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M. CACHOTI





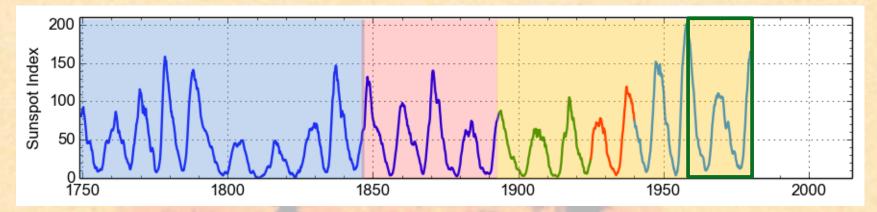
New re-calibrated sunspot numbers and the past solar output

SPECOLA SOLARE TICINESE LOCARNO MONTI

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Sunspot Number: a composite series



 $R = k(10.N_G + N_S)$

Historical reconstruction (1749-1849):

• Scale adjusted to Wolf's observations

Primary Wolf observations (1849-1893):

- Standard 83mm refractor
- Small 40mm travel telescopes

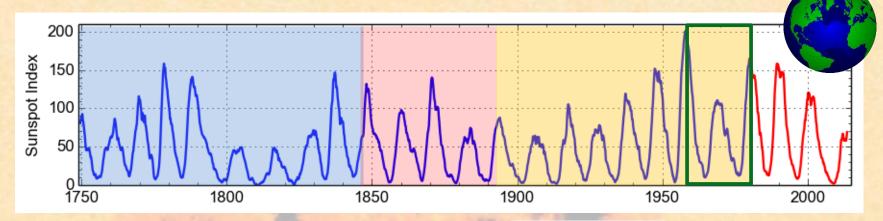
Zürich period (1894-1980):

- 3 reference observers: Wolfer, Brunner, Waldmeier
- New counting method: 0.6 factor
- 1957: Zürich + Specola (Locarno) stations





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Brussels period (1981-now):

- New pilot station: Specola (Locarno)
- Statistics over worldwide network

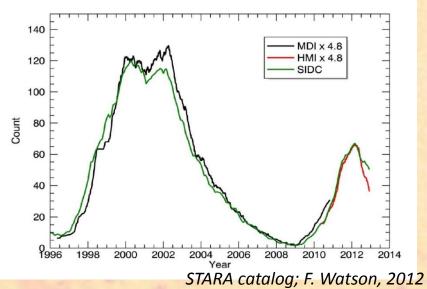
$$R = k(10.N_G + N_S)$$

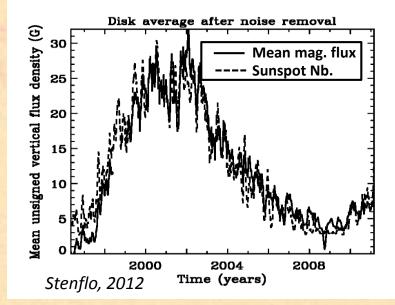


Sunspot Number versus modern measurements

- High correlation with photospheric parameters:
 - automated counts (MDI,HMI), sunspot area, emerging magnetic flux Mx
- Quantitative measure
- Lower correlation with chromospheric and coronal indices (F_{10.7cm}, Call K, MgII, TSI)
 - Additional component: magnetic decay (plages, network)
 - Non-linearity, time lags

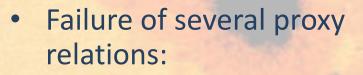
Are those relations stable over long durations ?



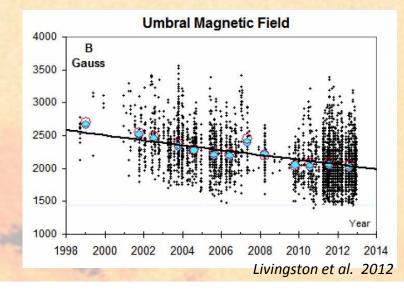


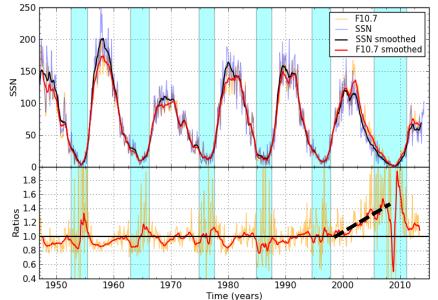
Cycle 24: Unexpected mismatches

- Unexpected late and weak cycle (Pesnell 2008, 2012)
- Decline of mean umbral magnetic field (Livingston & Penn 2009, 2012)
- Selective deficit of small sunspots: factor 2 (Lefèvre & Clette 2011 2012, Kilcik et al. 2011, Nagovitsyn 2012)



 Drop of SN versus F_{10.7cm} after 2000: up to -20% (Svalgaard & Hudson 2010, Lukianova & Mursula 2011, Clette & Lefèvre 2012)





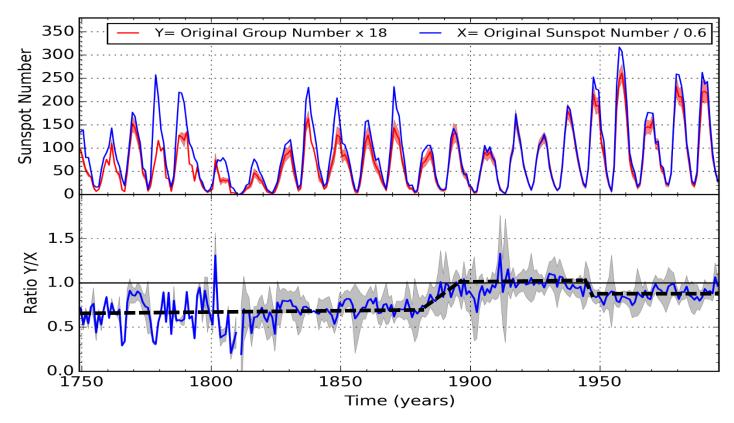
Two incompatible sunspot records

• Only alternate series:

Group Number (Hoyt & Schatten 1998)

- Larger data set, back to 1610
- Only groups: more immune to cruder early observations

Large persistent discrepancies between the series (up to 40%)



Sun-Climate Symposium, Savannah, Nov. 10-13, 2015

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

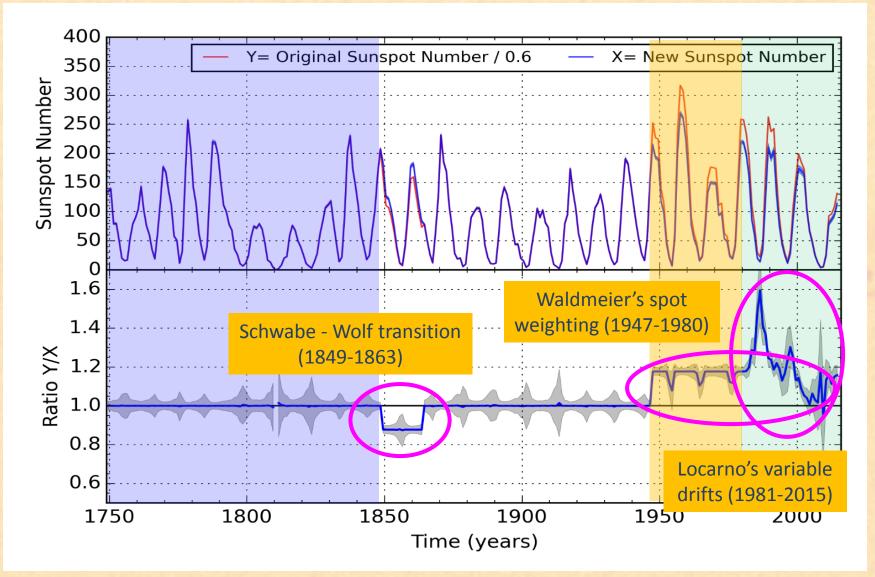
A necessary revision: Sunspot Number Workshops

- 4 workshops (2011-2014): Sac. Peak, Brussels, Tucson, Locarno
- Multiple diagnosed problems in the SN and GN:
 - Clette, F., Svalgaard, L., Vaquero, J.M., Cliver, E.W.: 2014, *Revisiting the Sunspot Number. A 400-Year Perspective on the Solar Cycle.* **Space Sci. Rev. 186, 35-103**
 - Solar Physics topical issue (early 2016):

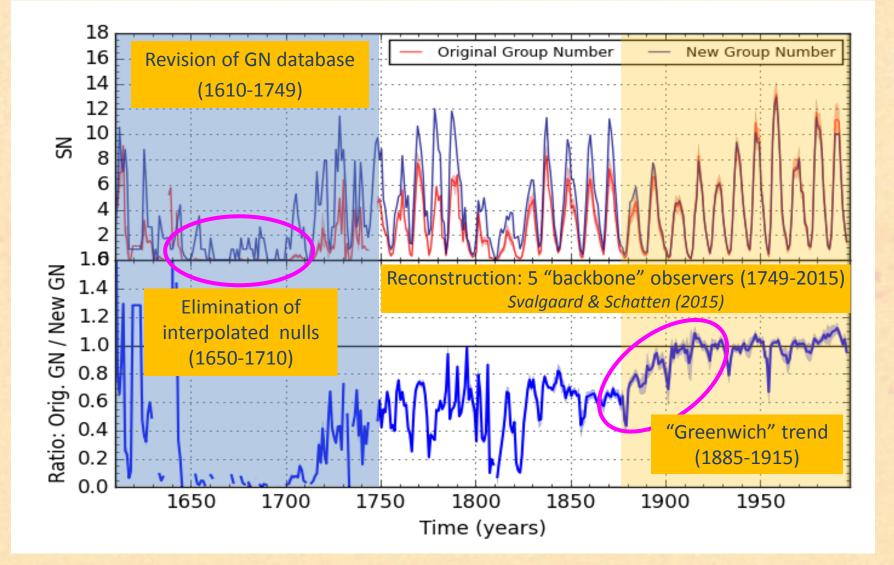
Clette & Lefèvre (New Sunspot Number), Svalgaard & Schatten (New Group Number)



Sunspot Number corrections: overview

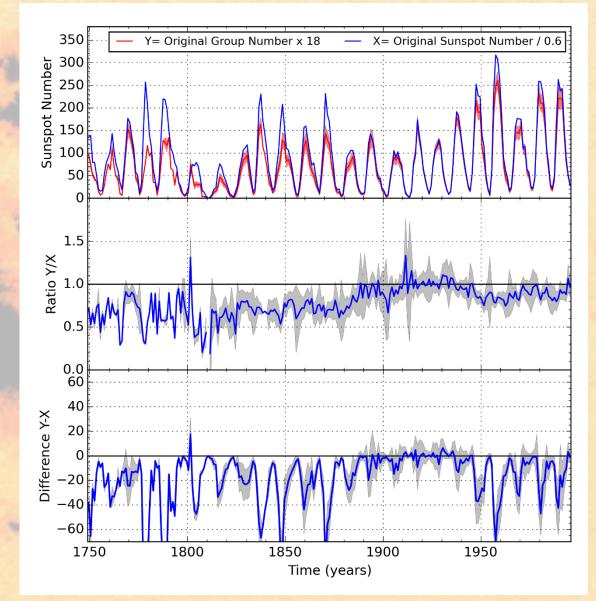


Group Number correction: overview



Combining all corrections: matching SN and GN

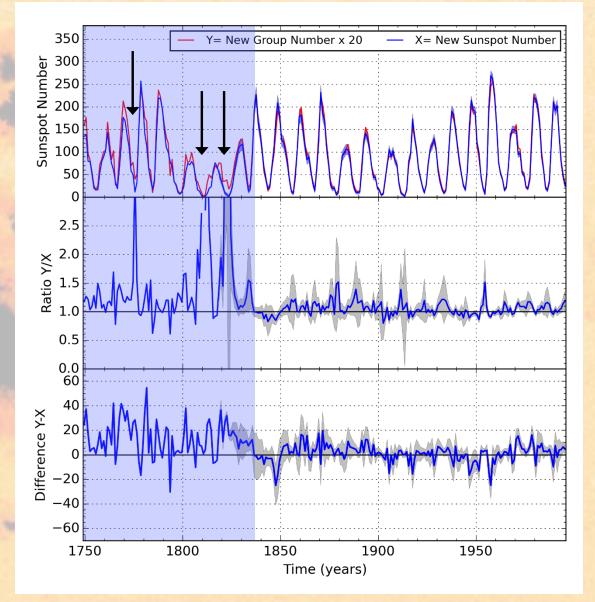
Original series: SN / 0.6 GN x 18.



Combining all corrections: matching SN and GN

Close agreement over the entire interval 1826-2015

Still significant
differences before
1826:
(10% - 20%):
→ Target for next
upgrade !

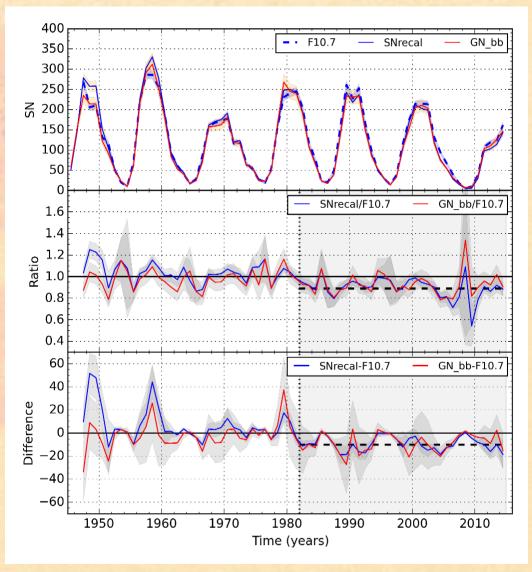


Better agreement with modern solar indices

 New comparison of F_{10.7} with the corrected SN and "backbone" GN (1945-2015)

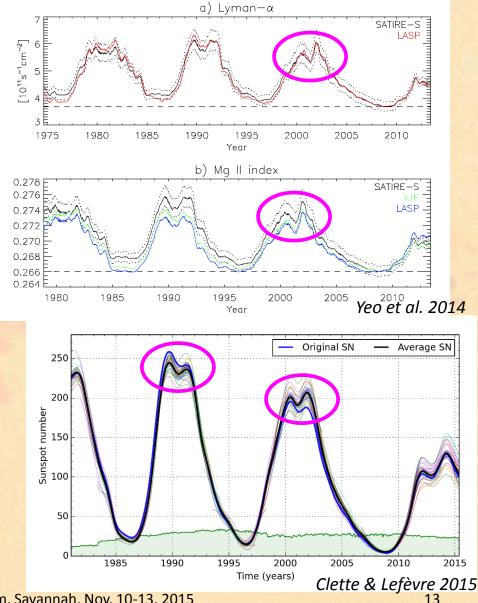
➡ No anomaly after 2000

➡ F_{10.7} is too high by 10% after 1983



Better agreement with modern solar indices

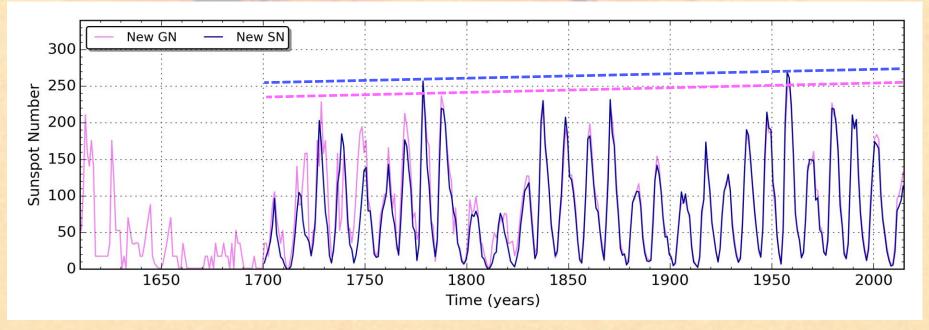
- Amplitude and shape of recent solar cycle maxima:
 - Mismatch between original SN and solar irradiances (TSI, MgII, Lyα, total sunspot magnetic flux)
- Second peak in cycle 23 (November 2001) now higher than first peak (July 2000)
- Main unexplained discrepancies are eliminated.



Uniform peak cycle amplitudes over last 3 centuries

- Original series: strong upward secular trend from the end of the Maunder Minimum to the mid 20th century ("Modern maximum", Solanki et al. 2004, Usoskin 2013):
 - GN: + 40% / century (red) SN : + 15% / century (green)
- New SN and GN= similar very weak upward trend < 5 %/century

Soon after the Maunder Minimum , solar activity returned to high levels equivalent to recent cycles of the 20th century



(blue, purple)

Conclusions: lessons learned

- Most diagnosed problems in SN and GN due to:
 - Improper processing methods
 - Method changes deviating from an original definition
- Processing methods have a bigger impact than random errors in the data
 - Defects diagnosed in the SN recalibration may still influence irradiance reconstructions (SATIRE, NRLTSI):
 - Trends in RGO photographic group areas and counts (Balmaceda et al. 2009)
 - Imbedded semi-empirical models based on the uncorrected Hoyt & Schatten Group Number series:
 - Cosmogenic isotopes and **open solar magnetic flux** (Solanky et al. 2002, Usosking et al. 2005, Lockwood et al. 2014)
 - Magnetic flux transport (Wang , Lean & Sheeley 2005)

Using the new SN as direct input parameter is not sufficient

Conclusions and next steps

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- SN Version 2.0 + new GN released on the new SILSO Web site: July 1st 2015
- New conventions: $R_i \implies S_N$ symbol
 - Elimination of Zürich factor : SN / 0.6 New reference = A. Wolfer (1893-1926)



ndex and I Solar ons	international sunspot number Major change of data set on July 1st, 2015: key	information
	Sunspot number series: latest update	Latest Sunspot Bulletin
ers wchive t be otices		Duly estimated samper number
	completed	18 July : 66
	Tedsy marked a triple transition for us: - Uploading the new Sunspot Number arithwe files containing the daily, monthly and yardy re-calibrated usingon runnbers and the new Greup Number - In our Web site, winkring to the new Tobas' pages giving access to the new files, to updated graphics and also to the page version of the Sunspot Number - Adapting and running the entire monthly protecture to produce the providential Sumpot Number for June 2015 and the associated E Sunspot Number - Made the state of the accession of the Sunspot Number - Adapting and nunning the entire monthly protecture to produce the providential Sumpot Number for June 2015 and the associated E Sunshift forecard and EINN- Thus a loss of work in a single day for our small team. After Interview explications and some inevitable bugs, we have new successfully completed this facts, absolution to revealing of the data was done. We sup- ble conventional facts, absolution to revealing of the data was done. We sup- let the Special Disservatory (Locarno) as pilot station but new usingmere Wed, 01 Jul 2015	Letter USET deservation (2003, Recursite) 17/07/2015

- From a locked archive to a living data series:
 - Open to future improvements (IAU supervision)
 - Archive of past versions
- Recent wave of interest for the past solar record
- Next developments (Version 3!):
 - Advanced methods for sparse data and time-variable uncertainties (PCA, ARMA, multiscale, Bayesian approaches)
 - Full SN reconstruction (1981 2015)

Stay tuned

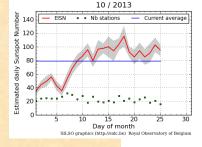


World Data Center – SILSO Sunspot Index and Long-term Solar Observations

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World Data Center for the production, preservation and dissemination of the

Welcome to the new central Web site for the international Sunspot Number

ICSU

We designed those new Web pages to offer you an easier access to the existing sunspot data and to the associated information. This new communication platform is destined to grow over the coming months and years, with new data and graphical products and new sections providing extra information about the World Data Center and its worldwide observing network. This initial version already features new items, more

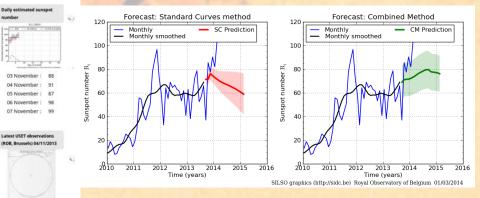
Fri, 18 Oct 2013

Supported by : working

New

Home Data

http://sidc.be/silso



SN workshops: http://ssnworkshop.wikia.com/wiki/Home

10/11/2015

Sun-Climate Symposium, Savannah, Nov. 10-13, 2015

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