The International Sunspot Index R_i

A perspective on the last 50 years

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SIDC – WDS "Sunspot Index"

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The questions

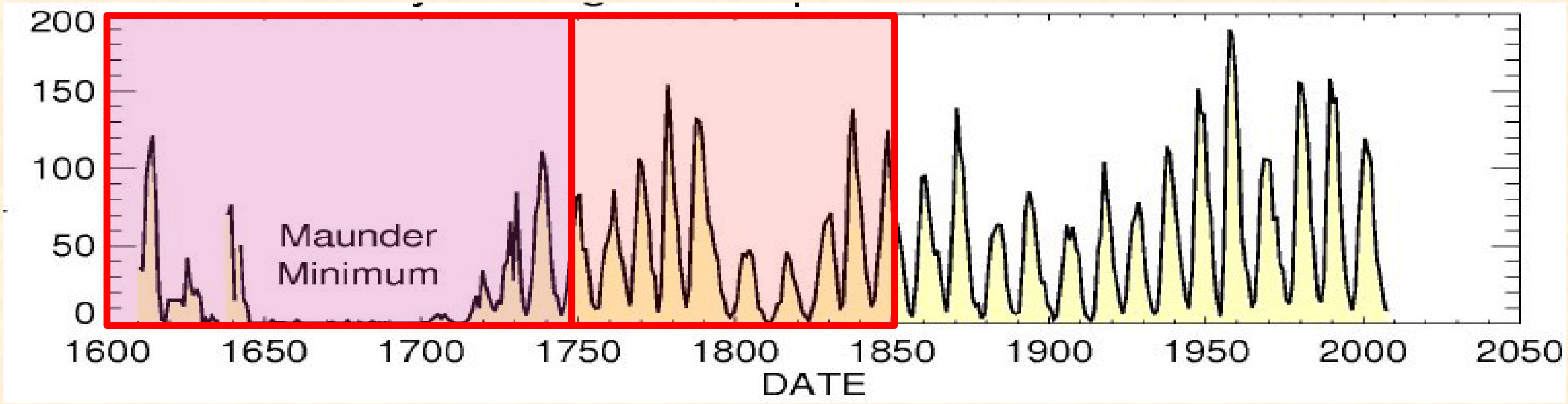
- How did the transition Zürich – Brussels occur ? *(1957 – now)*
- How is R_i currently produced ? *(The method)*
  - What is the connection between R_z and R_i ?
  - What is the array of SIDC sunspot products ?
- Subjectivity versus objectivity?

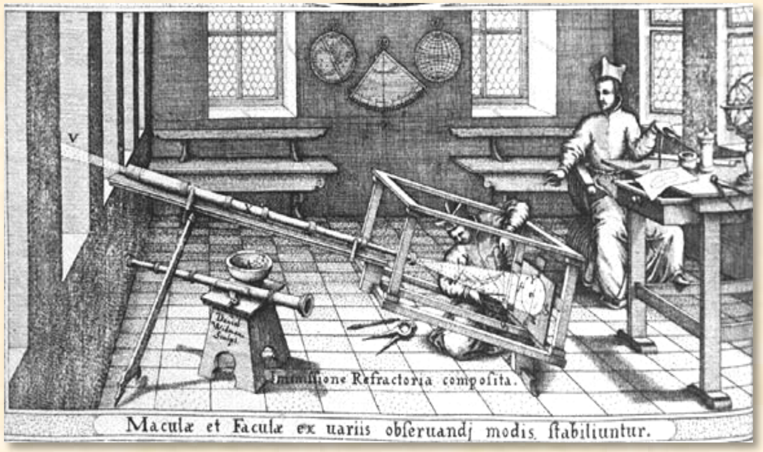
  The actual strengths and weaknesses of the visual index

- How do R_z and R_i compare with other indices ?
- What can we do next?

  Perspectives for better understanding R_z & R_i

Wolf and his historical reconstruction

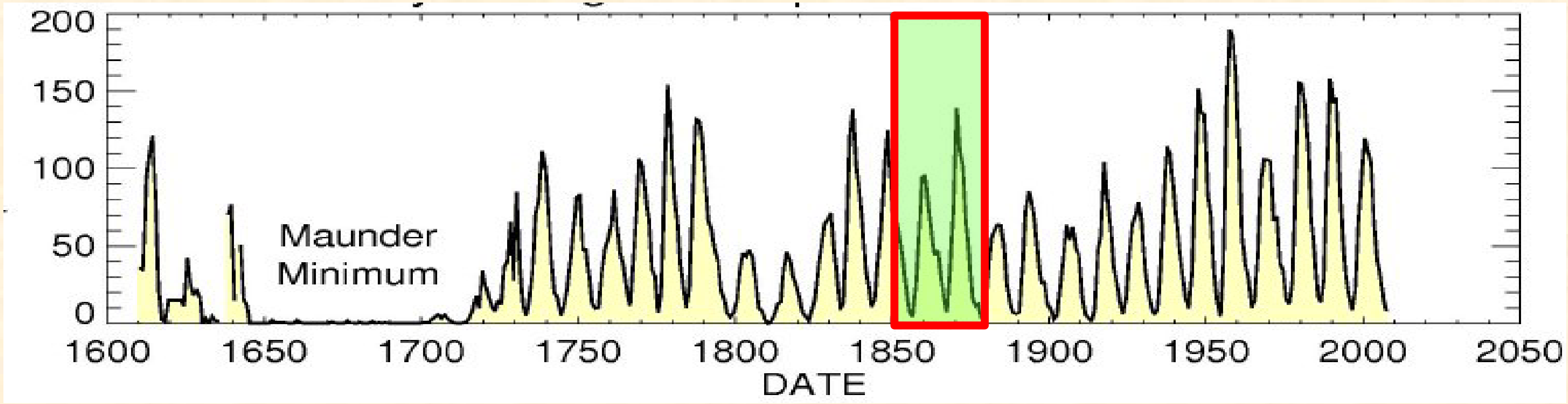




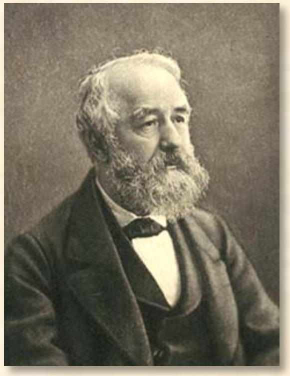
Observations	Sparse
Obs. technique	Variable
Stations (daily)	Base: 1
Geog. Distrib.	W-Europe
Processing	Manual
Reference	Successive obs.
K coefficients	Estimates
Est. Accuracy	20 – 50%

- Galileo, Scheiner, Harriot, Fabricius
- Herschel, Staudacher
- *S.H. Schwabe (1789-1875)*

The Wolf era



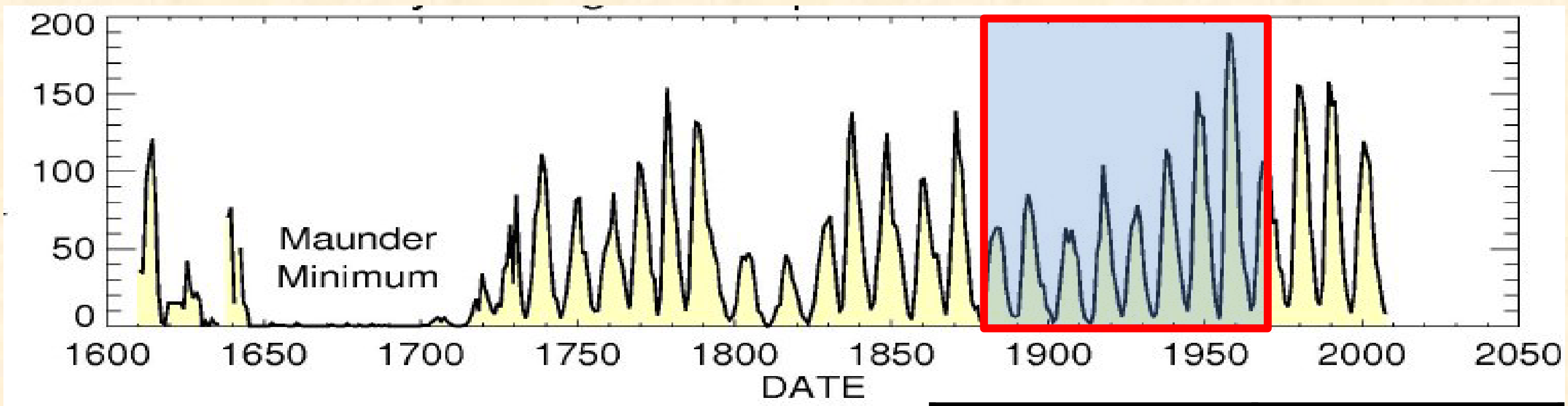
- *R. Wolf (1816-1893)*
- Primary station: Zürich
- Daily values (from 1852)
- Adjusted using geomagnetic measurements



“Standard” 83 mm refractor

Observations	Systematic
Obs. technique	Eyepiece
Stations (daily)	Base: 1 Aux: a few
Geog. Distrib.	W-Europe
Processing	Manual
Reference	Wolf (Zürich)
K coefficients	Regular
Est. Accuracy	20%

The Zürich era

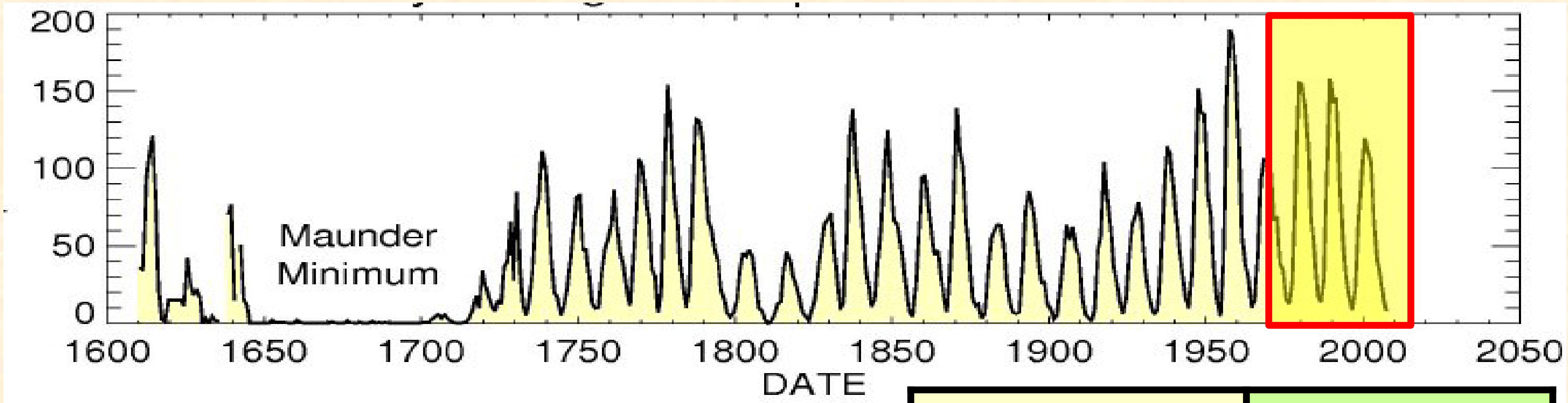


M. Waldmeier

Observations	Systematic
Obs. technique	Eyepiece
Stations (daily)	1 primary ~30 auxiliary
Geog. Distrib.	Europe + Asia
Processing	Manual
Reference	Zürich+Locarno K=0.6
K coefficients	Systematic (yearly)
Est. Accuracy	5 – 10%

- Primary Observers (Zürich Observatory):
  - A. Wolfer (1882 - 1926), W. Brunner (1926 - 1945), M. Waldmeier (1945 – 1979)
  - Since 1957, 2nd station: Locarno (aperture 80mm)
- 1882: new counting method (all spots) K=0.6

The SIDC-Brussels era

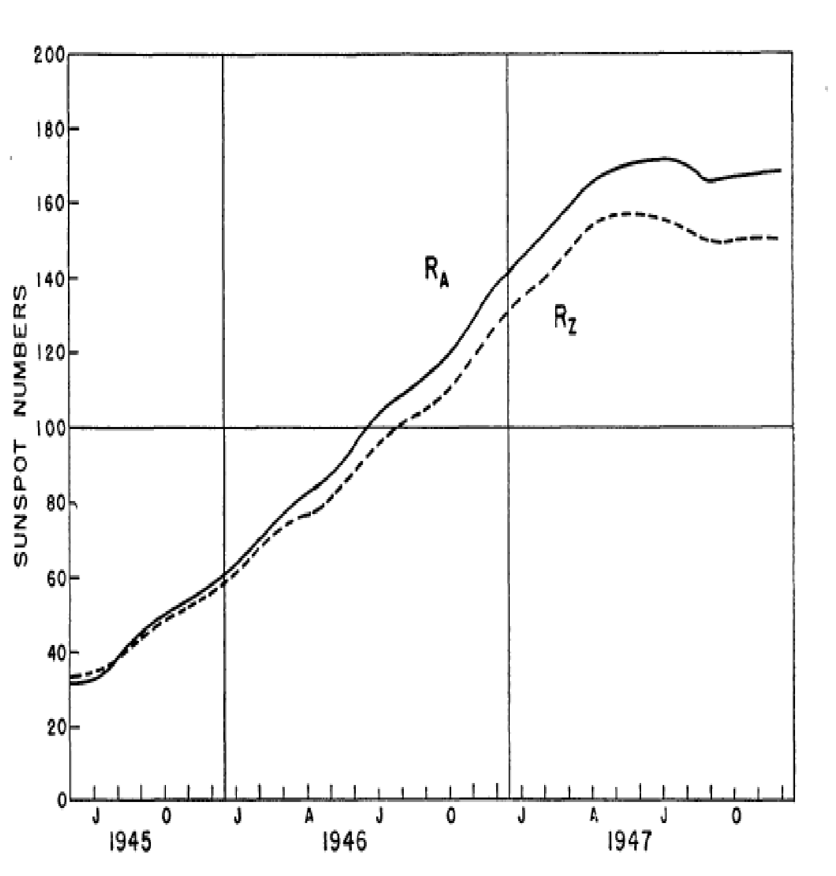


- 1981: transfer to Brussels (ROB)
- Extended network (80 stations)
- Computerized processing
- **Pilot station**: Specola Solare, Locarno
- New products:
  - **Hemispheric SSN (since 1992)**
  - **12-month predictions**
  - **Daily estimated SSN (since 2005)**
- 4 directors: A.Koeckelenbergh (1981-1994), P. Cugnon (1994-2002), R. Van der Linden (2002-2011), F. Clette (since 2011)

Observations	Systematic
Obs. technique	Eyepiece or drawing (proj.)
Stations (daily)	Base: 1 + full network (~45)
Geog. Distrib.	Worldwide
Processing	Computer
Reference	Locarno K=0.6
K coefficients	Systematic (monthly)
Est. Accuracy	~ 5%

The Zürich – Brussels transition (1979-1981)

- An adverse general context:
  - General mistrust towards the visual index in favor of new indices ($F_{10.7cm}$ radio flux)
  - Growing discrepancies between R_Z and the American sunspot number R_A (A. H. Shapley, AAVSO)
- In 1978-80, IAU Working Group involving A.H. Shapley & J.A.Eddy favoring the termination of the visual sunspot number

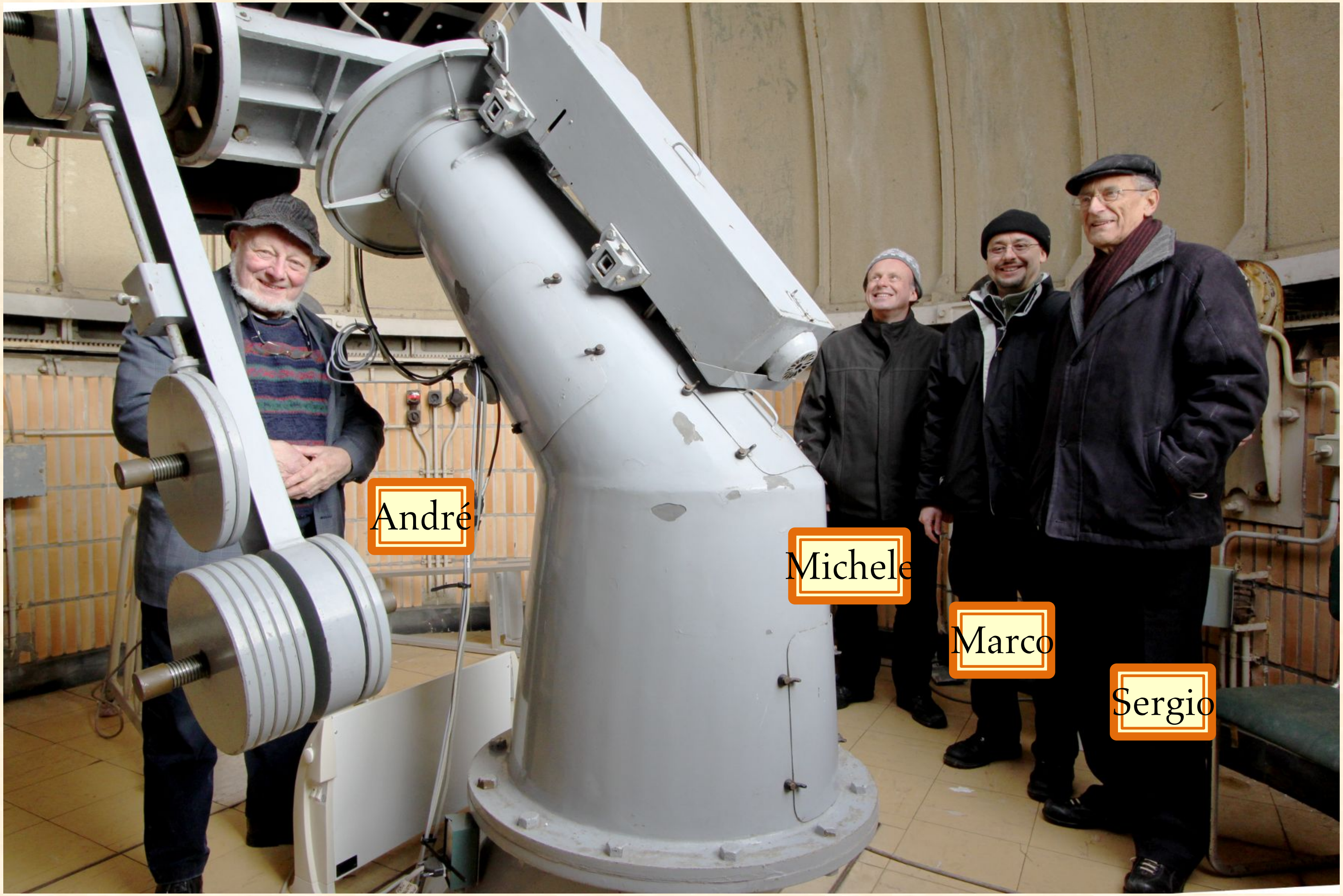


The Zürich – Brussels transition

- Internal reorganization at the Zürich Observatory:
  - In the 1970, integration in the Eidgenössische Technische Hochschule (ETH, Federal Institute of Technology).
  - New ETH Director J.O. Stenflo: new orientation in high resolution polarimetry
  - Global wish to close the Waldmeier era (felt as too authoritative)
- Strong support from international scientific community:
  - 1978: COSPAR resolution and URSI support requesting the continuation of the SSN
- Feb. 1980: call to the community issued by the Zürich Observatory
  - Contacts with A. Koeckelenbergh of the ROB (Uccle station)
- June 3-6, 1980, meeting at ETH Zürich (O.Stenflo, K.Dressler, M.Waldmeier, S. Cortesi, A. Koeckelenbergh):
  - Formal decision to transfer the WDC sunspot to Brussels (initially at the Université Libre de Bruxelles)

Meeting at the ROB: February 2011

Meeting at the ROB: February 2011



Creation of the Sunspot Index Data center

- **Wolrd Data Center endorsed by 3 Unions: IAU, URSI, IUGG**
  - Official declaration: 1982, IAU General Assembly (Patras)
  - Supervision through ICSU, International Council of Scientific Unions (UNESCO; www.icsu.org)
  - Since early 2012, integrated in the new **World Data Services (WDS)**
- New name: **"Sunspot index data Center": SIDC**
- New index: **International Sunspot Number R_i** (new method)
- **Funding**:
  - Mostly ROB: Integration among international services hosted by the ROB
  - Very limited resources: ROB computer infrastructure, running costs (mailings)
- **Staff** (all part time):
  - 1 lead scientist (Director) > F. Clette
  - 1 programmer/system manager > L. Wauters
  - 1 employee: O. Boulvin
- **Directors**:
  - 1981-1992: A. Koeckelenbergh — SIDC founder, retired (prime information source!)
  - 1993-2002: P. Cugnon — deceased 2002
  - 2003-2011: R. Van der Linden — ROB Director since 2005
  - Since March 2011: F. Clette — involved since 1990

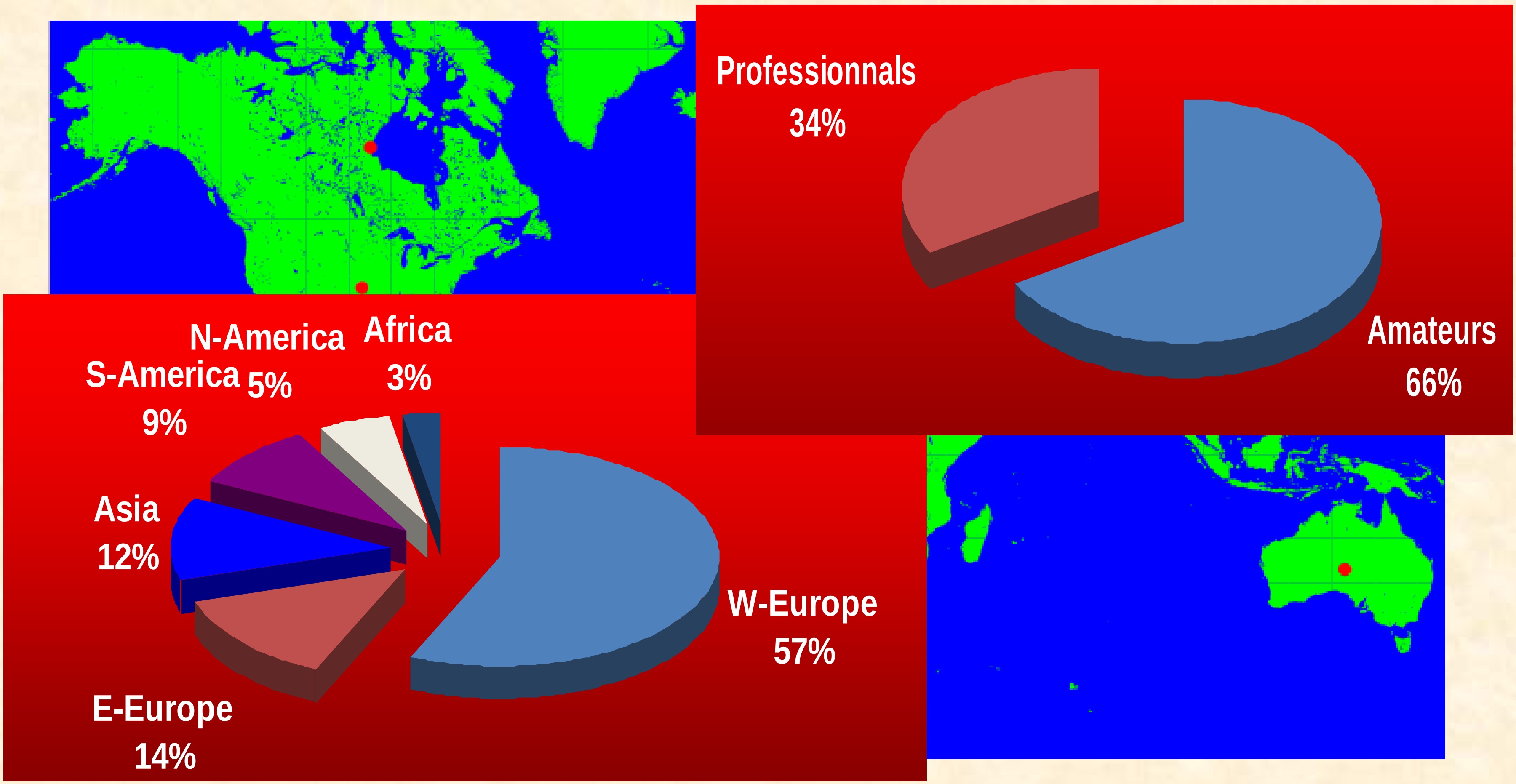
The R_i production method

The SIDC network in 1981

- 50 stations in 23 countries

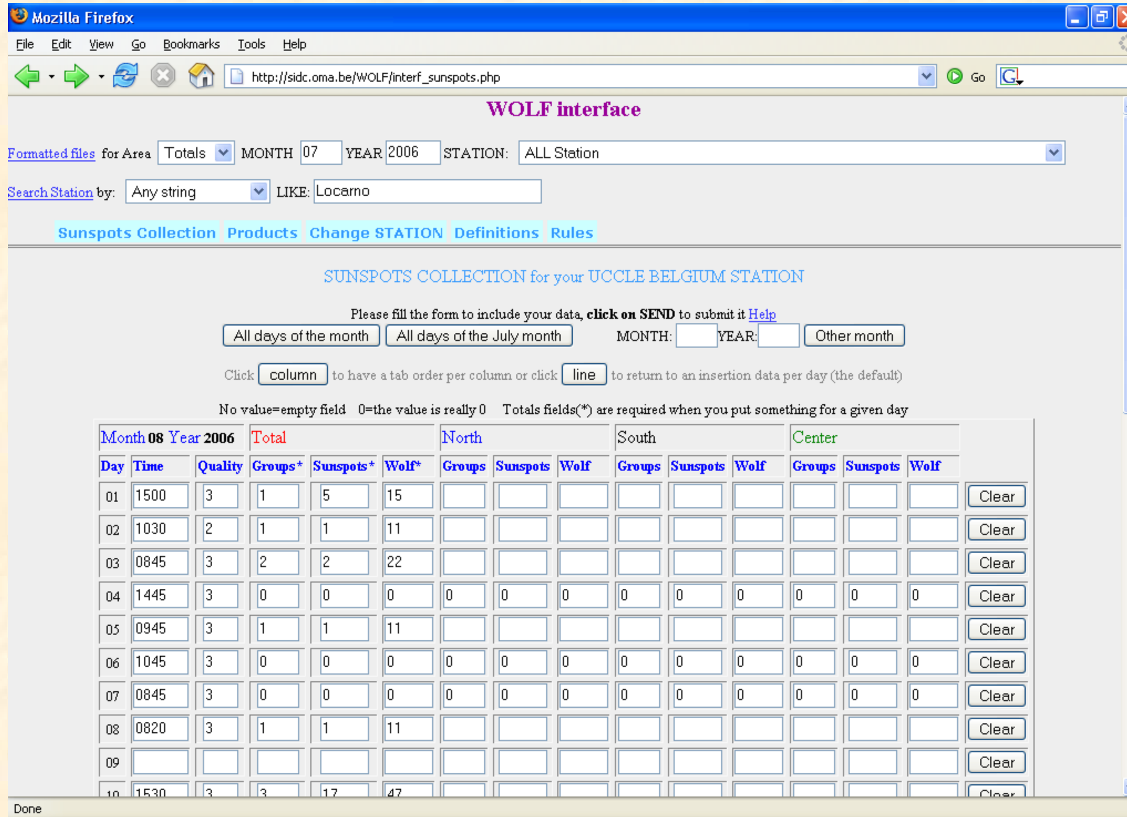
The SIDC network in 2011

- 89 stations in 32 countries
  - Still highly concentrated around Europe
  - Low participation in N-America (AAVSO)



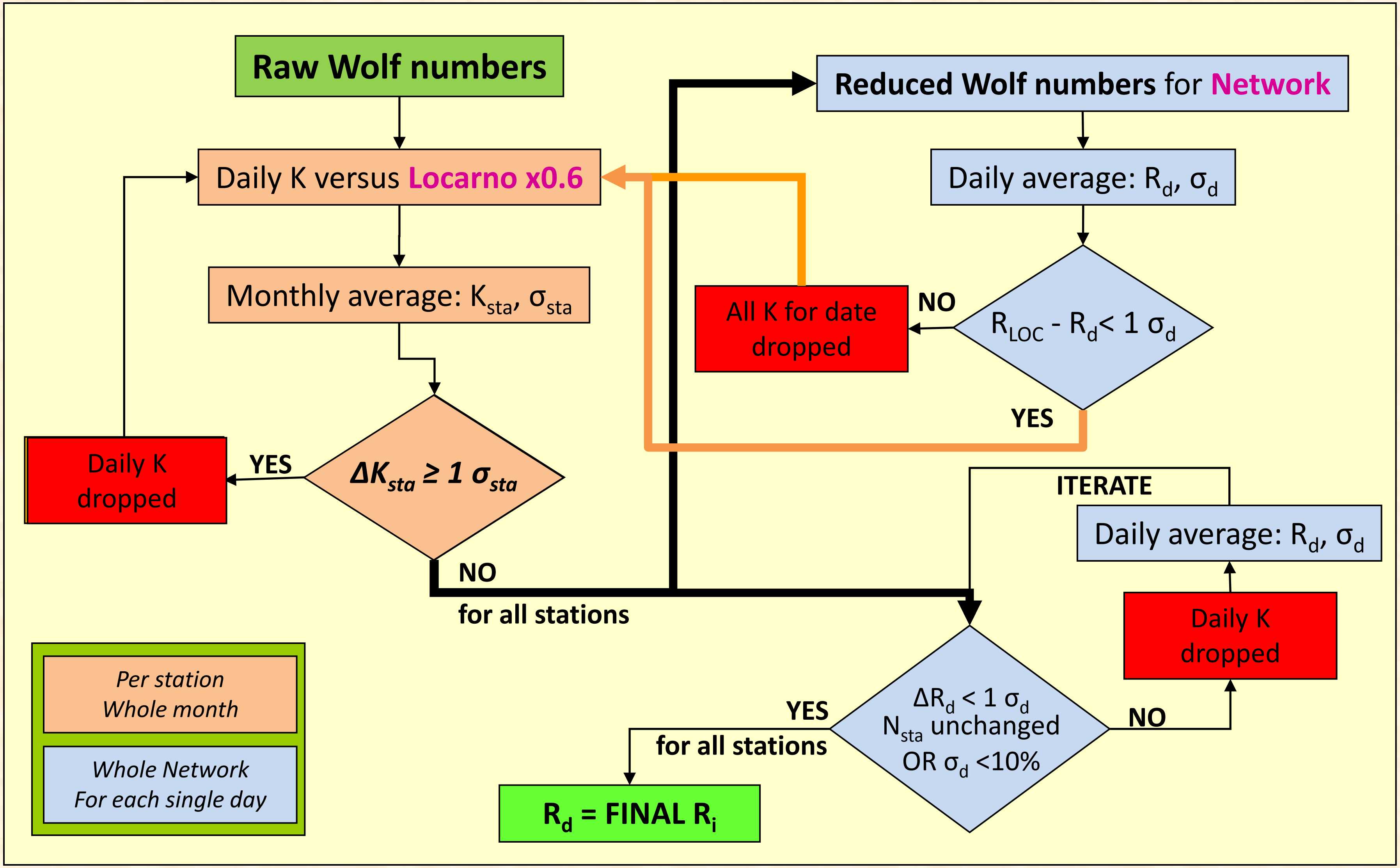
Data import

- Past: postal mail, faxes, e-mails
  > manual encoding, conversions
- **Since 2005, Web-based form**:
  - Private page for each observer
  - “Live” data consistency feedback (PHP)



- Data archival:
  - **All raw reports to SIDC since 1981 (spot & group counts)**
  - **Digitization of past reports to Zürich since 1950 (in progress)**

R_i processing flowchart



Special processing rules

- **For consistency with R_Z** (single base station Zürich)**:**
  - No value allowed between 0 and 7
  - **If $0 < R_i \leq 7$ *(11*0.6)*, R_i set to 7   otherwise R_i=0**

- **Treatment of low R_i values (many stations reporting W=0):**
- Principle:
  - R≠0 at a significant number of stations = strong indication that there was a spot (part of the day?).
  - R=0 at a few stations: not sufficient to decide that there was no spot.
- Rule:
  - **If 20% < $N_{(R=0)}$ < 80% then only stations with R≠0 are taken into account.**
  - Based on the histogram of all observed R_i values
- Rule invoked only during minima (< 2-3 % of all days)

Definitive sunspot numbers

- Computed quarterly
- 3-month delay to leave time for late reports (snail mail)
- Typically 10 - 15 additional stations
- Same processing as the provisional SSN
- **Provisional values are not automatically replaced by the new values !** Most provisional values are left unchanged.
- Rule:
  - **R_i(Prov) is replaced by a new R_i(Def) value only if $|R_i(Def)-R_i(Prov)| > 5\%$**
- Manually supervised process:
  - Histograms of raw input data
- Once determined, definitive values cannot be changed !

R_i versus R_z

- Fixed computerized processing chain ("hard-wired" processing)
- **Short timescales (< 1 month):**
  - Continuous use of the entire network
  - Exclusion of anomalous daily Locarno values
  - Use of the K coefficient of the current month instead of the average of previous year

➡ **Reduced dispersion: higher precision for daily and monthly values**

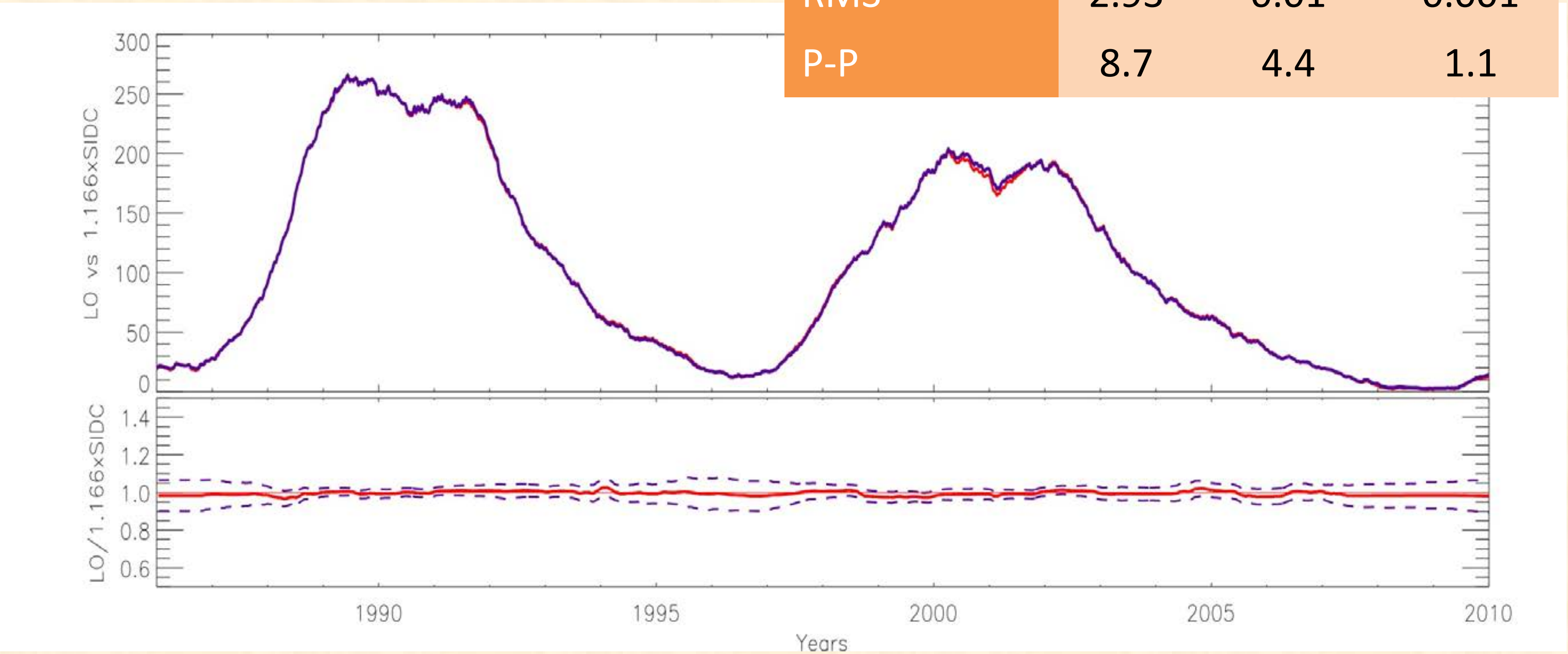
- **Long timescales (> 1 month):**
  - Scaling of each station to Locarno (monthly average K)

➡ **Still a central role played by the Locarno station for the long-term scaling.**

The key role of the Locarno station

- R_i has accurately tracked the Locarno pilot station
- Trends fully removed for timescales > 1 month

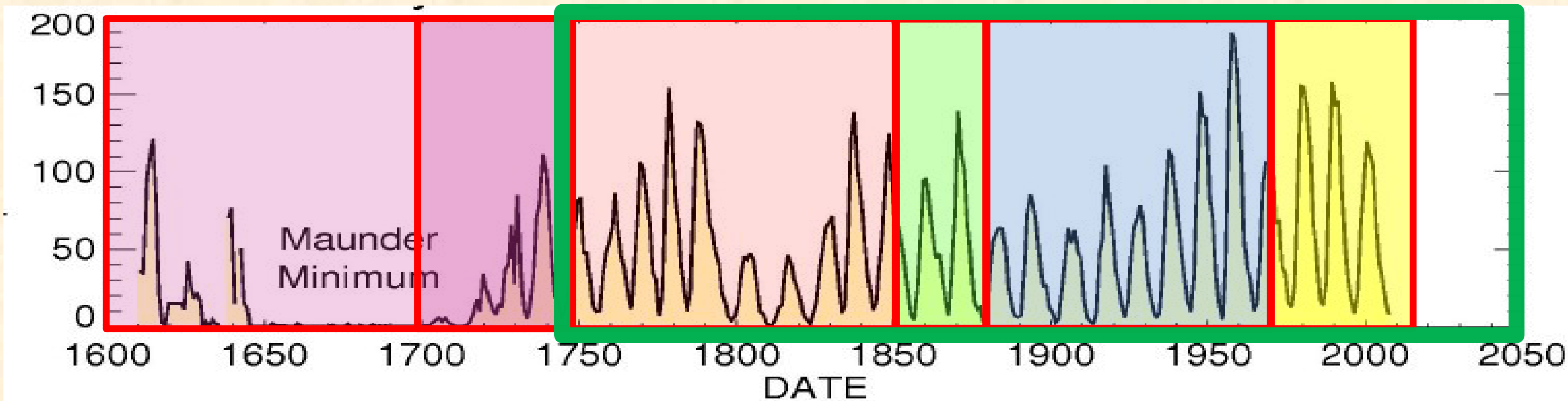
Dispersion %	Daily	Monthly	Yearly
RMS	2.93	0.01	0.001
P-P	8.7	4.4	1.1



→ R_i and $W_{Locarno}$ are almost equivalent

The SIDC data products

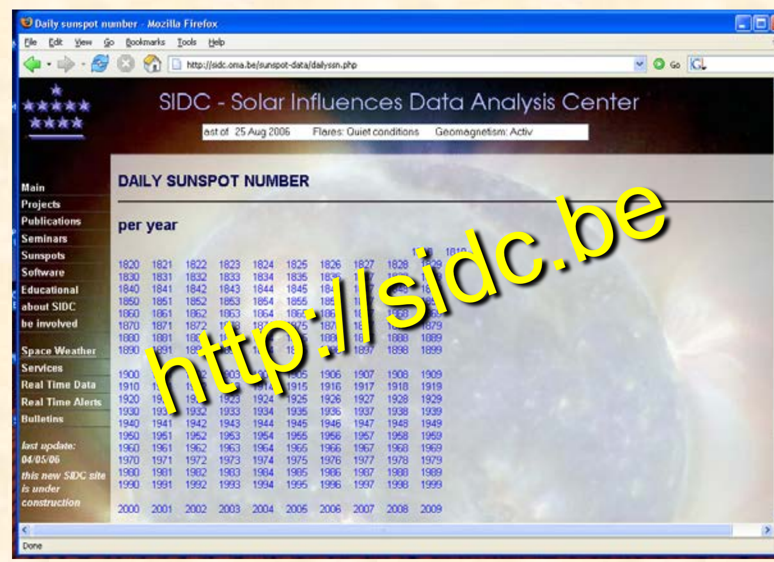
R_z-R_i: the whole series (25 cycles)

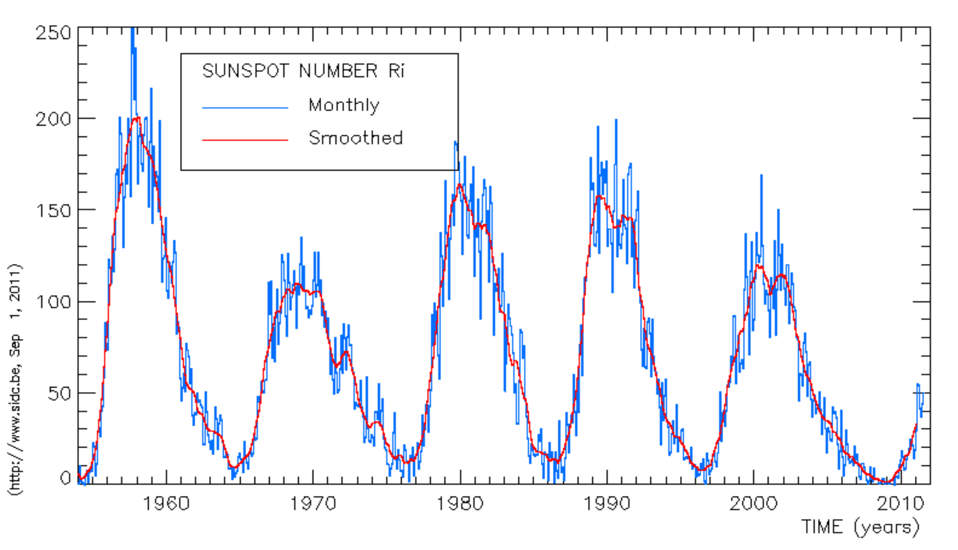


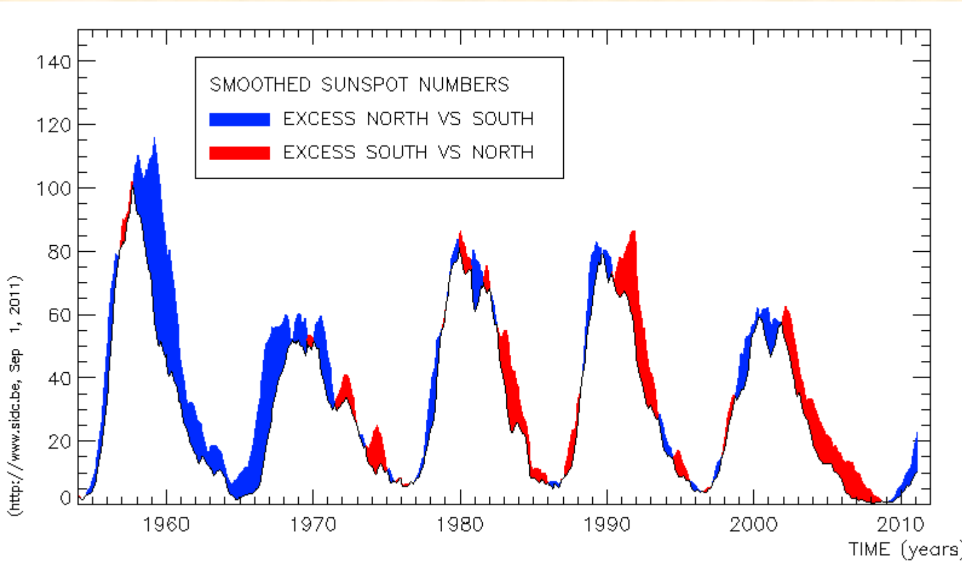
- Daily index: 1818 – now
  (1818 – 1847: some gaps)
- Monthly average: 1749 - now
- Yearly average: 1700 – now
- Monthly smoothed: 1755 - now

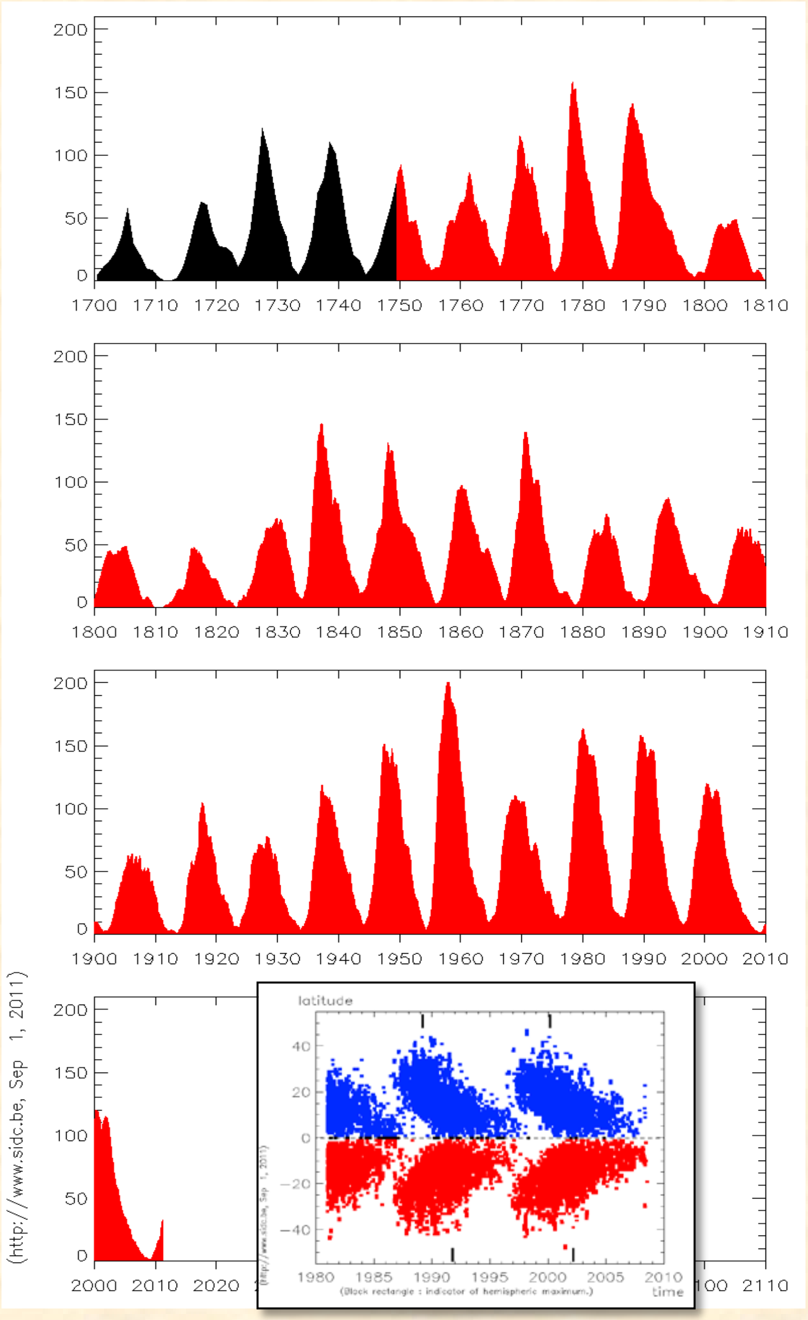
$$\overline{R_i} = \left(\frac{R_{-6}}{2} + \sum_{x=-5}^{+5} R_x + \frac{R_6}{2} \right) \Big/ 12$$

- Hemispheric: 1950 - now

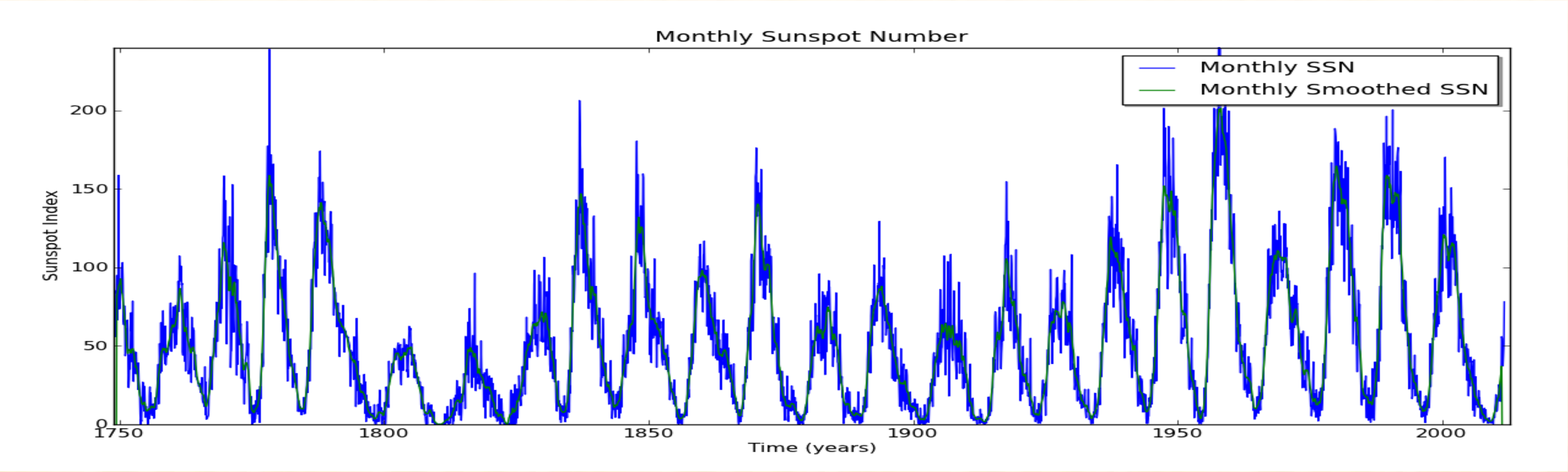


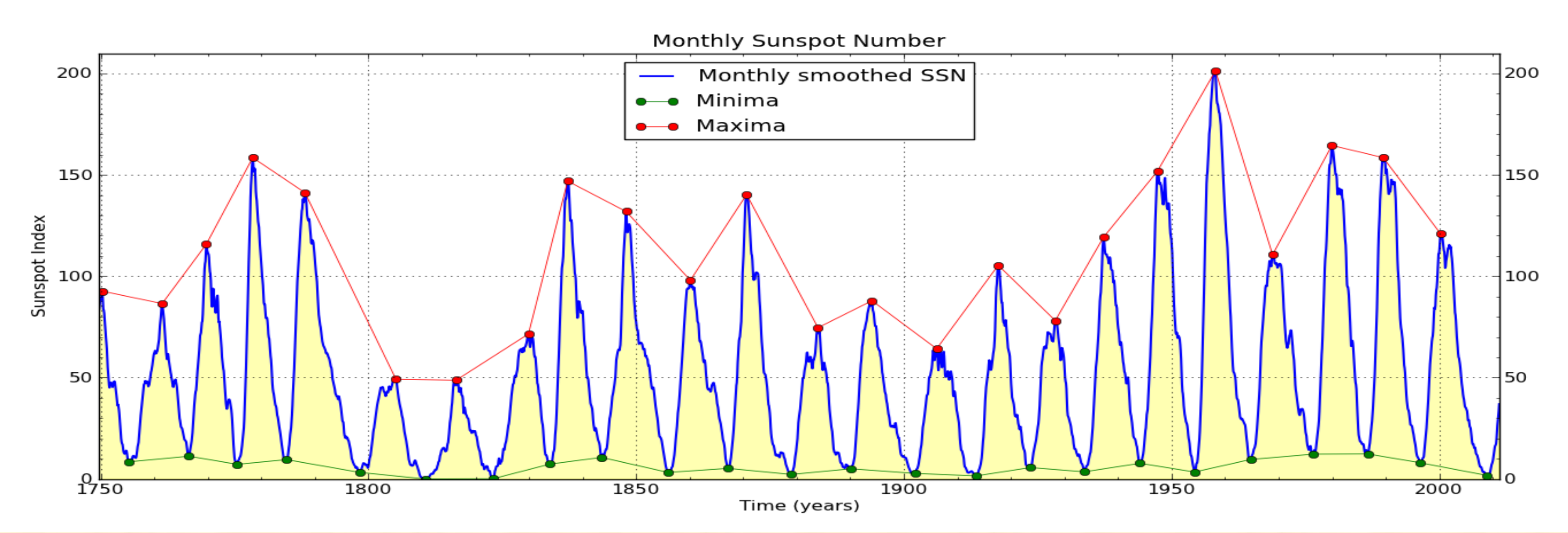

SUNSPOT NUMBER Ri
Monthly
Smoothed
TIME (years)
(http://www.sidc.be, Sep 1, 2011)


SMOOTHED SUNSPOT NUMBERS
EXCESS NORTH VS SOUTH
EXCESS SOUTH VS NORTH
TIME (years)
(http://www.sidc.be, Sep 1, 2011)

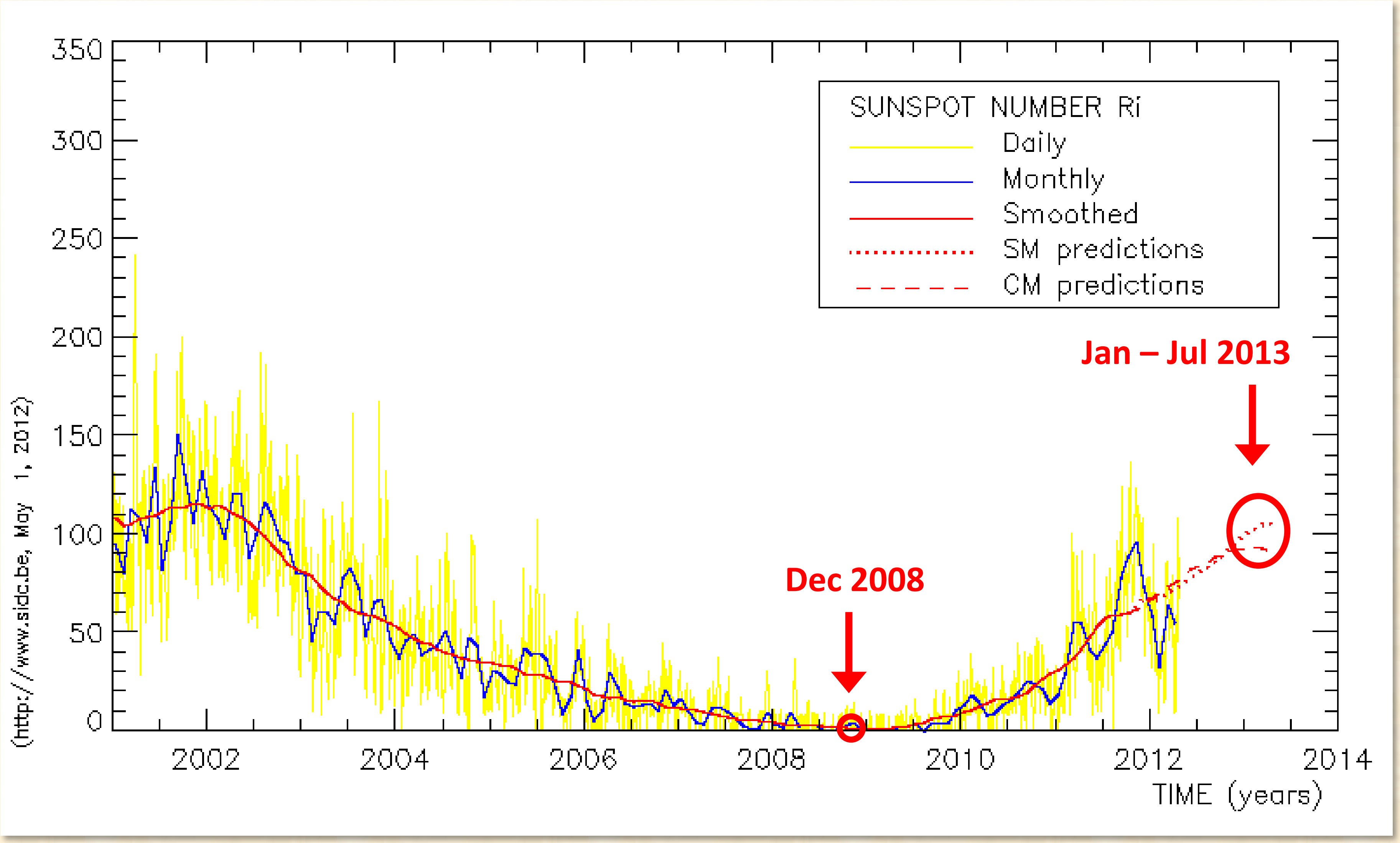

(http://www.sidc.be, Sep 1, 2011)
latitude
time

25 cycles: monthly values and extrema



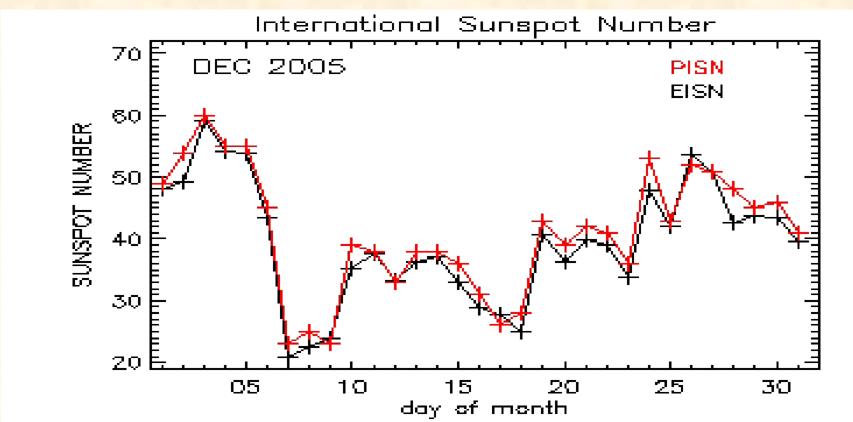


The last 11 years and forecasts



Estimated International SSN (EISN)

- Increased demand for a daily sunspot index
- Derived from a subset of up to 15 stations providing data before 12:00UT.
- Simple average of raw counts
- Multiplied by the K personal reduction coefficients produced by the full monthly processing.
- Published in the daily SIDC URSIGRAM at 12h30UT:
  - Values for today and yesterday

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SOLAR FLARES  : Eruptive (C-class flares expected, probability >= 50%)
GEOMAGNETISM  : Quiet (A<20 and K<4)
SOLAR PROTONS : Quiet
PREDICTIONS FOR 20 Dec 2005  10CM FLUX: 088 / AP: 019
PREDICTIONS FOR 21 Dec 2005  10CM FLUX: 088 / AP: 005
PREDICTIONS FOR 22 Dec 2005  10CM FLUX: 082 / AP: 001
COMMENT: The solar wind speed has been systematically rising in the
last 24 hours and is currently at 600km/s. We presume that this is due
to the influence of small coronal hole half way between active regions
NOAA837 and NOAA835. We expect that the influence on geomagnetic
conditions will in any case remain small. As of today, we start with a
new data product, the 'Estimated International Sunspot Number', which we
will distribute through these daily messages. Note also the link at the
bottom of this message where you can find more information.

ESTIMATED ISN       : 041, BASED ON 02 STATIONS.

SOLAR INDICES FOR 19 Dec 2005
SUNSPOT INDEX       : 069
10CM SOLAR FLUX     : 090
AK CHAMBON LA FORET : 018
AK WINGST           : 014
ESTIMATED AP        : 013
ESTIMATED ISN       : 044, BASED ON 04 STATIONS.

NOTICEABLE EVENTS SUMMARY
DAY BEGIN MAX  END  LOC    XRAY OP  10CM RADIO BURST TYPES    Catania NOAA NOTE
NONE
END
```

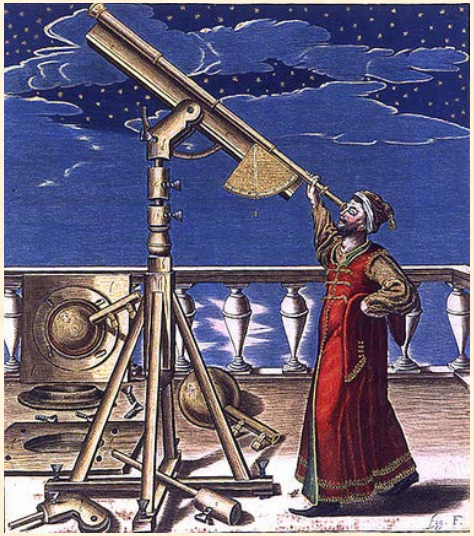
The R_i "subjectivity": the human factor

The R_i human factor: subjective or objective ?

- Four steps where the human factor can play a role:
  - **Individual observations**:
    - Visual factors (human vision)
    - Optical factors (instrument, seeing)
    - Observer practice (state of mind, personal habits)
  - Choice of **processing method**

The R_i human factor: human vision

- No biological change in the detector at century scales (eye + visual cortex)
- **Capacity to "integrate" seeing distortions** (not a simple averaging !):
  - Visual cortex plays an essential role
  - Until recently (SDO, HMI), capacity to detect the smallest spots was superior to photography and CCD
- **Imaging data not directly comparable or substitutable**:
  - Effects of sensor/optical resolution, seeing will have a different influence on the resulting counts for images and human eye



The R_i human factor: optical factors

- ***No specific aperture required for SIDC contributing observers***
- *How is the detection of the smallest spots influenced by the resolution?*
- Two factors:
- **Theoretical optical resolution** (unobstructed aperture):
  - Rayleigh criterion: $\theta = 138 / D(mm) \quad arc\sec$
  - Dawes criterion: $\theta = 116 / D(mm) \quad arc\sec$
- **Seeing:**
  - variable with time, daytime range similar for all low-altitude sites:
    1.5 to 3, typ. 2 arcsec (equiv. D= 45 – 90 mm, typ. 70 mm)
  - Large apertures more affected (size of turbulent eddies ~8 -12 cm):

➡ **Reduces the difference of effective resolution between small and large apertures (> 10 cm)**

What is the smallest possible sunspot ?

- Overall agreement: lowest spot size near 2000 km (3 arcsec) *(Bray & Laughhead 1964, Husar 1967, Bruzec & Durrant 1977, McIntosh 1981)*:
  - Dictated by granulation dynamics rather than sunspot physics.
- Best “observational” definition:

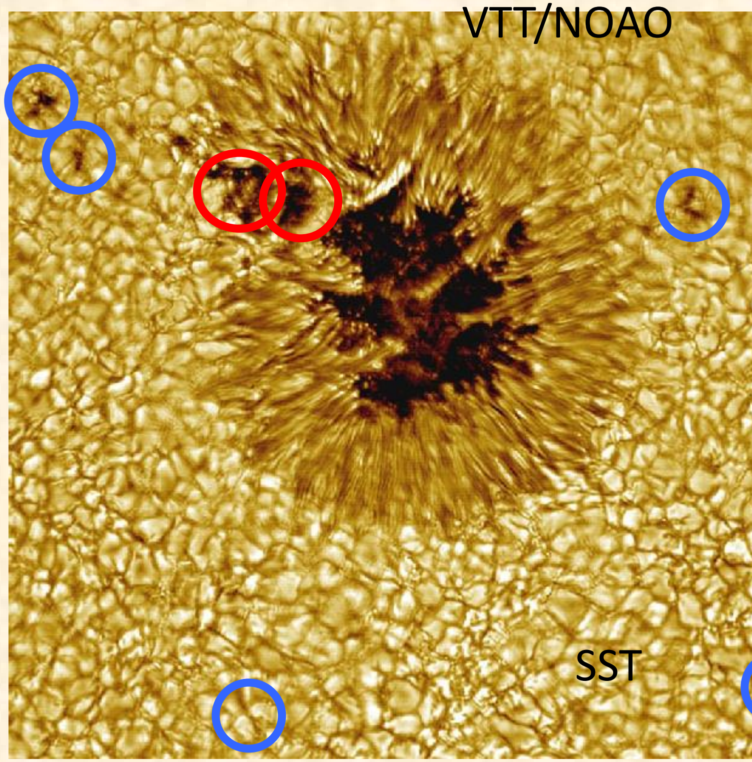
	Diameter	**Lifetime**	**Outline**	**Contrast**	Penumbra
Granulation “pore”	< 3” (2500km)	**< 30 min**	**Fuzzy, Irregular**	**Low**	none
Sunspot	> 3” (2500 km)	**> 30 min**	**Sharp ~ round**	**High Dark core**	none

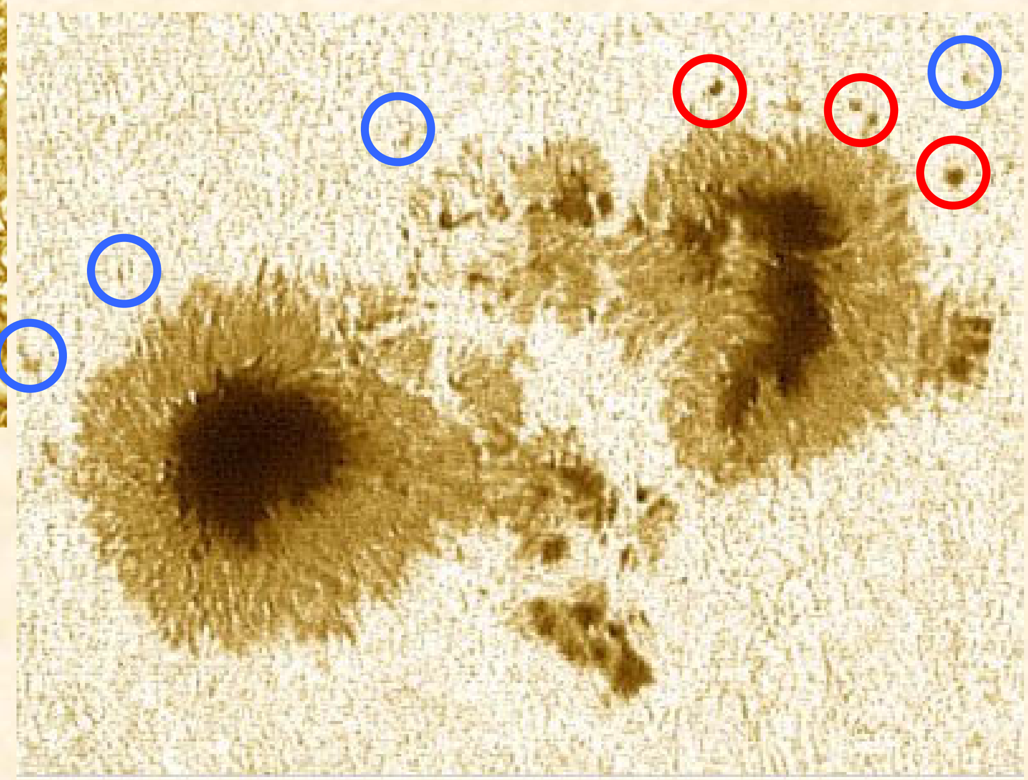
- Simple criteria naturally adopted by all observers
  - No major discrepancies due to personal subjective interpretation
- Match of the smallest real-spot angular size with the usual seeing (3 arcsec) and telescope aperture D= 50 mm:
  - Limited gain in spot counts at apertures > 50 - 80 mm

(cf. Svalgaard, private communication)

- **Small-aperture bias only expected for early historical observations before the 19th century (D << 70mm)**

Sunspots and “pores”





Sunspot

Pore

The R_i human factor: random variations

- **Causes of random variations**:
  - Daily mood, mistakes
  - Daily changes of the observer (group splitting, umbral splitting)
  - Seeing variations
- **Sampling = One-day binning (UT)** >> "aliasing":
  - Random daily subset of network contributors (local weather) ~50/85
  - Fast small-scale changes in active regions (small short-lived spots)
  - Limb transits of large active regions
  - Strong effect mainly when a single spot/group on the solar disk!

- Equivalent to **detector noise**

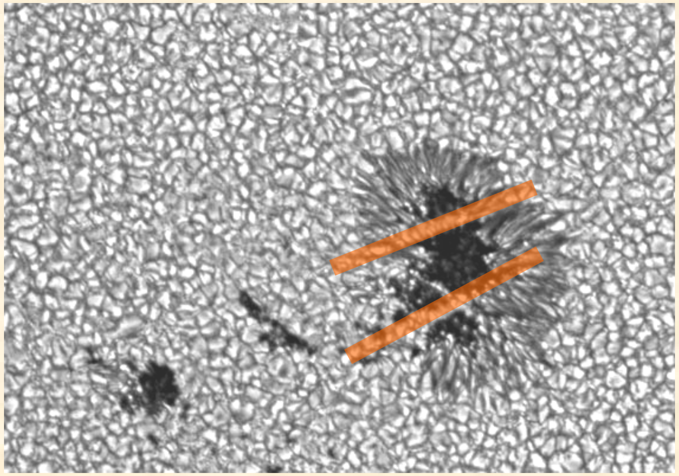
➡ **Filtered out by the daily tracking of K coefficients:**
  - Variations at different stations are **uncorrelated**
  - Elimination of outliers based on standard deviation of daily K values.

Main bias sources: Group and umbral splitting

- **Group splitting:**
  - Topological criteria without external information (magnetograms)
  - No general scientific rule
  - Impact on Wolf number limited:
    - Involves only a minority of groups
    - Can raise or lower W
- **Umbral splitting**:
  - Each umbra in common penumbra is counted as a separate spot (Wolfer rule)
  - Two umbrae considered as split only if separated by a complete light bridge
  - Prone to interpretation
  - Can lead to a net bias

Various group splitting rules *(Kunzel 1976)*:

- Non-bipolar groups: all spots within 5°x5° (60,000 x 60,000 km)
- Bipolar groups: longitudinal extension < 20°
- Rules for marginal cases:
  - Two spots up to 15° apart form a single group if they are the remainder of a large extended group
  - A bipolar collection of spots forms one group if Lat(West) ≤ Lat(East)
  - Typical tilt angles: 1-2° at 10° latitude, 4° at 30° latitude



The R_i human factor: systematic observer bias

- **Causes of biases**: observer practice
  - **Splitting of large complex groups**
  - **Splitting of multiple umbrae in common penumbra**
  - Frantic quest for the largest count (including tiny ephemeral blemishes)
  - Prior consultation of other observations (WEB CCD images) leading to expectations:
    - Bias emerging in recent years?
- **Sources of trends** (slow variations in the personal biases):
  - Observer ageing (visual acuity for age > 50; slow evolution of practices)
  - Trend in sky quality (urbanization)
  - Slow evolution of network members
  - Instrument ageing

➡ **Tracked by K-coefficient system**:
  - **Uncorrelated biases (network)**: independent worldwide observations
  - <u>**One special case: the Zürich-Locarno reference station**</u>

An essential step: processing method

- **Change in the data processing method**
  = primary cause of possible biases

➡ ***Problem common to all indices !***

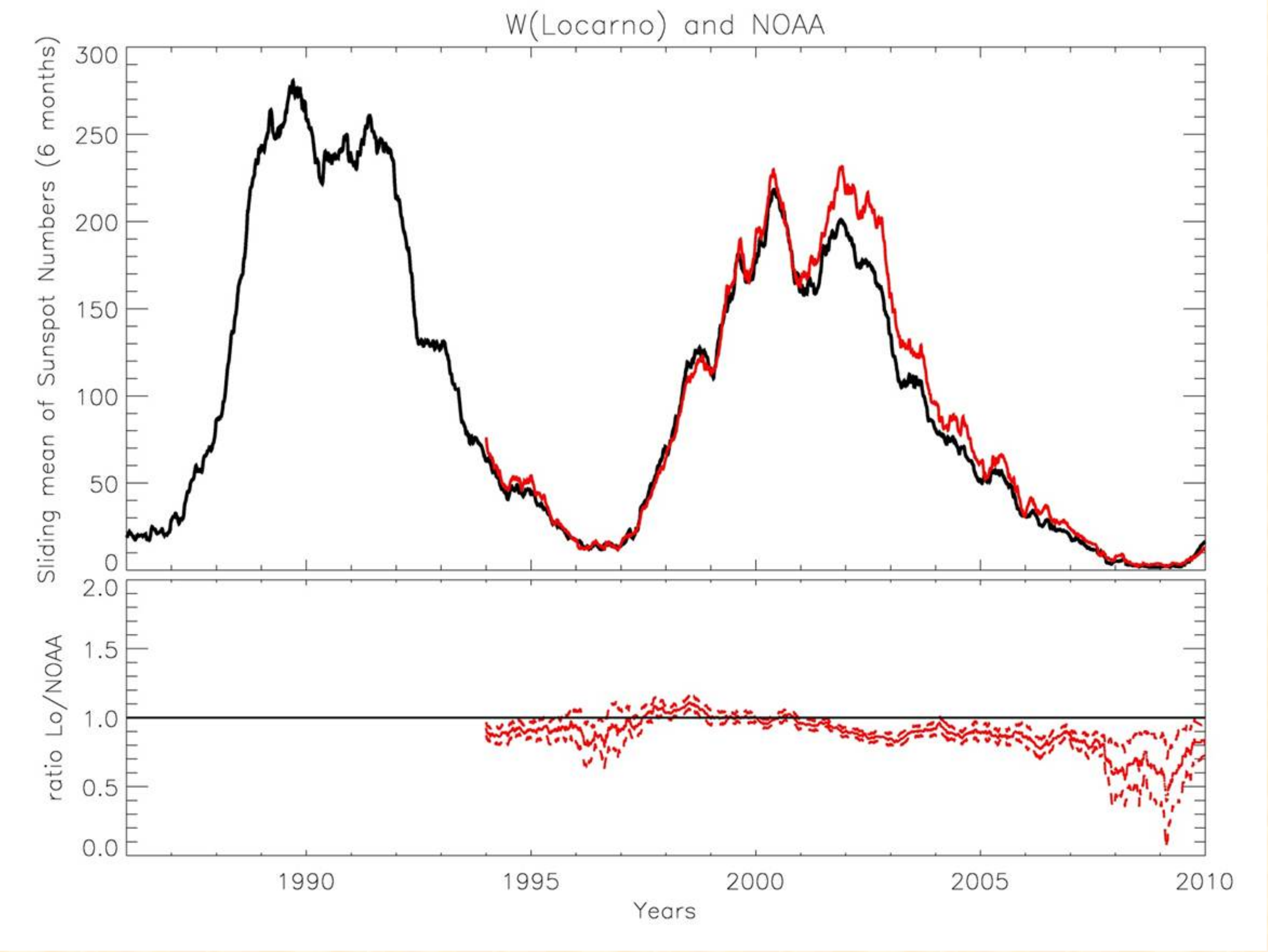
- **Zürich-Locarno Sunspot Index**:
  – Choice to drop smallest spots (Wolf)
  – Magnetic needle corrections (Wolf)
  – Weighting of sunspot counts (Wolfer, Brunner or Waldmeier ?)
  – Change of primary station (Zürich – Locarno)
  – Change in the composition of network (observer mix, geographical distribution): e.g. Zürich-SIDC transition
    - Smaller impact for large networks (SIDC strategy)
  – Manual method: sparsely documented (occasional indications scattered over many different issues of the Mitteilungen)

R_i and other sunspot numbers

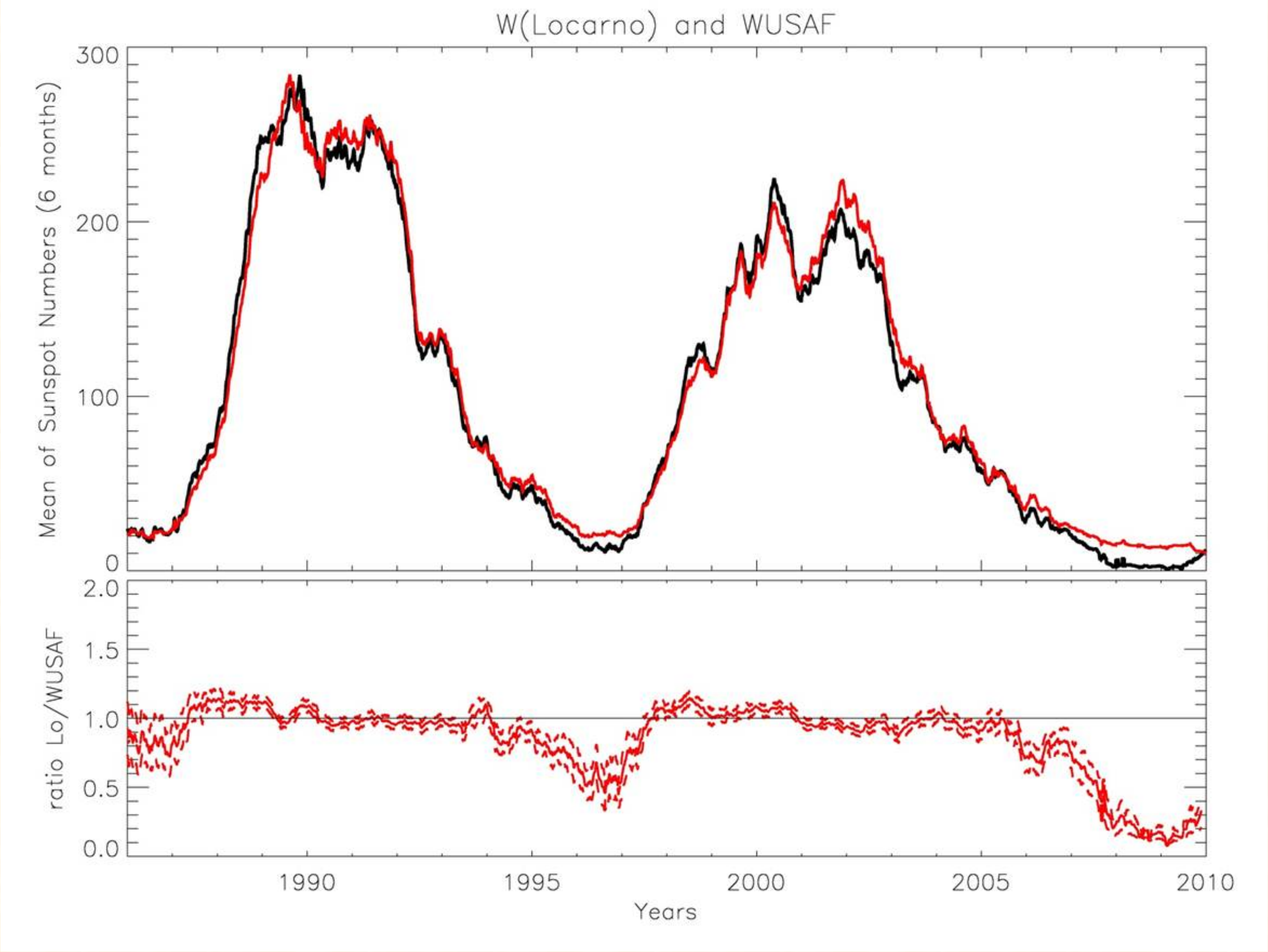
Long term stability of the Locarno station

- Two kinds of validation: intrinsic and comparative
- **Cross-comparison with external data series**:
  - **Sunspot numbers from individual stations**
  - **Sunspot numbers from independent networks**
  - **Other solar indices (sunspot area, F10.7cm, CaII-K, MgII)**

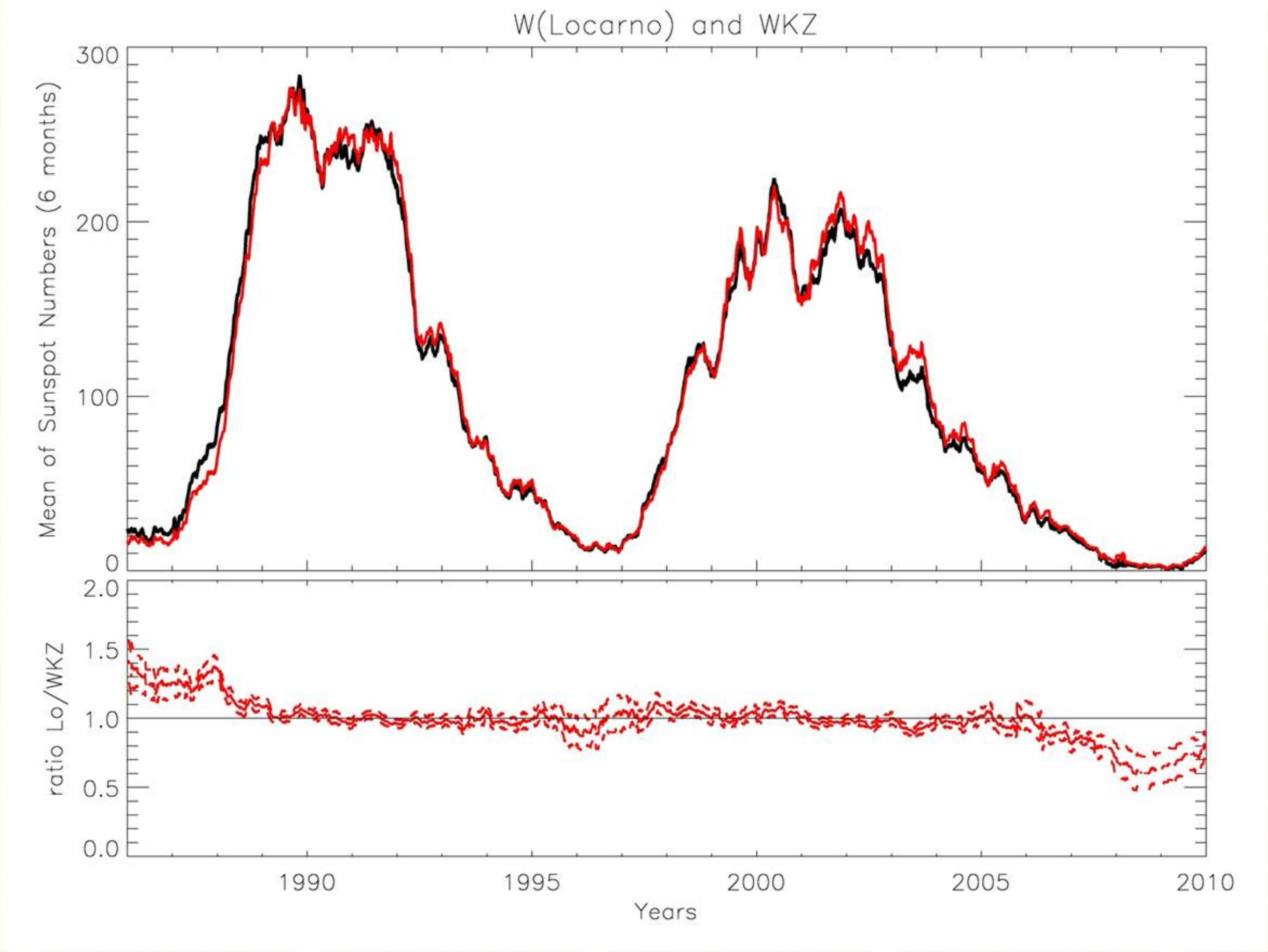
Locarno versus NOAA-Boulder SSN



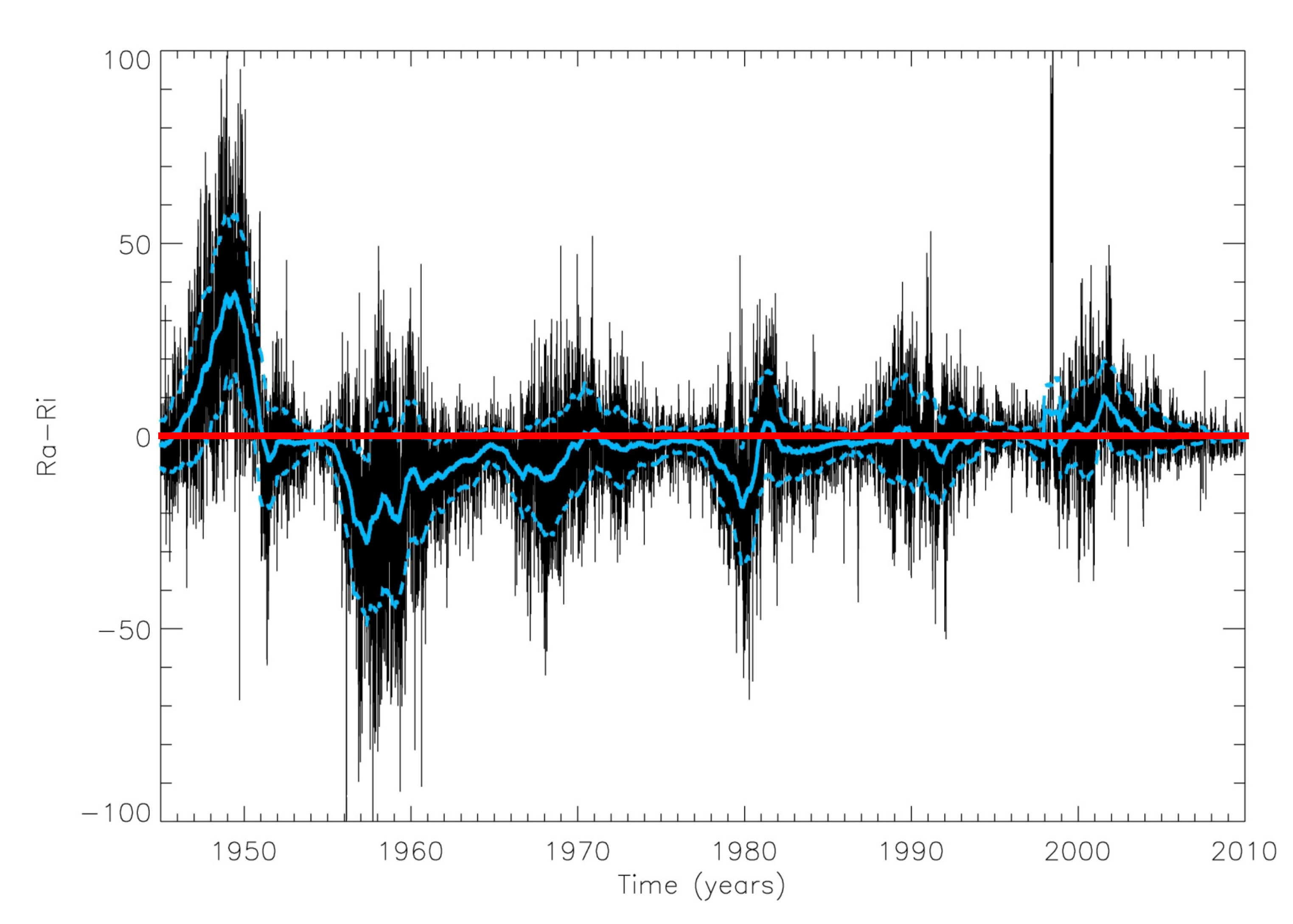
Locarno versus USAF/SOON SSN



Locarno versus Kanzelhöhe



Locarno versus R_A SSN (AAVSO)

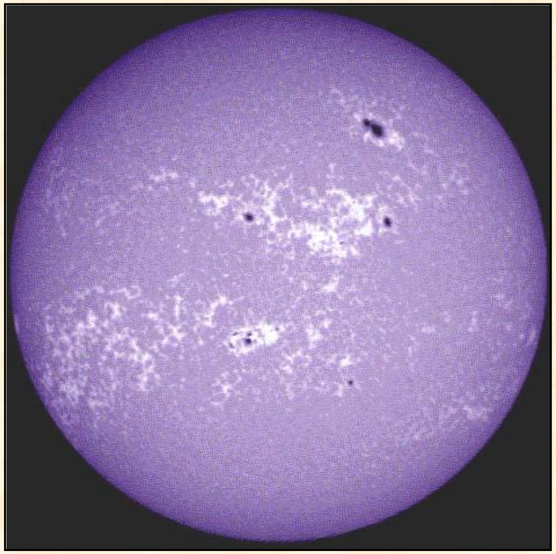


R_i compared to other solar indices

- Most indices are chromospheric or coronal ($F_{10.7}$, CaII-K, MgII c/w) or contain a wide mix (TSI):
  - Different physical relation to the underlying magnetic flux emergence:
    - **Non-linear relation**
    - **Time lags**
  - **R_i closely related to magnetic flux emergence**:
    - High threshold on magnetic field (> 1500 Gauss)
    - Spots disappear early in the magnetic decay of an active region
  - **Chromospheric and coronal indices contain a strong contribution from weak decaying fields** (flux dispersion):
    - plages, faculae, ephemeral regions, quiet Sun/ coronal hole relative area.

➡ Discrepancies do not mean disagreements and flaws !

- ***Index differences = solar information***



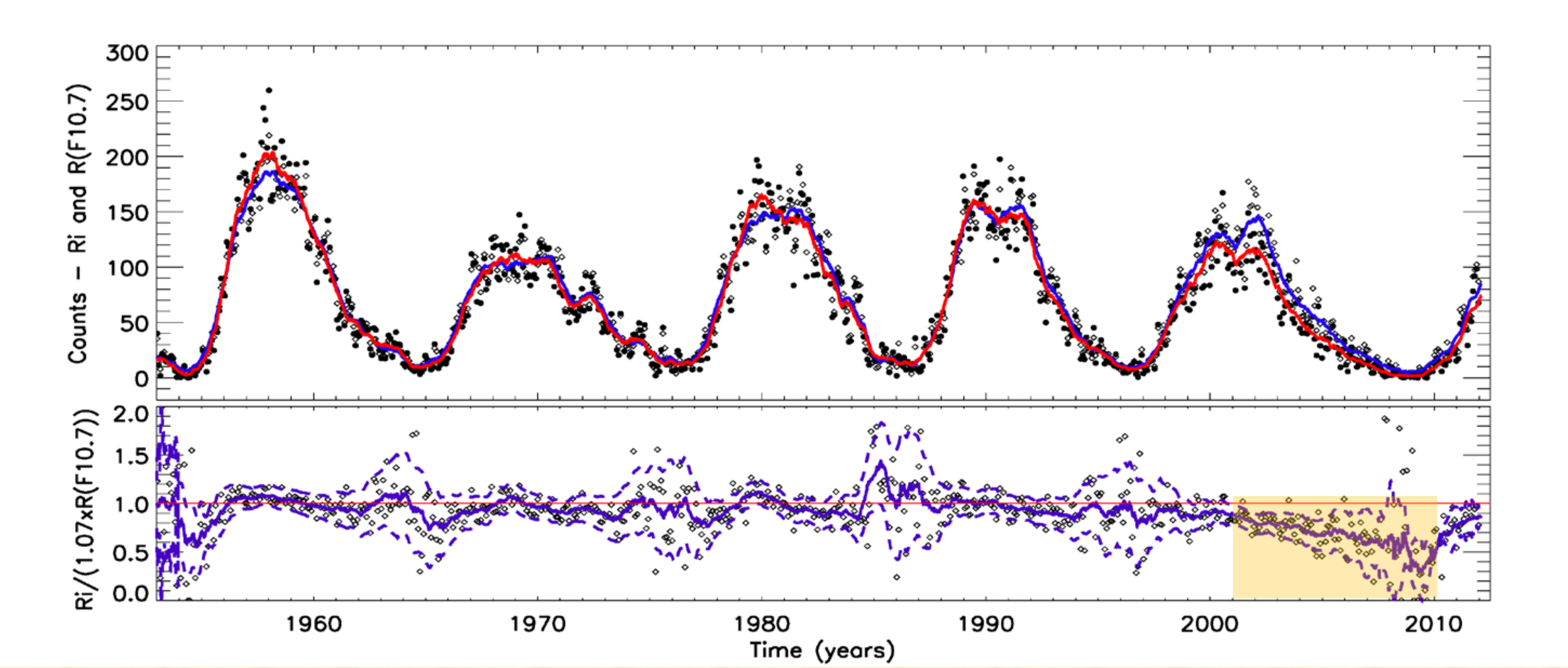
CaII K, Kitt Peak Obs.

Nobeyama, radio, 17GHz

A tight agreement R_i – $F_{10.7}$ … until recently

R_i= 1.14 $F_{10.7}$ – 73.21
(Tapping, K.F. 1999)

- 1950 – 2000: stable quasi-linear relation
  Linear Correlation = 0.98
- Since 2000: **R_i ~15% below its $F_{10.7}$ proxy** *(Svalgaard & Hudson 2010, Lukianova & Mursula 2011)* (+ other chromospheric indices)



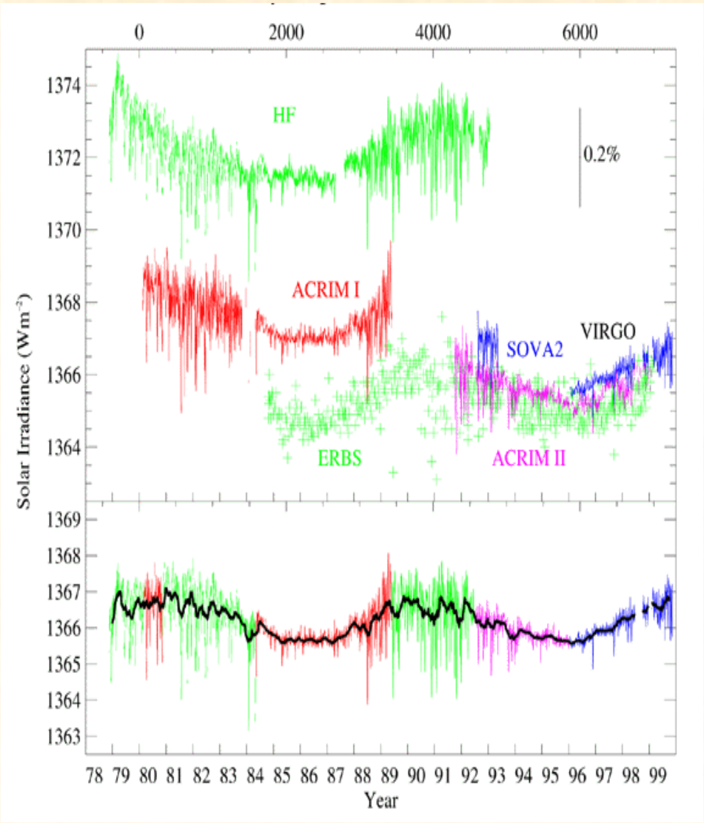
R_i and other solar indices

- High correlation of R_i with recent indices:
  - > 97% with photospheric indices
  - ***R_i is a quantitative index***
- **Advantages of other indices:**
  - Based on a quantitative "impersonal" measurement (flux, area)
  - Precision equal or higher than R_i
- **Limitations of other indices:**
  - Short duration (only recent solar cycles)
  - **Difficulty of long-term absolute calibration**
    - Single or few stations (no cross-validation or trend diagnostics)
    - Short-lived instruments replaced by new different ones (space)
    - Few non-overlapping or discontinuous data sets
  - **Empirical subjectivity "layer" at the processing stage:**
    - Index definition (assumptions: choice of thresholds, boundaries)
    - Instrument modeling (assumptions: ageing, response, stray light, etc.)
    - Elimination of artifacts: empirical filters and criteria

Assumptions in all solar indices

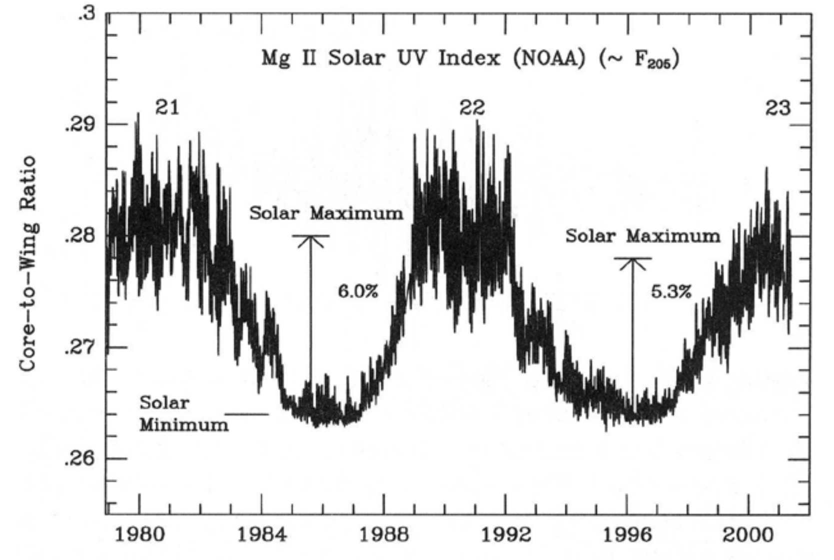
$$R_g = \frac{1}{N}\sum_{i=1}^{N} k_i 12.08\, g_i$$

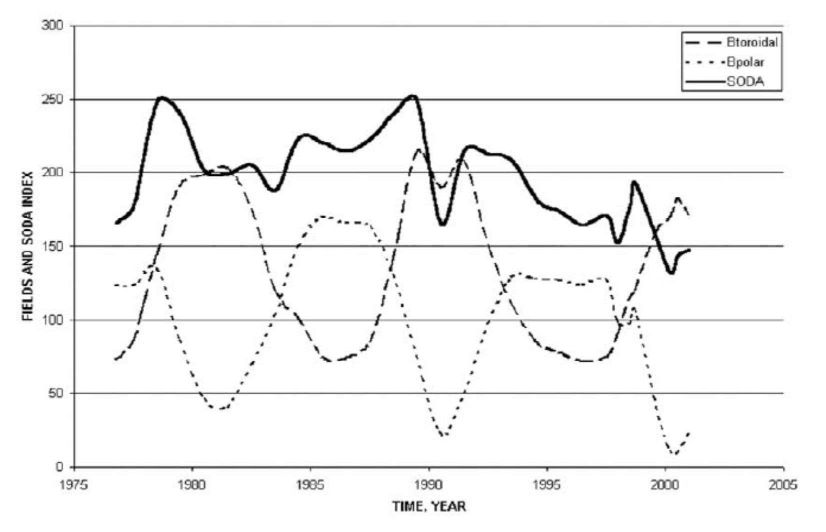
- **Group sunspot number**:
  - All groups contain the same average number of spots at all epochs
- **Total Sunspot area**:
  - Choice in the definition of sunspot boundary: error up to 100% *(Pettauer,T. & Brandt, P.N. 1997)*
  - Different methods (RGO, ISOON) > 1.4 scaling factor *(Wilson & Hathaway, 2006)*
- **F10.7 radio flux**:
  - Undersampling and empirical filtering rules *(Tapping, K.F.& Charrois, D.P. 1994)*
- **Total solar Irradiance**:
  - Assumptions in instrument models: 0.6% disagreements = 4x amplitude of solar cycle in TSI.



Assumptions in all solar indices

- **CaII-K plage index** *(e.g. Foukal,P. 1996, 1998)*:
  - Different photographic plates
  - Assumptions in definitions of plage areas and brightness
- **MgII c/w ratio** *(e.g. White et al. 1996; Svalgaard 2007):*
  - Assumption: core to wing ratio cancels out instrumental effects
  - Not true! Disagreement > 5% between UARS and earlier spacecraft calibrations
- **Polar magnetic field** *(Schatten, K.H. & Pesnell,W.D. 1993; Schatten,K.H. 2002)* :
  - Grazing LOS: projection effect
  - Incomplete view of polar regions
  - Assumptions (radial field lines, etc.)



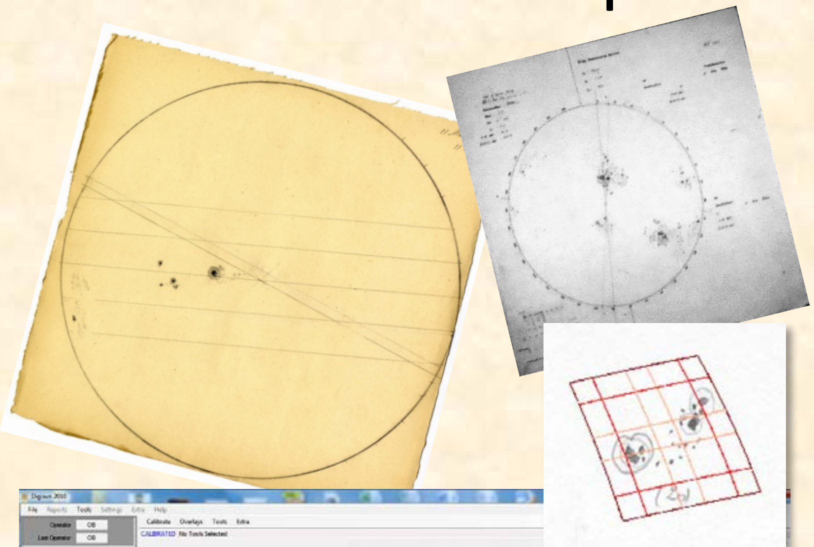


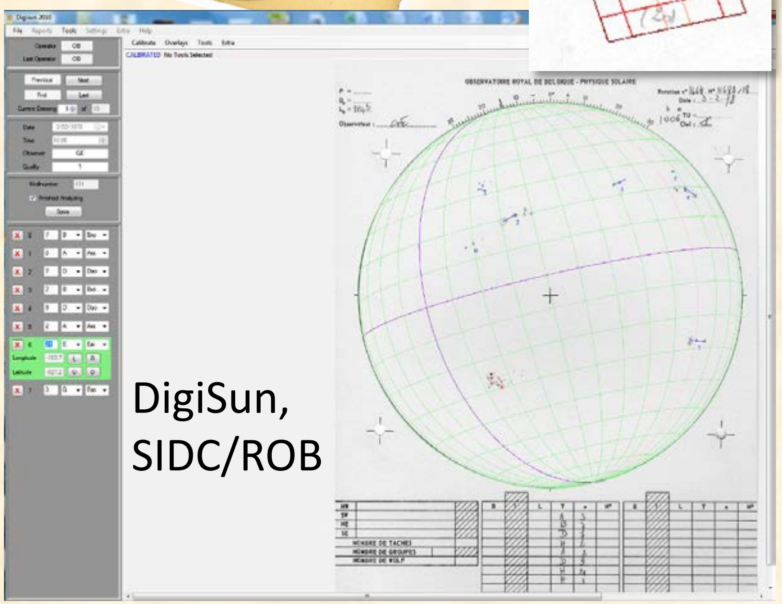
Future prospects

Future prospects for R_i: Exploring and understanding R_Z to improve the current R_i

- ***Scaling of the Wolf values before 1882? Size of the corrections? Weren't raw values better?***
- ***What is the actual date of the introduction of large spot weighting still in use at Locarno?***

➡ Need to recover information about individual sunspot groups: historical sunspot drawings
  - in particular collections from observers who contributed to R_Z
- **Exploitation of historical sunspot drawings**:
  - Digitization
  - Measurements >> catalogs, databases



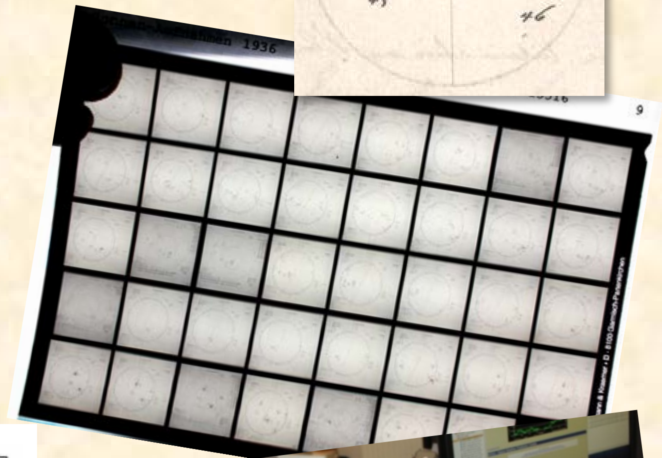


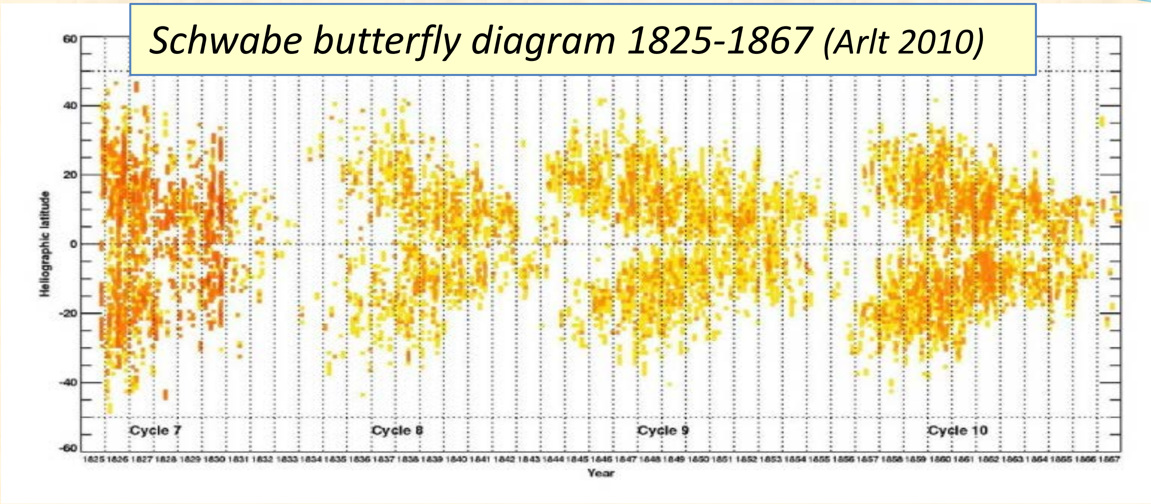
DigiSun, SIDC/ROB

The future: looking back

- 1-D scalar information expanded to:
  - Count, area, position, morphology, dipole size & orientation, evolution, growth, decay, rotation rate, global distributions in latitude and longitude.
- **New long-term direct proxies by multiple sunspot parameter combinations**:
  - Principal component analysis *(ROB, Univ. Orléans)*

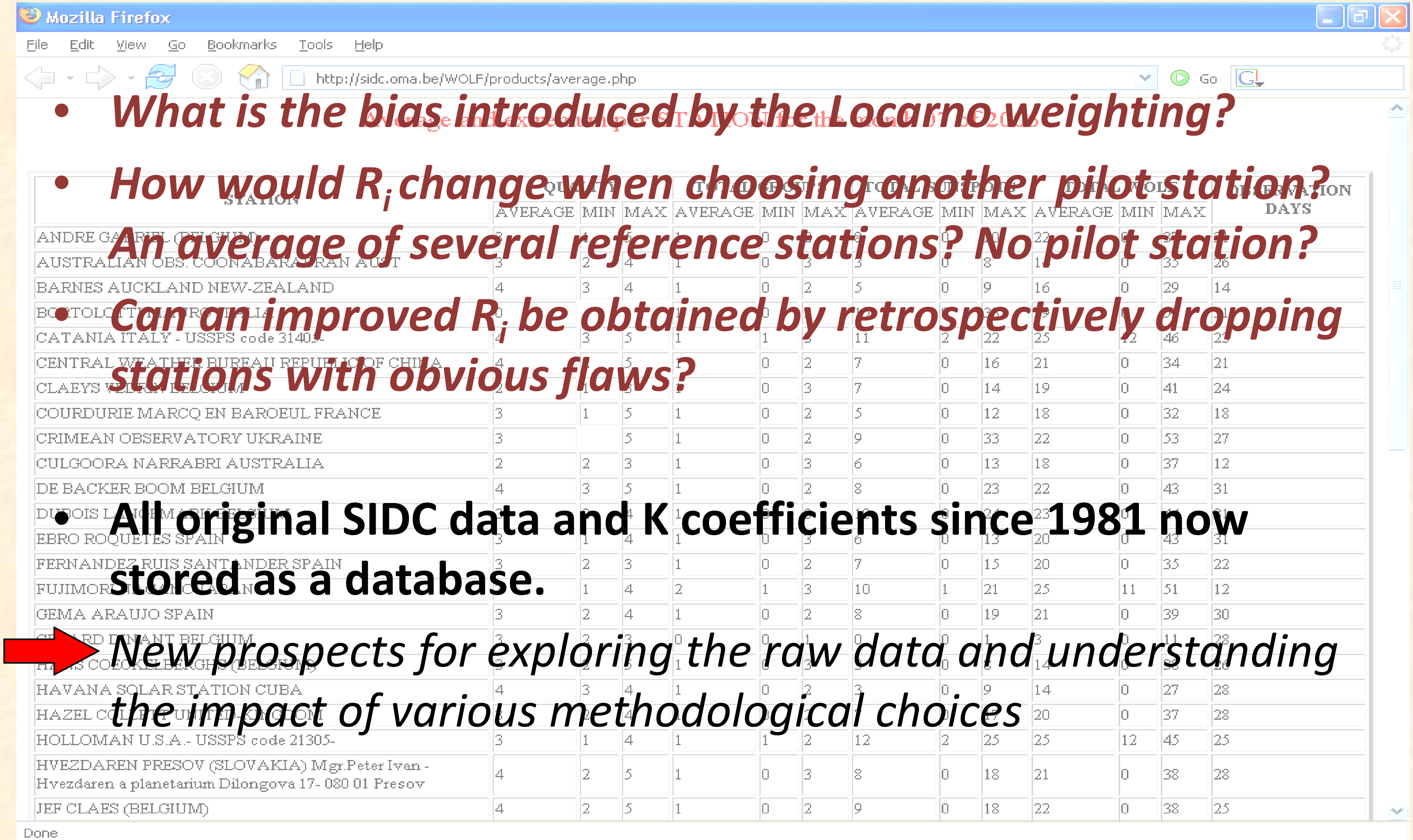
Zürich & Locarno original sunspot drawings awaiting processing ! (1883-1983 on microfilm)





Schwabe butterfly diagram 1825-1867 (Arlt 2010)

Future prospects for R_i:
Exploring R_i to better understand the past index R_Z



- *What is the bias introduced by the Locarno weighting?*
- *How would R_i change when choosing another pilot station? An average of several reference stations? No pilot station?*
- *Can an improved R_i be obtained by retrospectively dropping stations with obvious flaws?*

- **All original SIDC data and K coefficients since 1981 now stored as a database.**

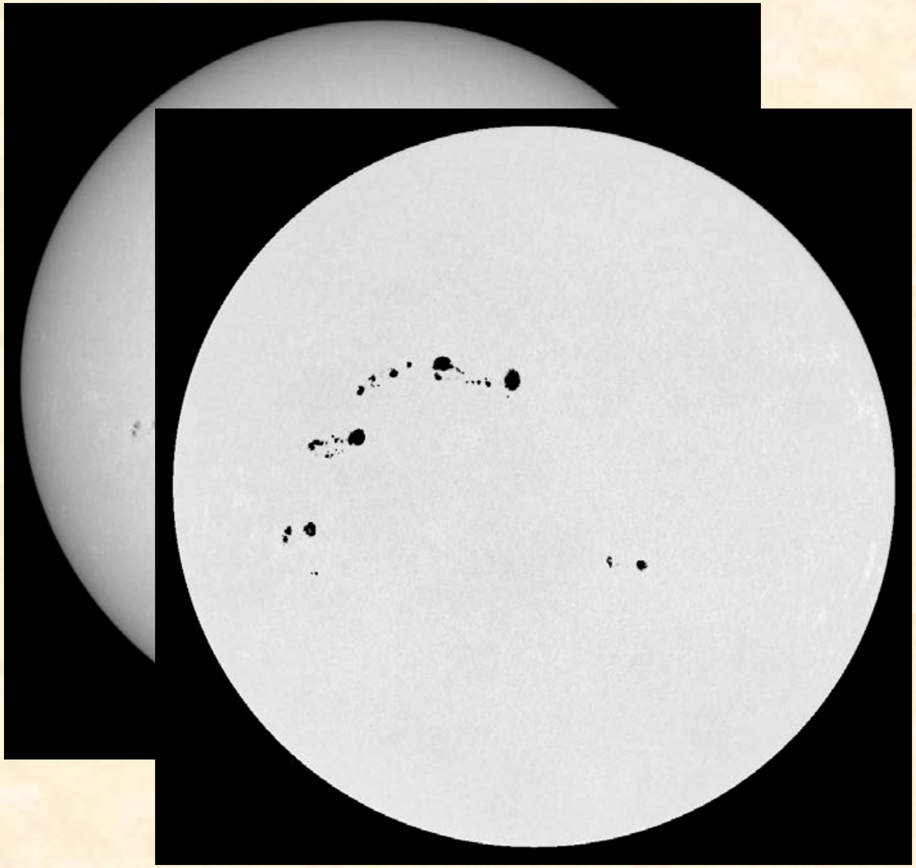
➡ *New prospects for exploring the raw data and understanding the impact of various methodological choices*

Future prospects for R_i: looking forward
Investigation of image-based indices (photo, CCD)

- ***Can a proxy of R_i be created in the future, based on images data?***

➡ require long cross-calibration (whole range of activity
  ➡ more than one cycle)
  - complex visibility of smallest spots vs seeing, contrast.

➡ No replacement soon.
  - New indices can be created but are distinct from R_i :
    parallel proxy series.



(Zharkova et al. EGSO, 2003)

$$R_W = \sum_g \left(10 + \sum_{f \in g} 1 \right) \quad \Rightarrow \quad R_C = \sum_g \left(W_g + \sum_{f \in g} A_f \right)$$

Conclusions

- **The R_i index = a decisive modernization vs the manual R_Z**
  - Large base of observers in a worldwide network
  - Constant & documented processing scheme over 30 years
- **R_i is still scaled according to a single pilot station: Locarno**
- Multiple validations confirm the **good stability of the pilot station over at least the last 25 years** *(cf. next session)*.
- **R_i is a quantitative measurement** highly correlated to equivalent modern "flux" indices.
- **The subjectivity in the SSN is limited by intrinsic factors.**
- **Biases can now be largely tracked and corrected by statistics over many stations.**

Conclusions

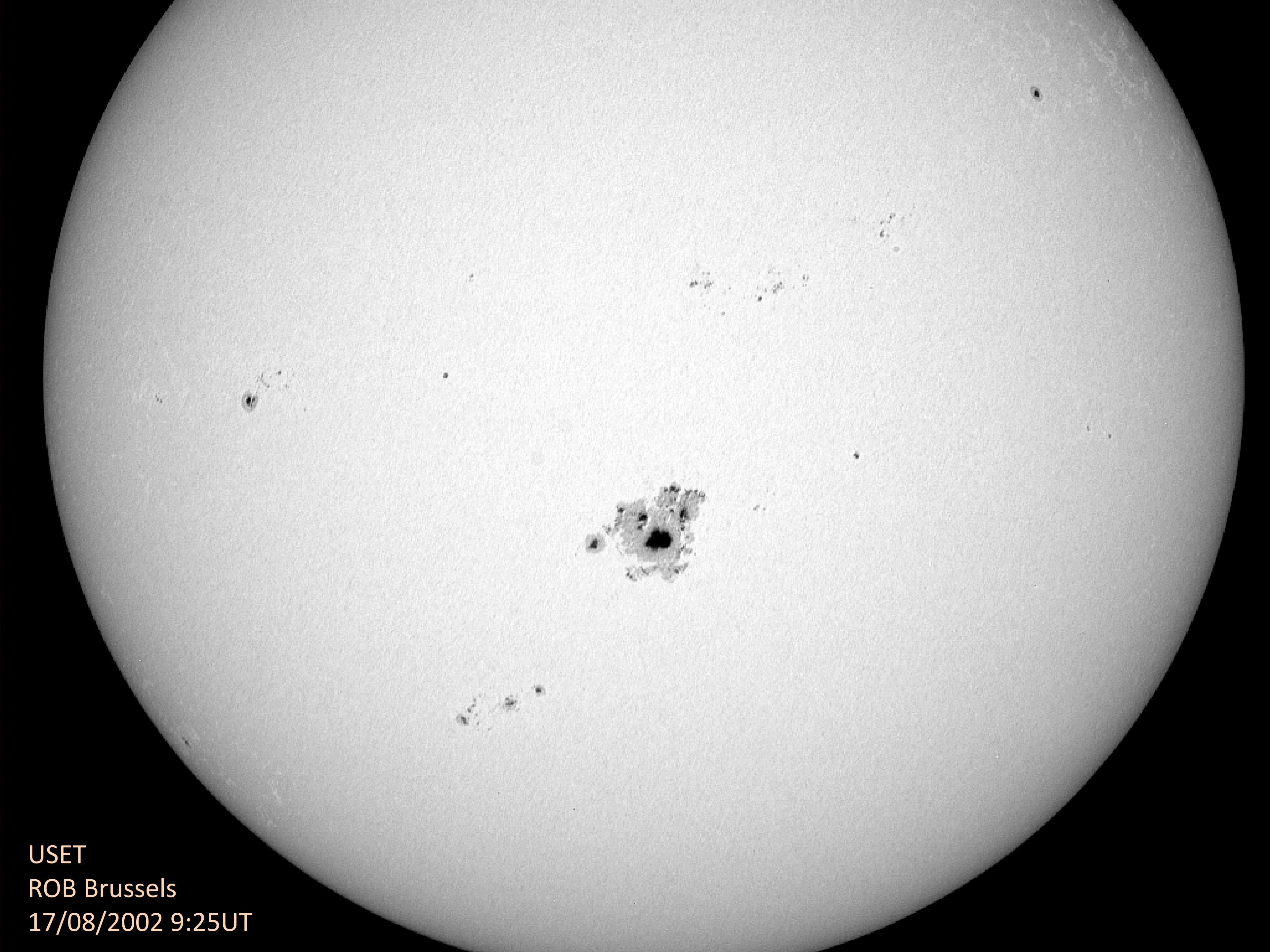
- **Interpretations of differences and drifts of SSN vs other indices must be done with caution**:
  - *Most indices include human assumptions (empirical, instrument model, etc.)*
  - *Different non-linear relations to magnetic flux emergence.*
    - **Cf. other talks !**

- **New prospects are opening up for better understanding R_Z and R_i:**
  - Exploitation of historical drawing collections: Zürich-Locarno
  - Full SIDC database of raw observations and K coefficients.

Conclusions

- **Unparalleled long-term robustness** of a visual index compared to other indices now and in the future:
  - Cheap and simple measurements ➡ permanent reservoir of observers
  - Many data sources (no interruptions, cross-validation)
  - High resilience to changes in the social & political context (wars, science budget cuts!)

- **Large educational and social impact**:
  - Easy to understand and part of public culture (songs, movies):
    ➡ Excellent support for communicating about solar physics and space weather
  - Anyone can take part and contribute:
    ➡ Entry point for many amateur astronomers and scientific vocations.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