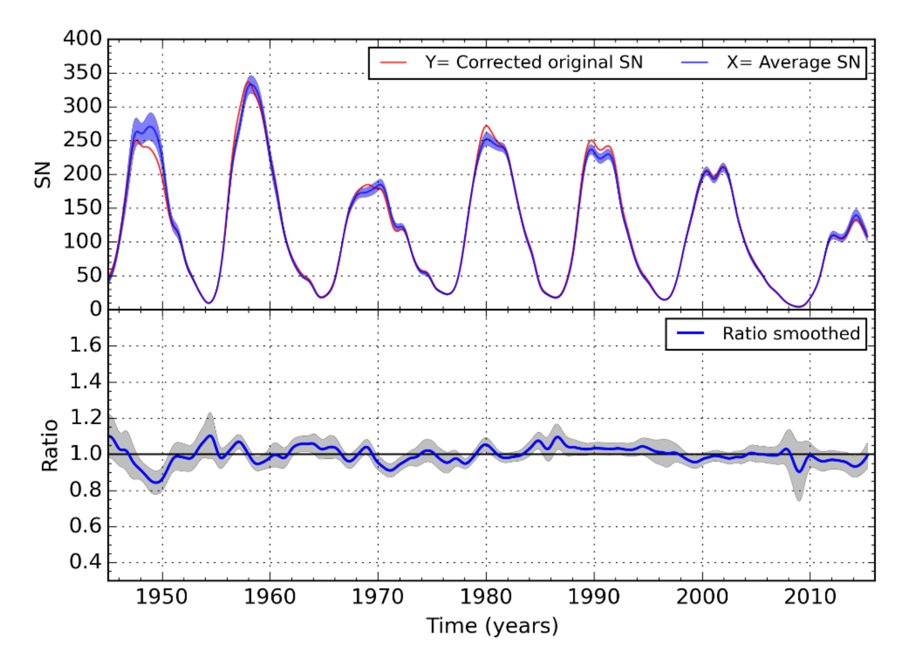
Locarno's variable drift (1981-2015)



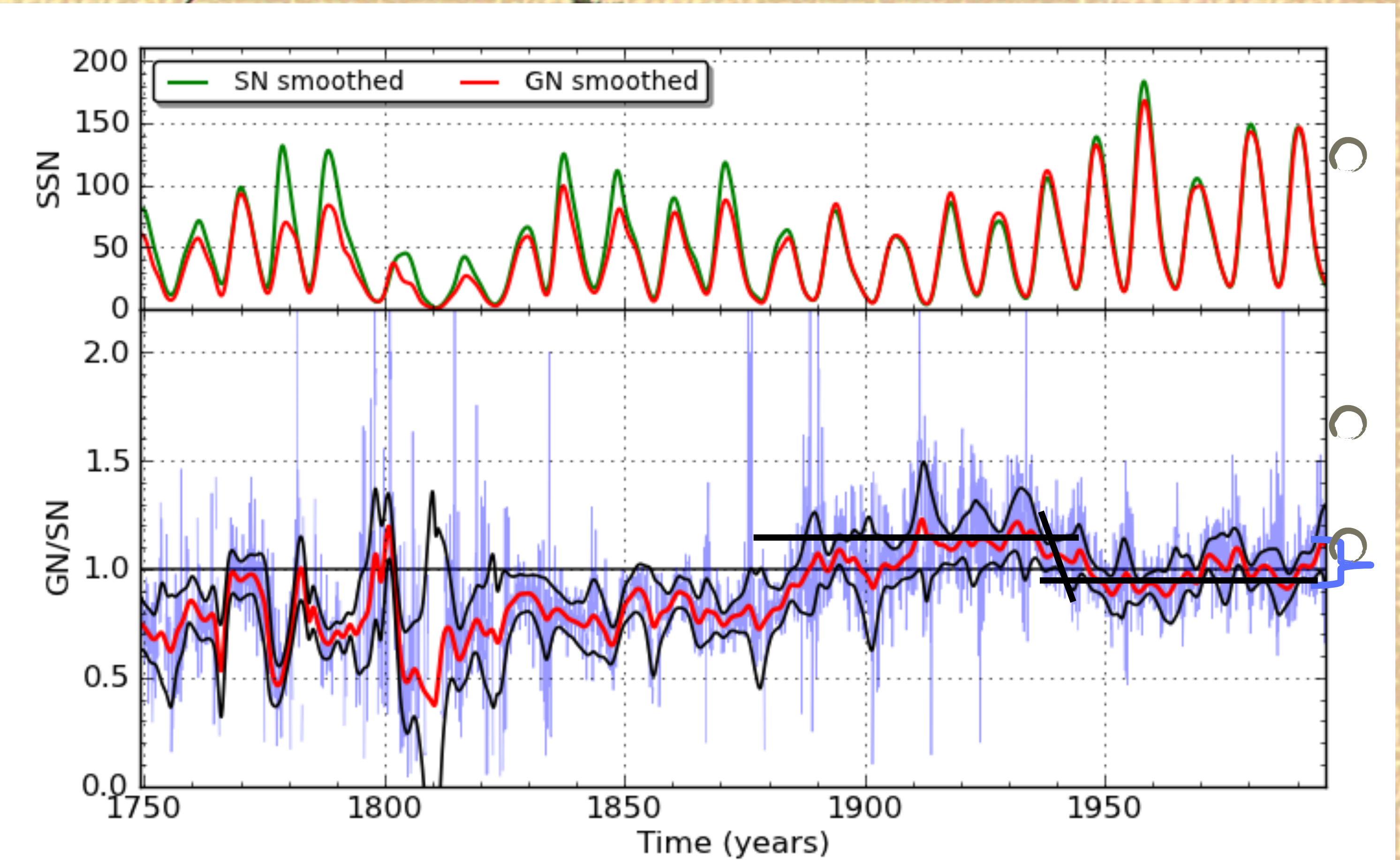


Locarno's variable drift (1981-2015)

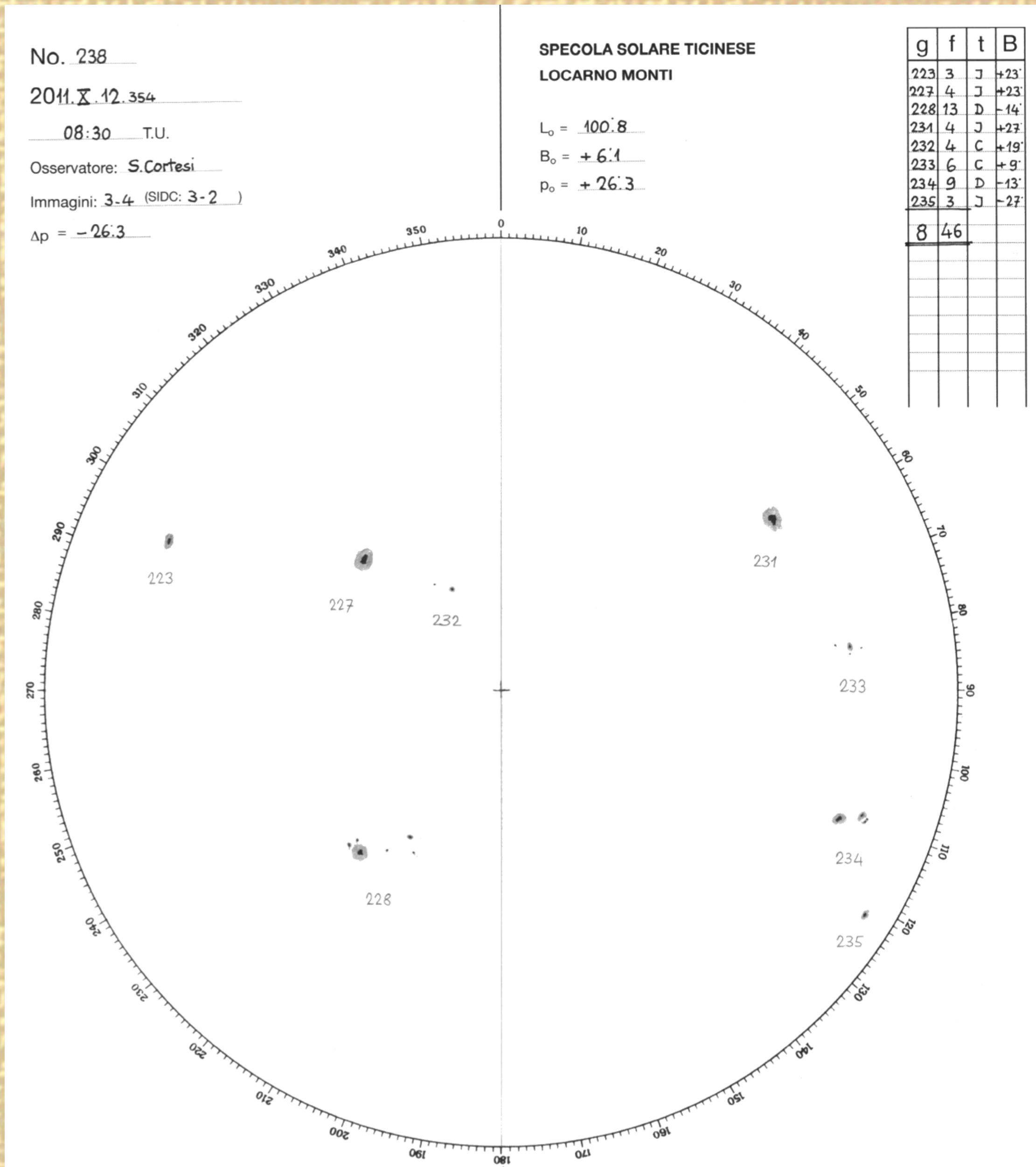




Waldmeier's weighted number (1947-1980)



- Difference in counting practice: weighting of sunspot counts
- Introduced by M. Waldmeier
- When ?
- Largely undocumented



Weighting of sunspot count

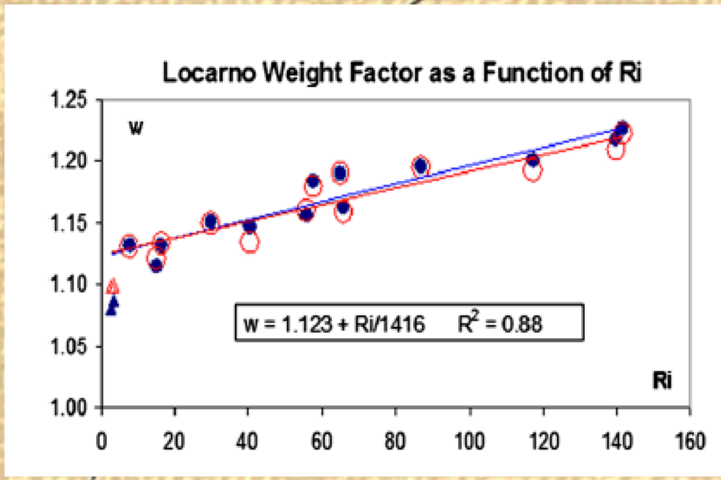
223	3	1
227	4	1
228	13	6
231	4	1
232	4	2
233	6	4
234	9	4
235	3	1
8	46	20
	126	100

26% inflated

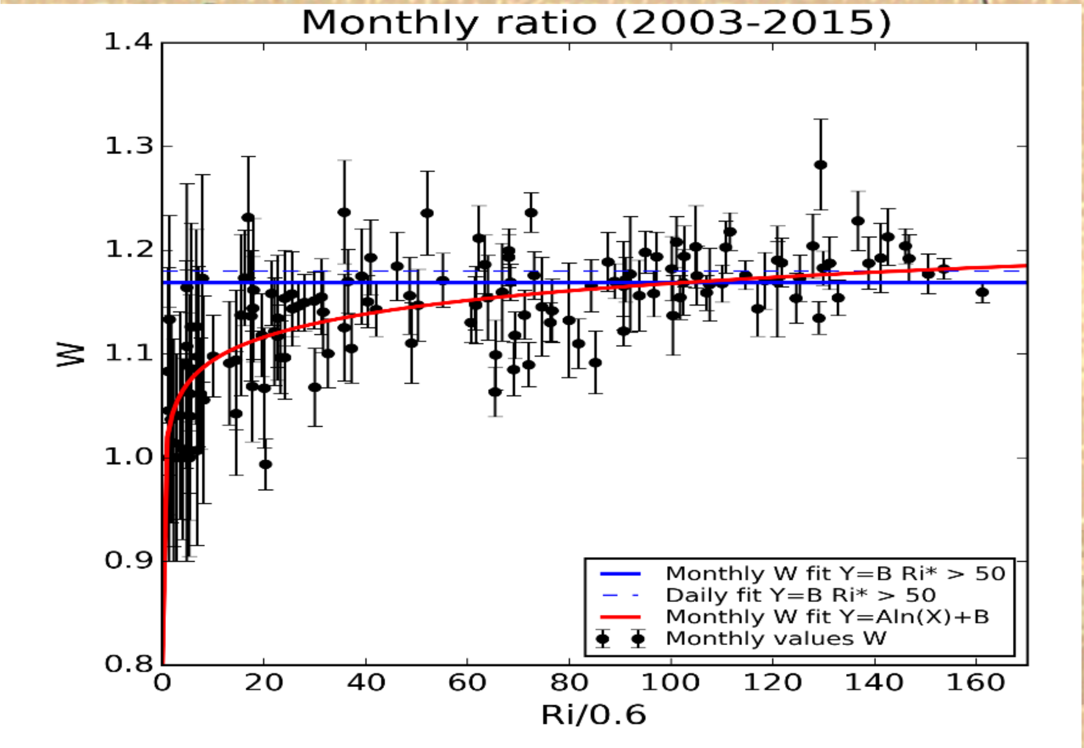
Unweighted count red

Waldmeier's weighted number (1947-1980)

A more robust determination



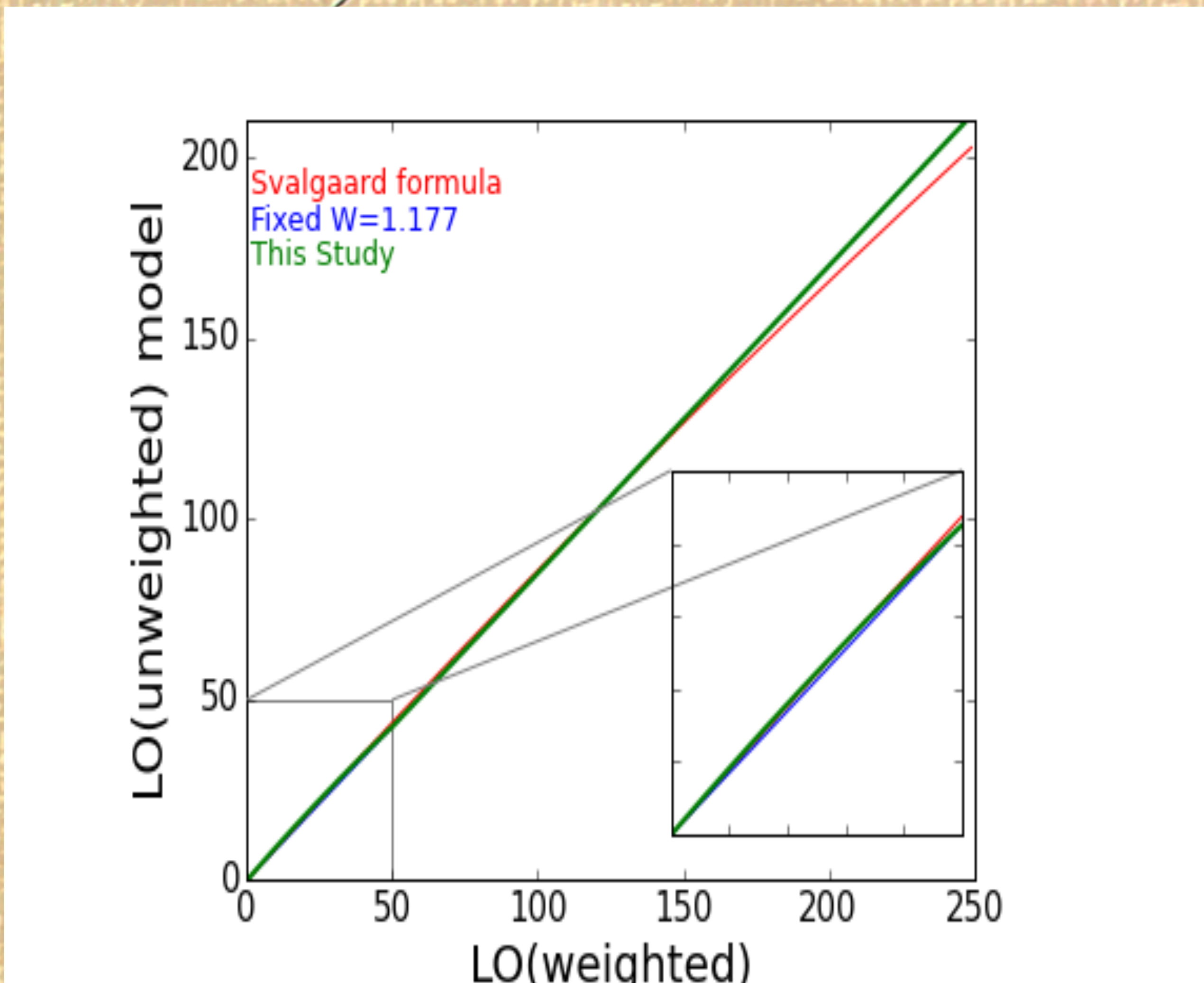
Previous determination from L. Svalgaard Review (Clette et al. 2014) : Factor of 1.2 (increase of 20% by the weighting method).



New determination : Clette et al. 2015 (Special Issue Solar Physics): dashed blue line at 1.177 (asymptotic increase of max 18%)

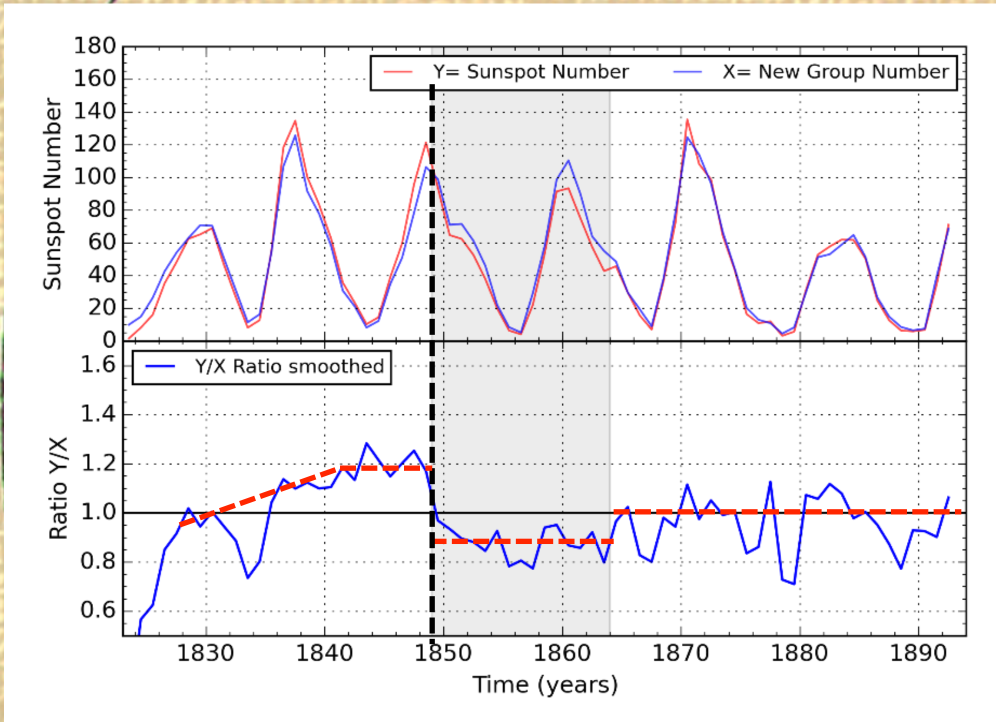
Waldmeier's weighted number (1947-1980)

A more robust determination



Main differences between the simulations od the weighting effects

The Schwabe- Wolf transition (1849-1863)

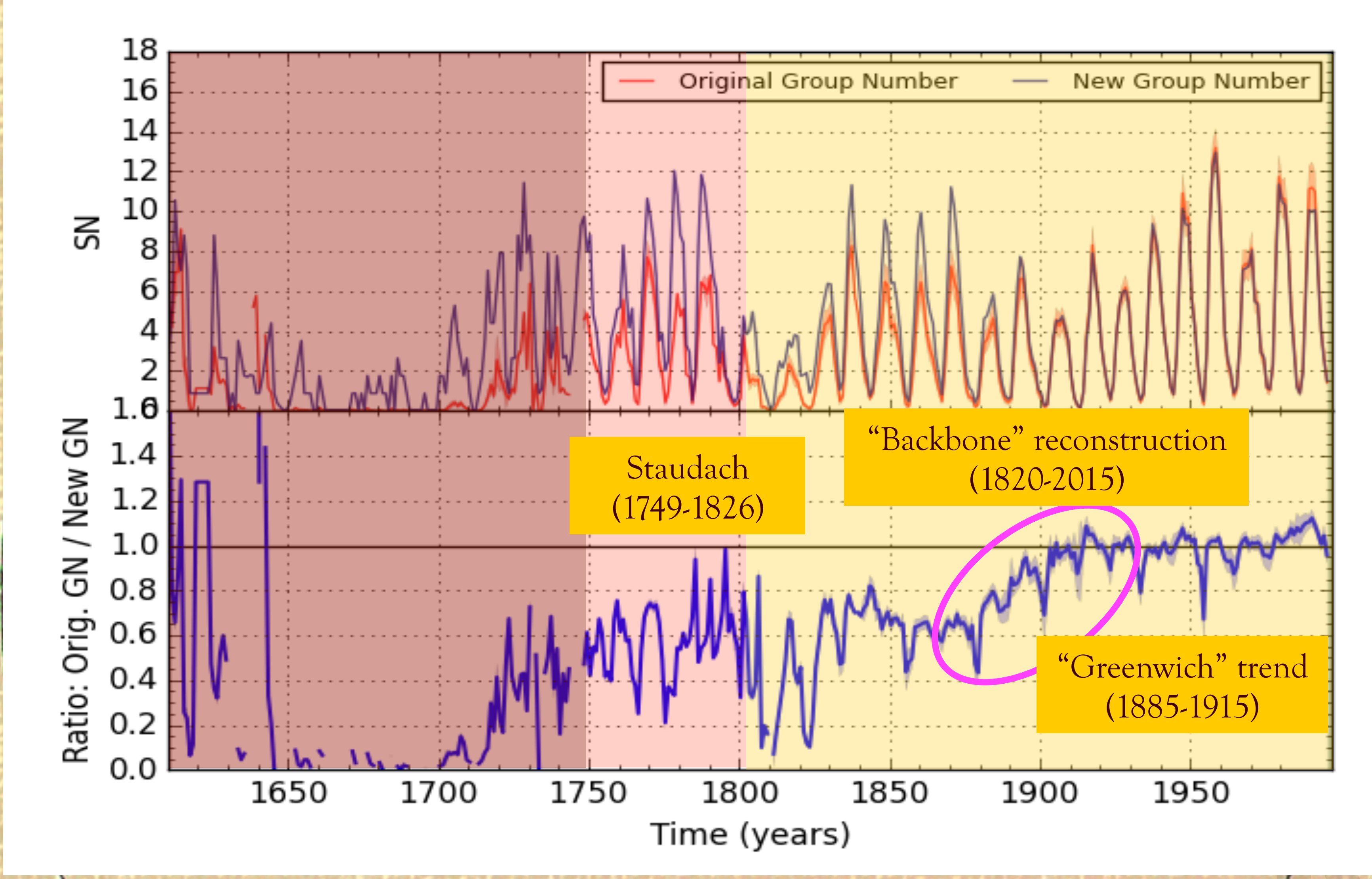


Wolf initially mixed the raw Schwabe numbers with his own observations (small portable refractors).

- Distinct markers only appear in published tables by 1863
- Standard 80mm Zürich refractor delivered in 1864

- Time-limited correction: **SN increased by 1.14 (+/- 0.02) over 1849-1863**

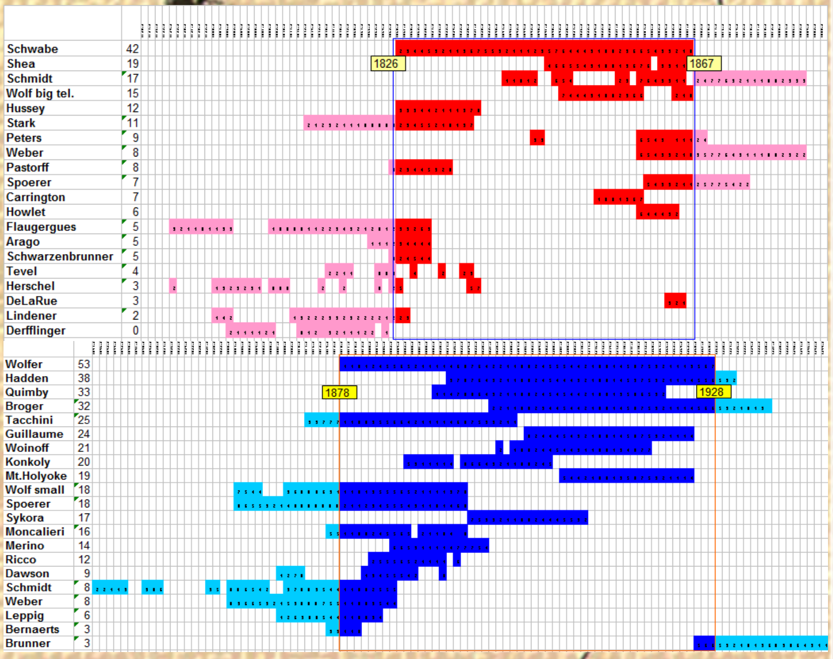
Group Number correction: overview



The "Backbone" Group Number (1749-2015)

- Original method (**Hoyt& Schatten 1998**):
  - daisy chaining of k coefficients between parallel observers, working backwards in time
  - **Non-visual reference after 1875:** photographic catalog from the Royal Greenwich Observatory
  - **Includes a 42% trend (1885-1915)** *(Clette et al. 2014)*
- **New approach for linking the scale of observers over centuries** *(Svalgaard 2012, Clette et al. 2014, Svalgaard & Schatten 2015)*:
  - "Backbone" provided by **5 long-duration observers to which other observers are normalized.**
  - Overlapping backbones are cross-calibrated
  - Only visual sunspot observers are used, including in the 20th century

Backbone observer	Main interval	Full interval	Nb Obsevers
Staudach	1749 - 1787	1740 - 1822	15
Schwabe	1826 - 1867	1794 - 1883	20
Wolfer	1878 - 1928	1841 - 1944	21
Koyama	1947 - 1993	1920 - 1996	36
Locarno	1957-2015	1950 - 2015	22



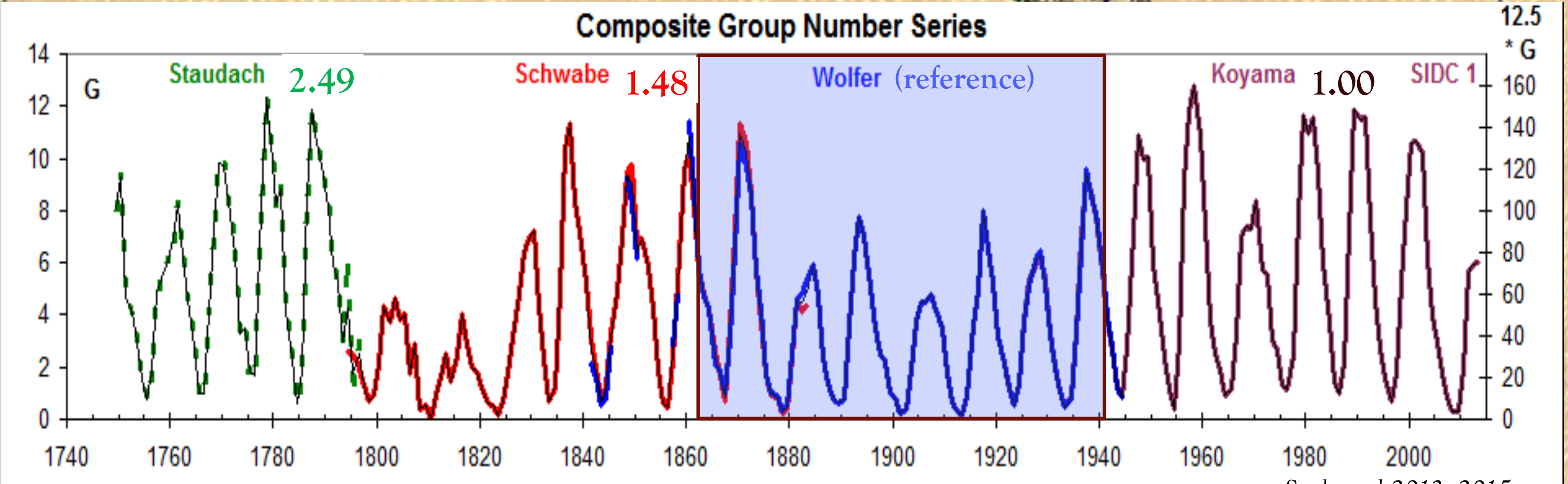
The “Backbone” Group Number (1749-2015)

- First Staudach backbone (1749-1787):
  - Insufficient group splitting: unrealistically large groups
  - Full recounting from original drawings *(Svalgaard 2015)*
- GN increased by 1.68 relative to Schwabe

Only 1 reported group

Staudach, Feb. 13 and 15 1760

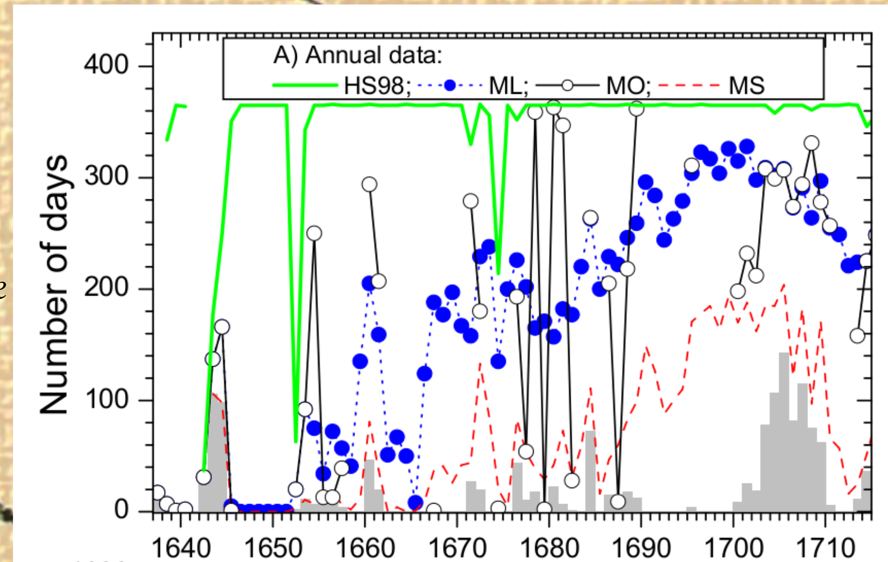
- Final 1749-2015 composite backbone:
  - Base reference: A. Wolfer (standard counts, standard refractor)



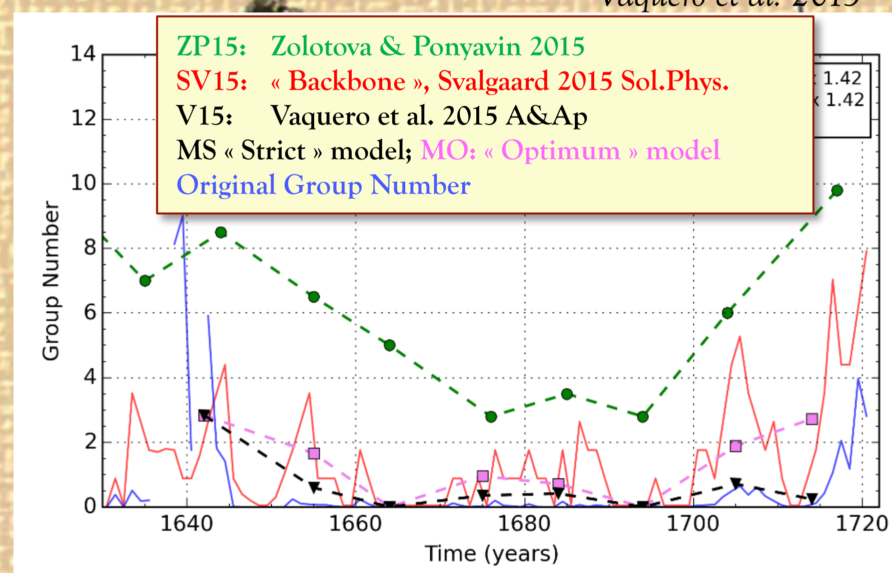
Svalgaard 2013, 2015

Revisiting the Maunder Minimum

- **Elimination of many interpolated null GNs in meridian transit observations** *(Vaquero & Gallego 2014, Clette et al. 2014, Vaquero et al. 2015 in press)*:
- Reduction of the actual coverage from ~100% down to ~60%
- **A new hypothesis** *(Zolotova & Ponyavin 2015)*: spots that did not look like round transiting planets were systematically ignored.
  - Only non-null observations are used
  - **Contradicted by several alternate approaches like the "active days" method** *(Vaquero et al. 2015, Usoskin et al. 2015)*
- **Slight increase in the sunspot numbers during the MM:**
  - Short 9-year solar cycles



Vaquero et al. 2015

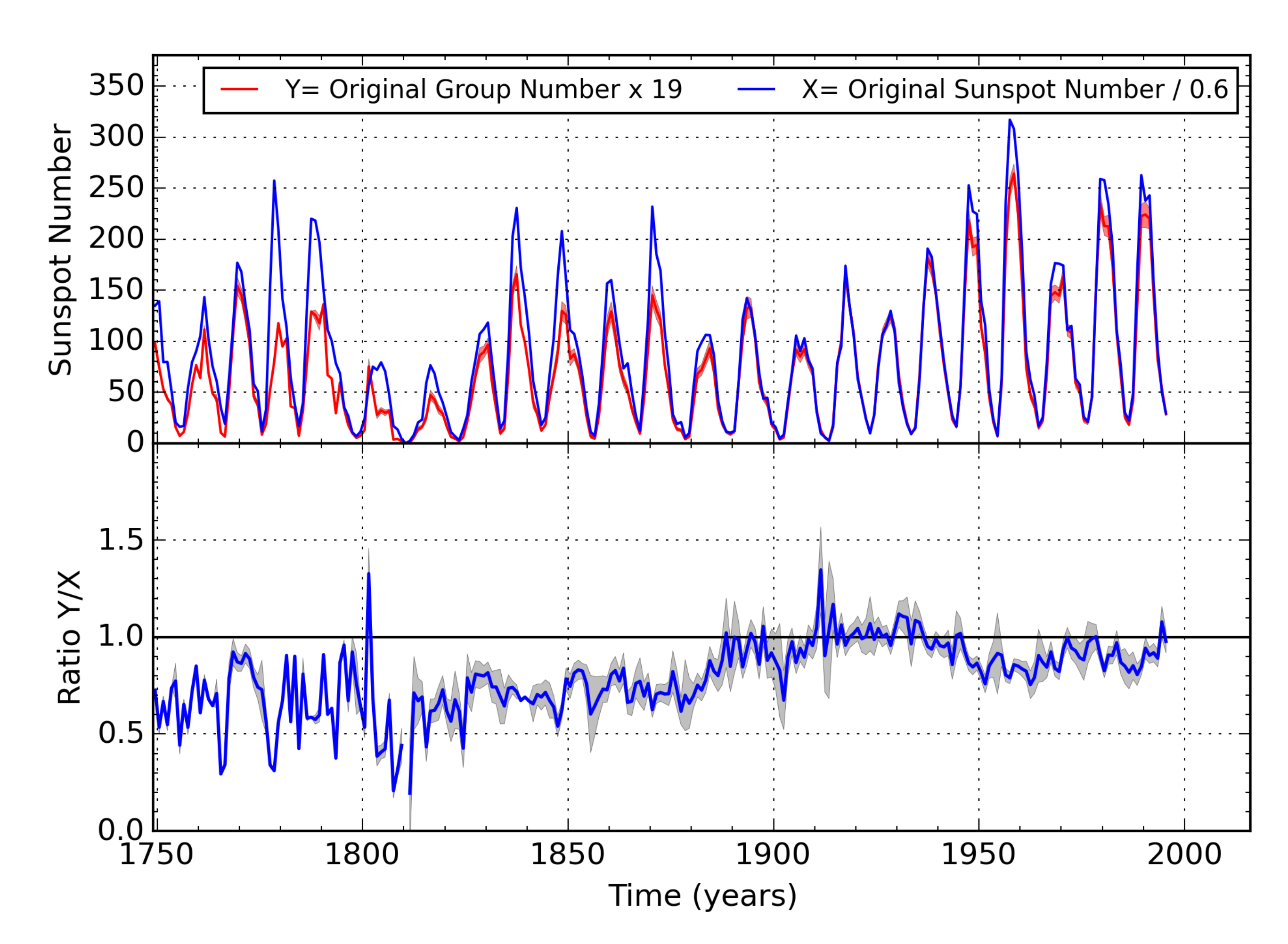


Combining all corrections: matching SN and GN

Original series:

SN / 0.6

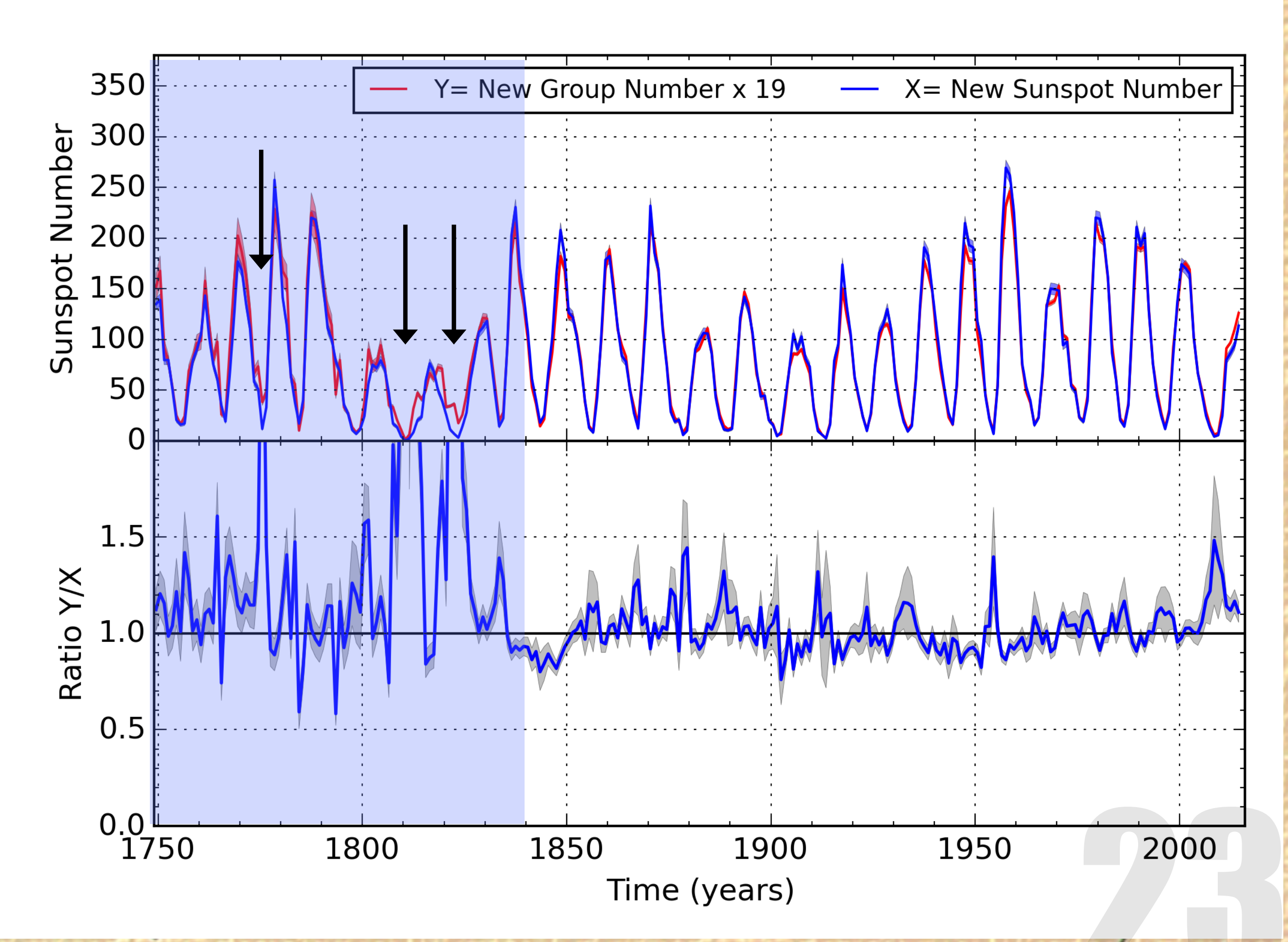
GN x 19.



Combining all corrections: matching SN and GN

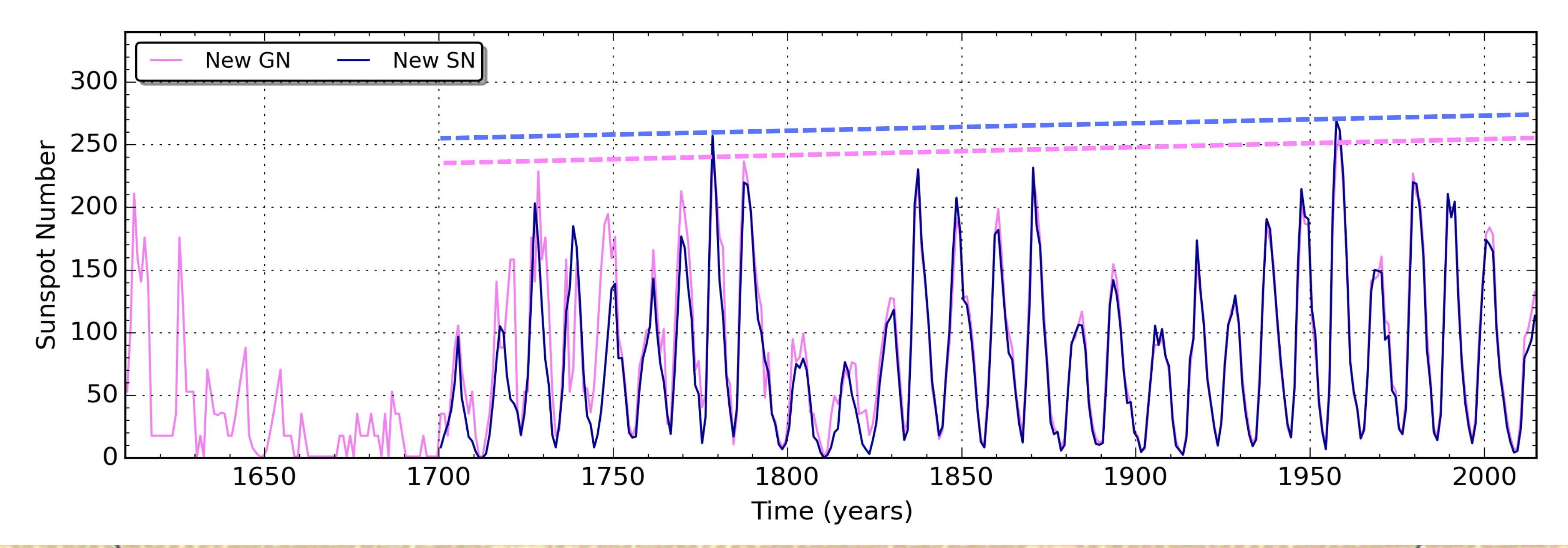
Close agreement over the entire interval 1826-2015

Still significant differences before 1826: more work is needed !



Conclusions

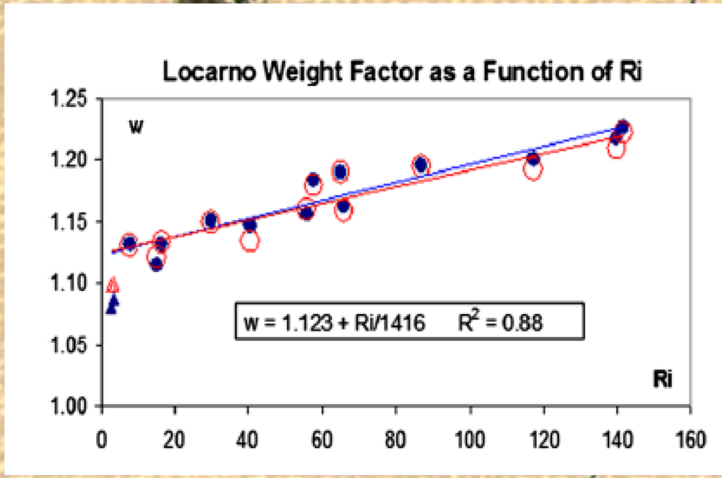
Uniform peak cycle amplitudes over last 3 centuries



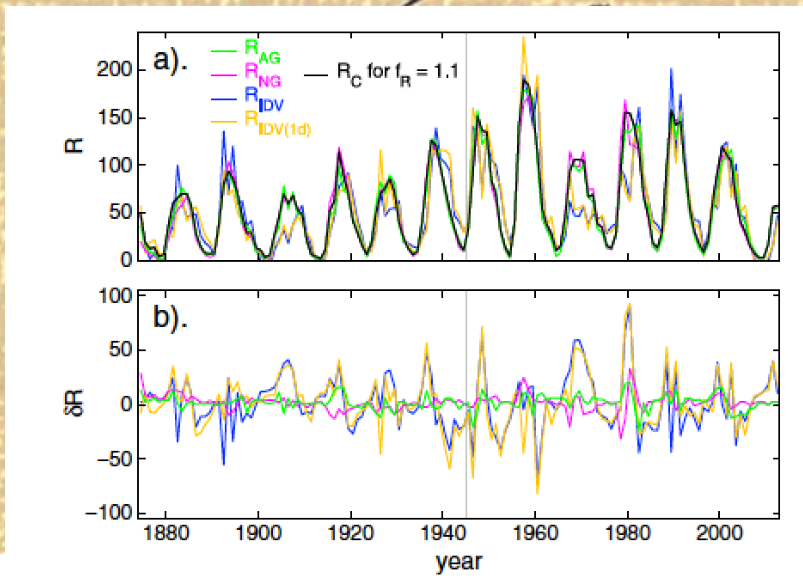
Thank you !

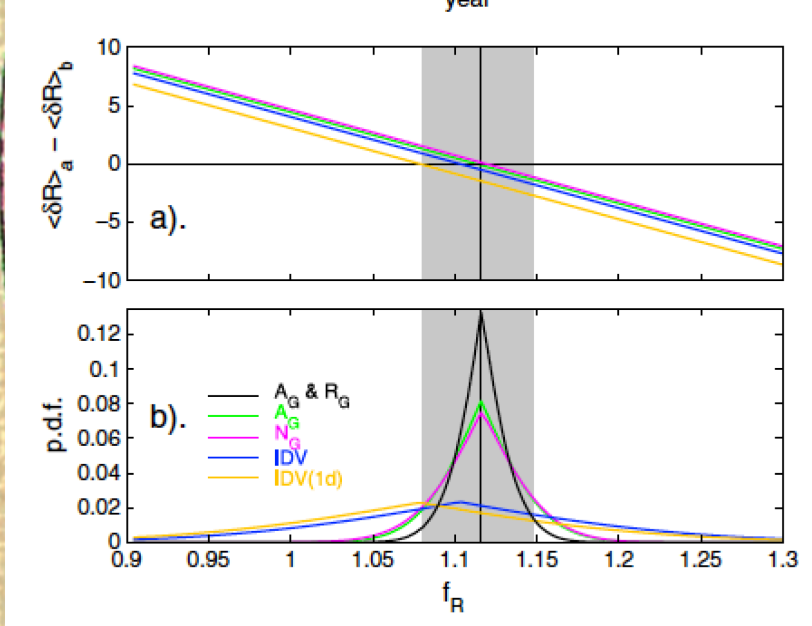
What is the influence of this weighting ?

- Previous analysis by L. Svalgaard (Clette et al., 2014).
- Jump around 20%



Waldmeier's weighted number (1947-1980)





Another analysis by Lockwood et al. (2014) evaluates the jump around 12% +/- 3%


AGU PUBLICATIONS

JGR

Journal of Geophysical Research: Space Physics

RESEARCH ARTICLE

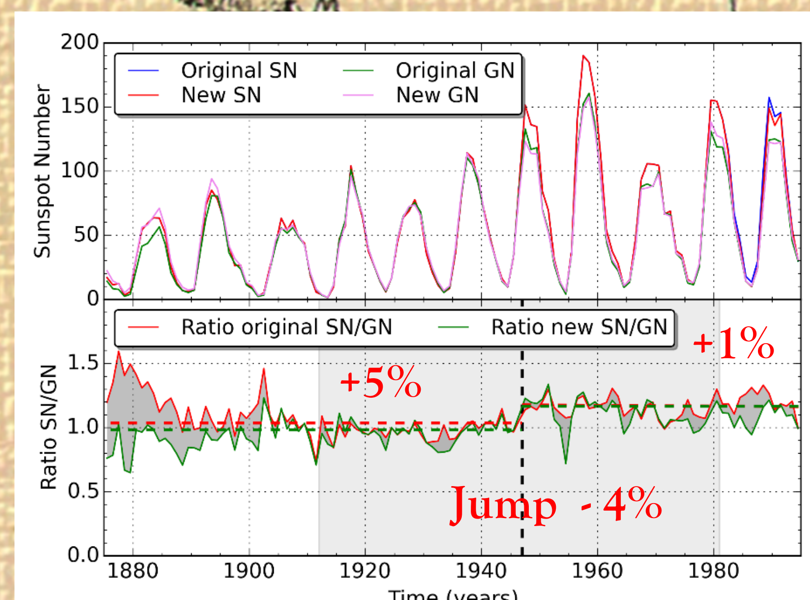
10.1002/2014JA019970

This article is a companion to *Lockwood et al.* [2014] doi:10.1002/2014JA019972; *Lockwood and Owens* [2014] doi:10.1002/2014JA019973.

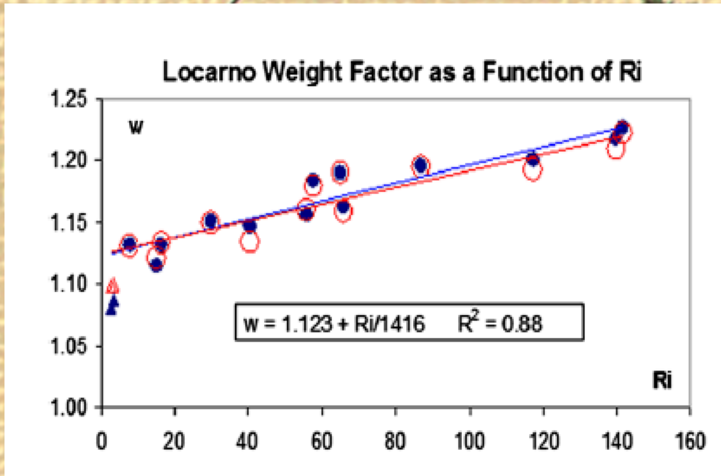
Centennial variations in sunspot number, open solar flux, and streamer belt width: 1. Correction of the sunspot number record since 1874

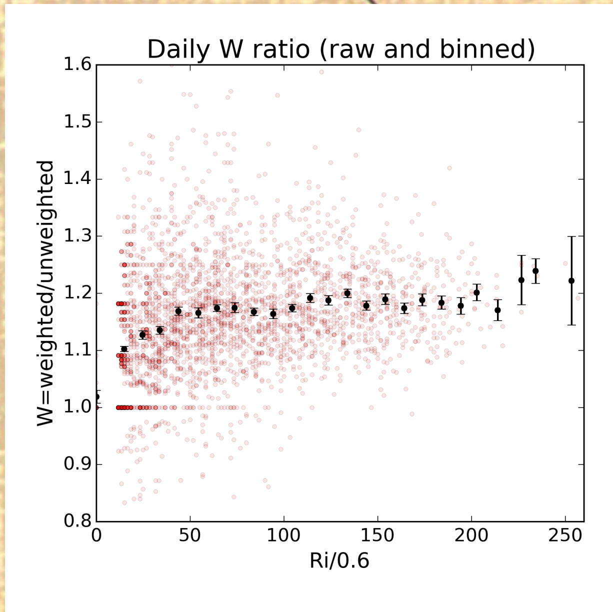
M. Lockwood[1], M. J. Owens[1], and L. Barnard[1]

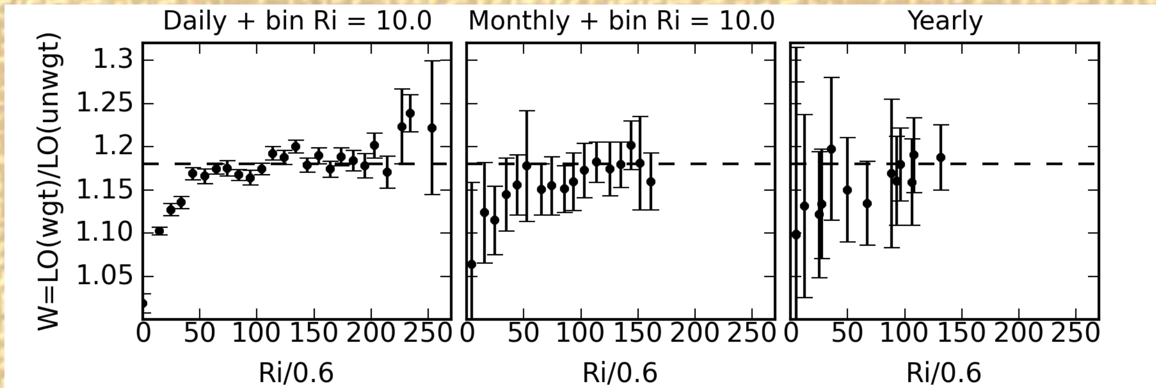
[1]Department of Meteorology, University of Reading, Reading, UK

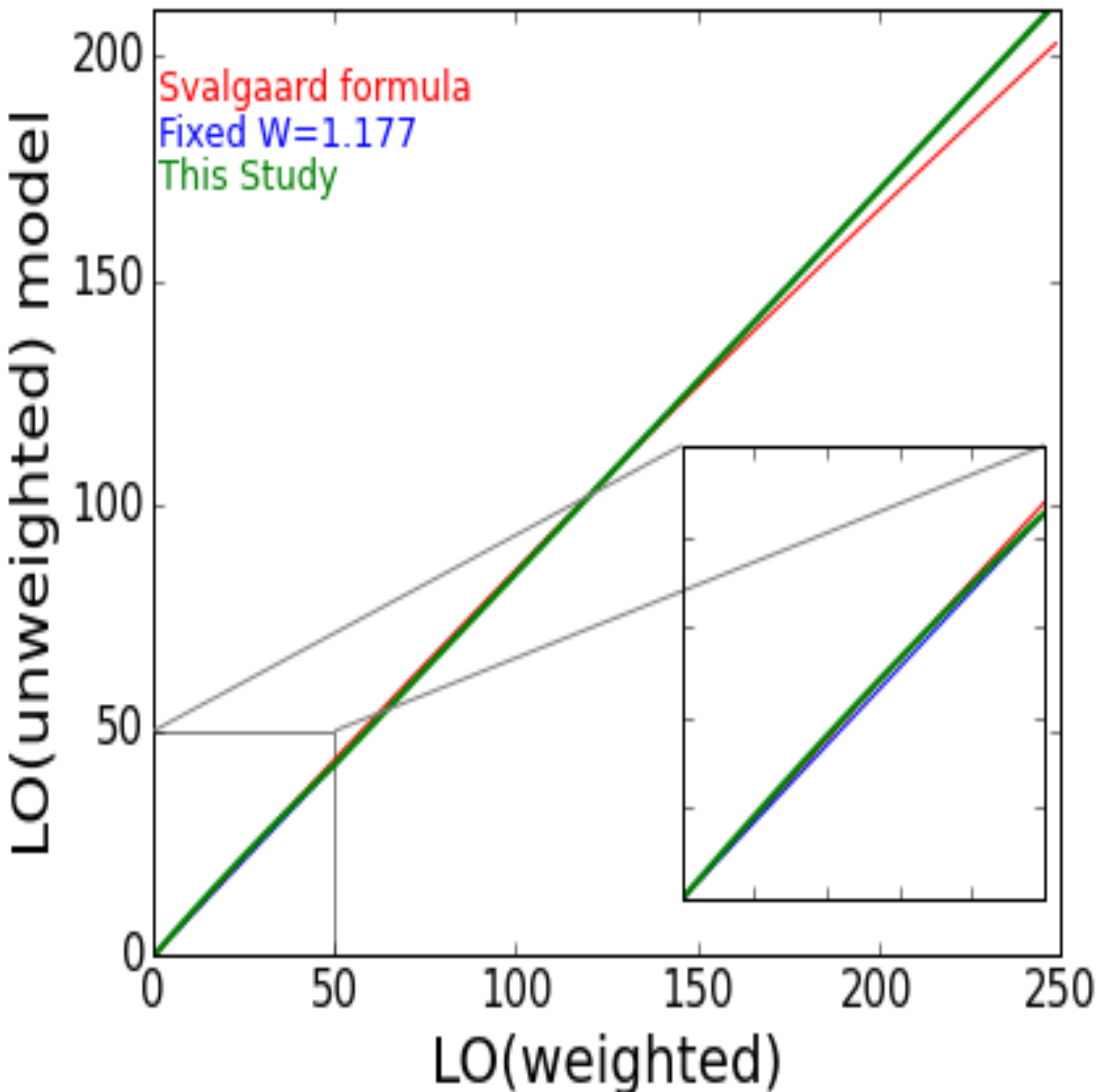


Waldmeier's weighted number (1947-1980)
A more robust determination









Svalgaard formula
Fixed W=1.177
This Study
LO(unweighted) model
LO(weighted)
0
50
100
150
200
250