A small-sunspot deficit in cycle 23

Sunspot Number Workshop

September 19th to 22nd 2011

Sunspot, NM

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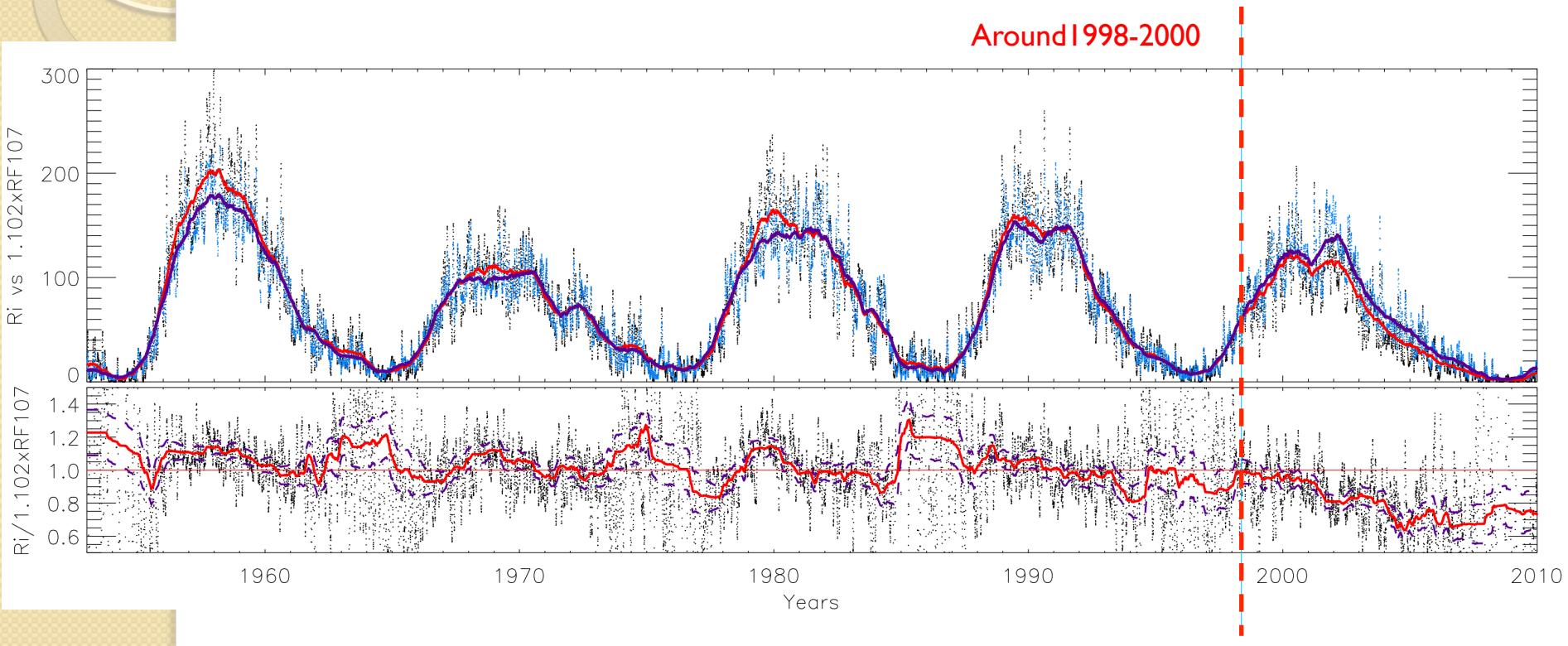
The problem

- Abnormally long minimum after cycle 23 (no-one could predict it beforehand)
- Indices at unprecedented low levels (TEC, TSI, foF2, EUV flux…)
- Disruption of mutual relations between indices … for example $F_{10.7}$ (~25% > R_i)
- Search for precursors :
  - Can precursor signs be found in the collective properties of sunspots ?

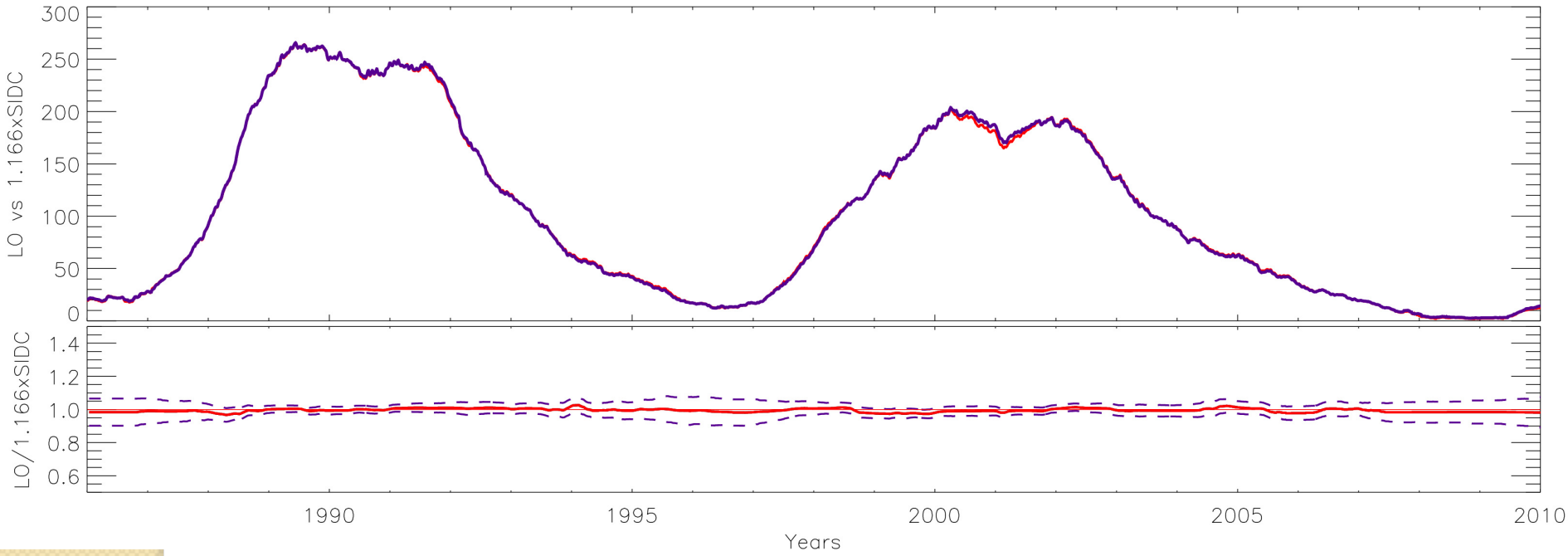
An unprecedented disagreement between R_i and $F_{10.7}$



R_i compared with $R_2(F_{10.7})$ from Johnson (2010)
$R_2(F_{10.7}) = (1/A) \times (F_{10.7} - B)^{(1/C)}$
A=67 & B=0.281 & C=1.3305

➔A problem in the Ri index ?

Locarno: the pilot station of the R_i-network



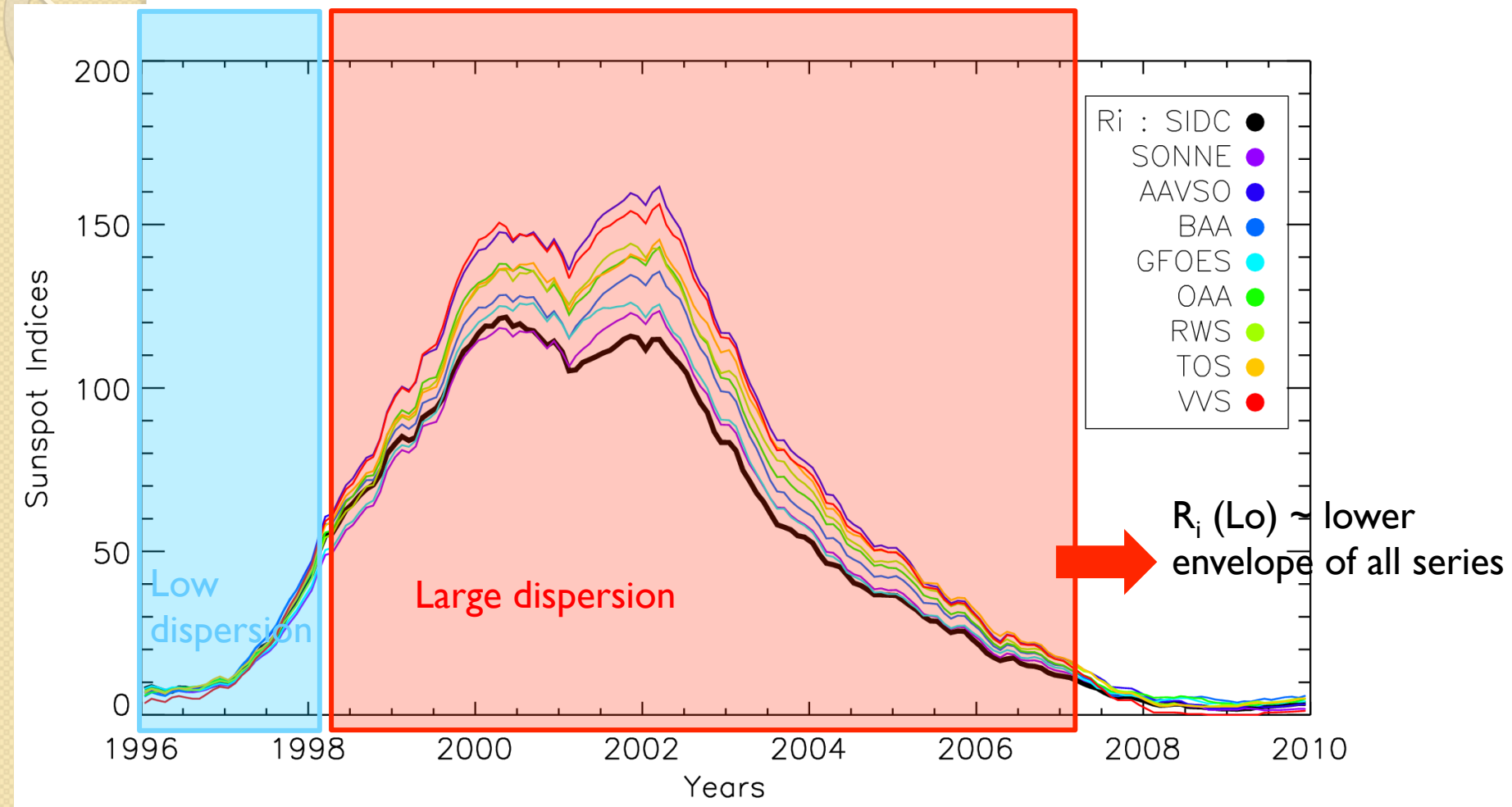
<u>Normalized RMS:</u>
Daily : 2.93%
Monthly: 0.01%
Yearly: < 0.001%

<u>Peak to peak values:</u>
Daily : 8.7%
Monthly : 4.4%
Yearly : 1.1%

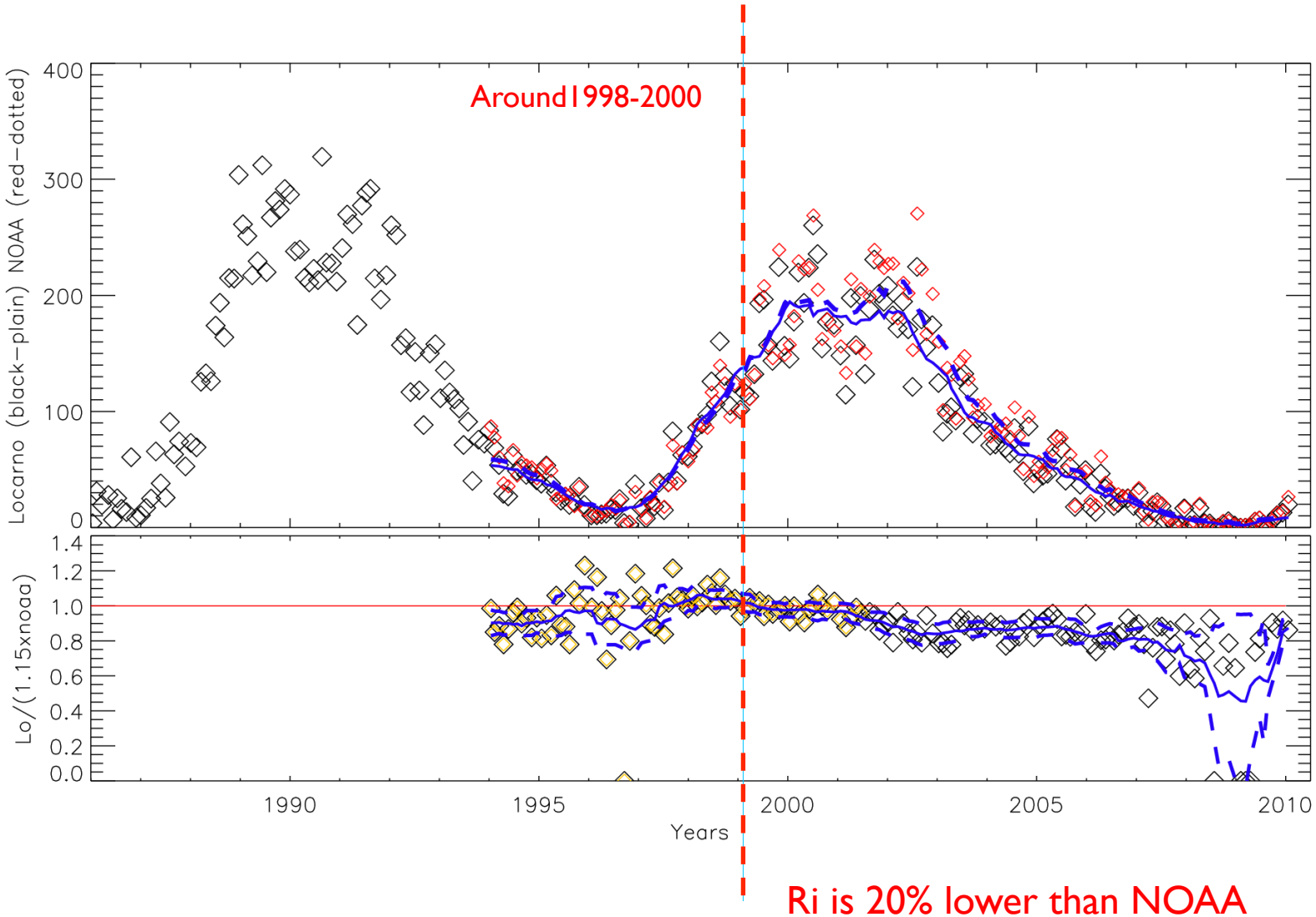
R_i closely follows its pilot station (Locarno)

➔No problems in the computation of the index
➔No problem intrinsic to the Locarno Station

Indices disagreements: outside the R_i-network

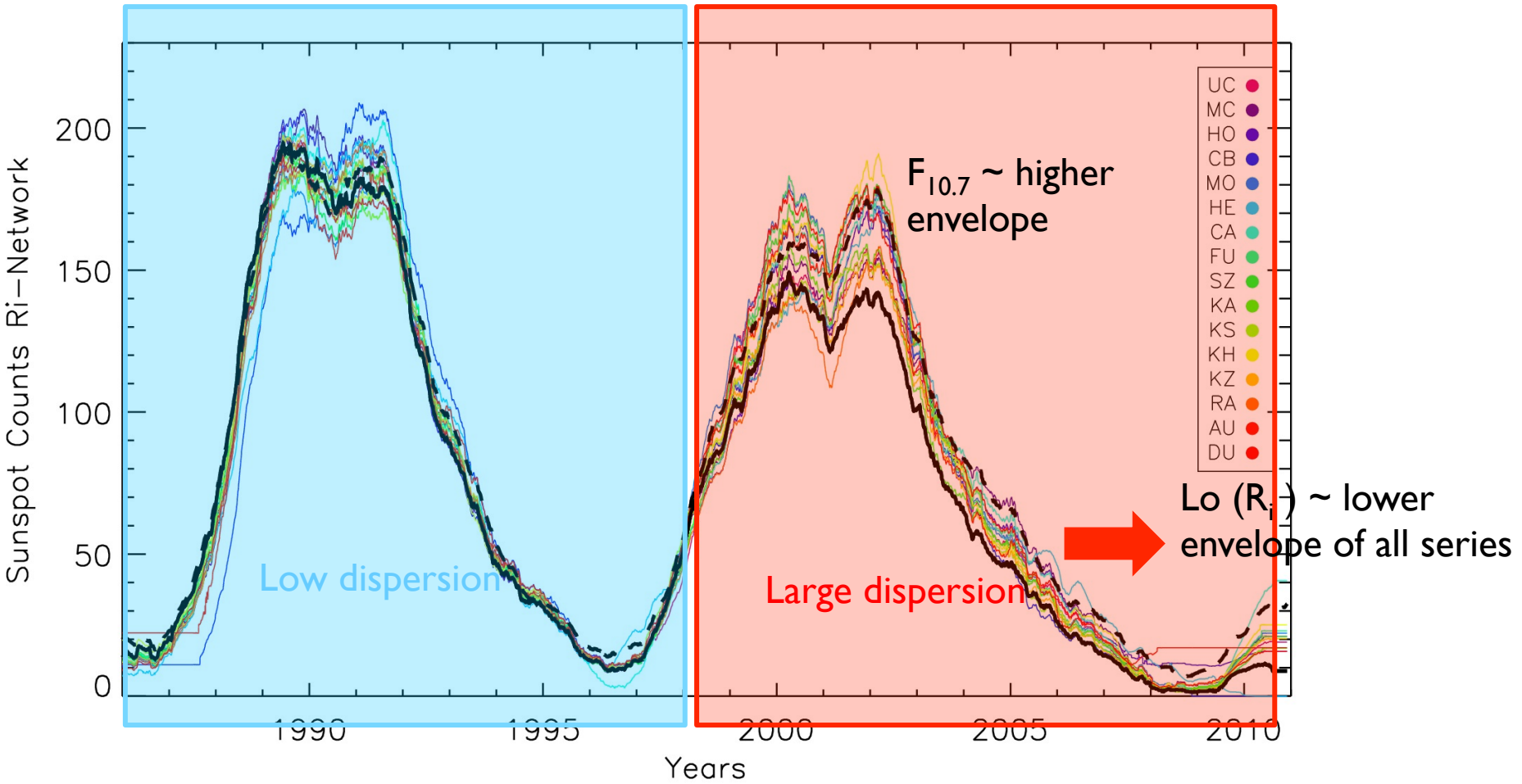


Indices disagreements : R_i vs. NOAA Boulder



Ri is 20% lower than NOAA

Indices disagreements: inside the R_i-network



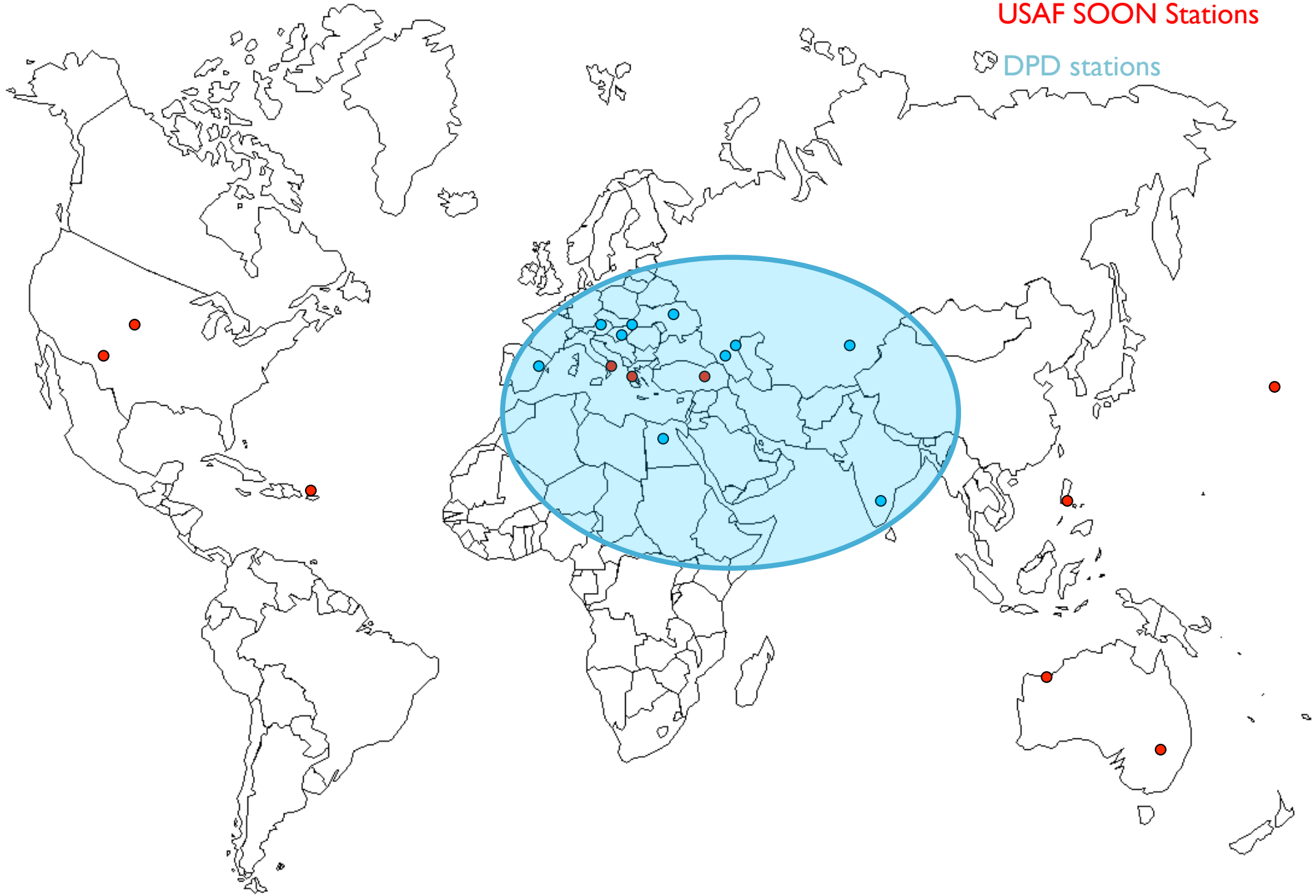
16 Stations : Kawaguchi, Fujimori, Kislovodsk, Kandili, Kanzelhöhe, Uccle, Helwan (Egypt), Camaguey (Cuba,CB),Holloman, Mac Kenzie, Mochizuki, Ramey, Coonabarabran (Australia,AU), Dubois (Belgium), Suzuki, Catania **+ Locarno + $R_2(F_{10.7})$**

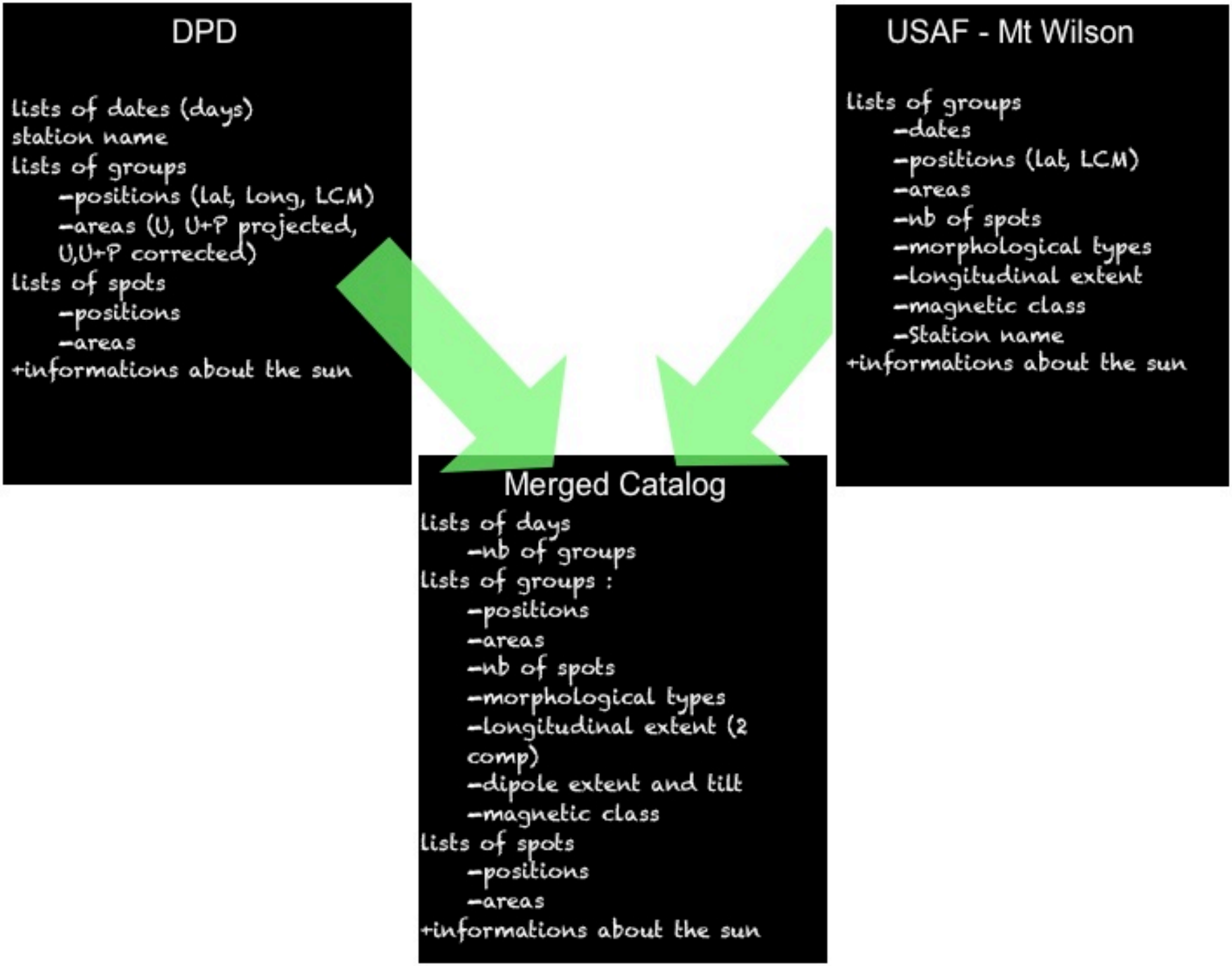
Could those deviations/disagreements have a solar origin ?

To answer this question we will use the information about individual sunspots that we have in our merged catalog.

Our merged catalog

- Merged Catalog based on DPD and ISOON-USAF
  - USAF -> end of 2010 (January 5th 2011)
  - DPD -> August 2011
  - Merged catalog is till Dec. 2010 at this point
- Details down to individual sunspots
- Added information about McIntosh types

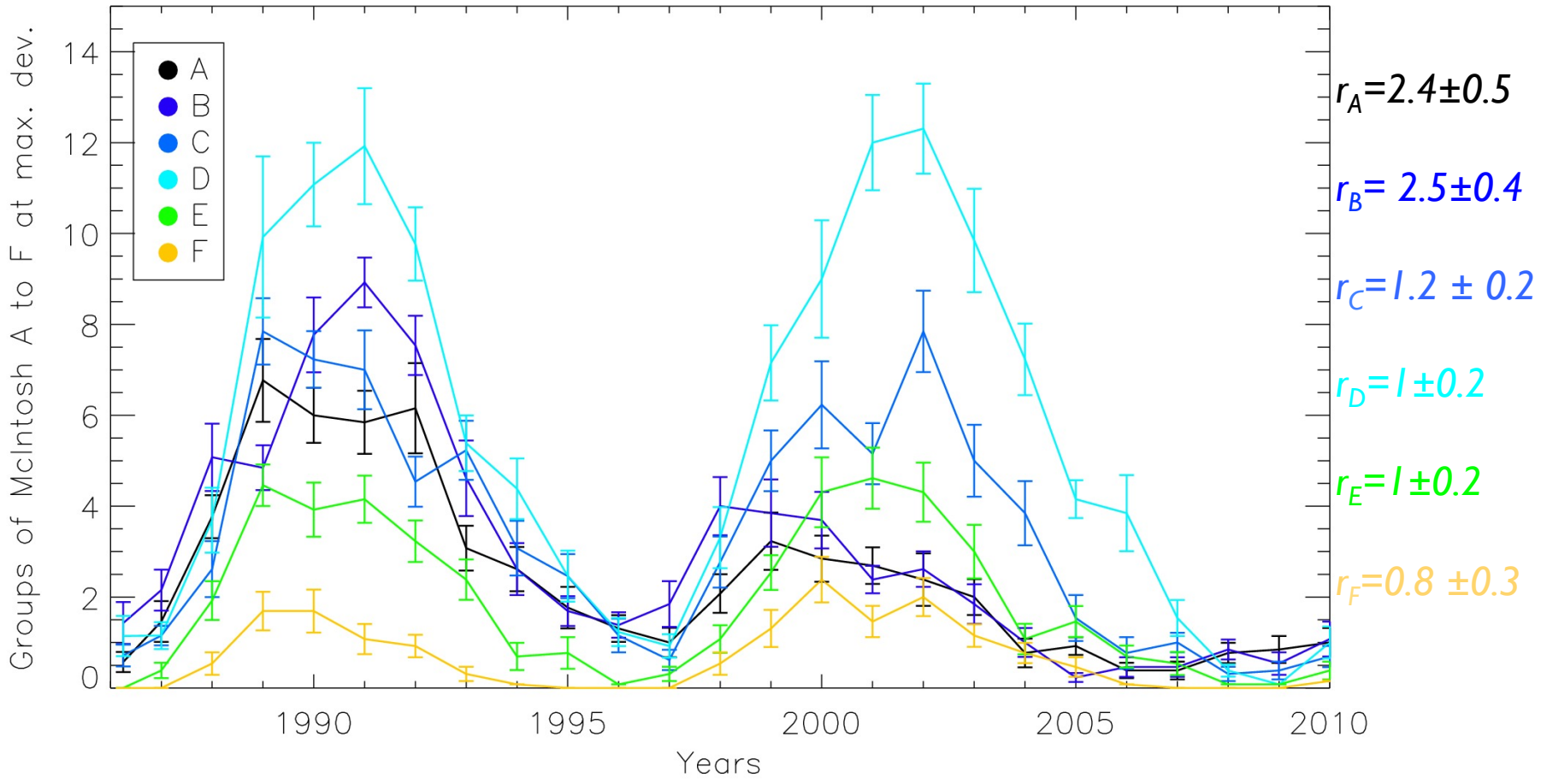

USAF SOON Stations
DPD stations


DPD
lists of dates (days)
station name
lists of groups
-positions (lat, long, LCM)
-areas (U, U+P projected, U,U+P corrected)
lists of spots
-positions
-areas
+informations about the sun
USAF - Mt Wilson
lists of groups
-dates
-positions (lat, LCM)
-areas
-nb of spots
-morphological types
-longitudinal extent
-magnetic class
-Station name
+informations about the sun
Merged Catalog
lists of days
-nb of groups
lists of groups :
-positions
-areas
-nb of spots
-morphological types
-longitudinal extent (2 comp)
-dipole extent and tilt
-magnetic class
lists of spots
-positions
-areas
+informations about the sun

Matching groups

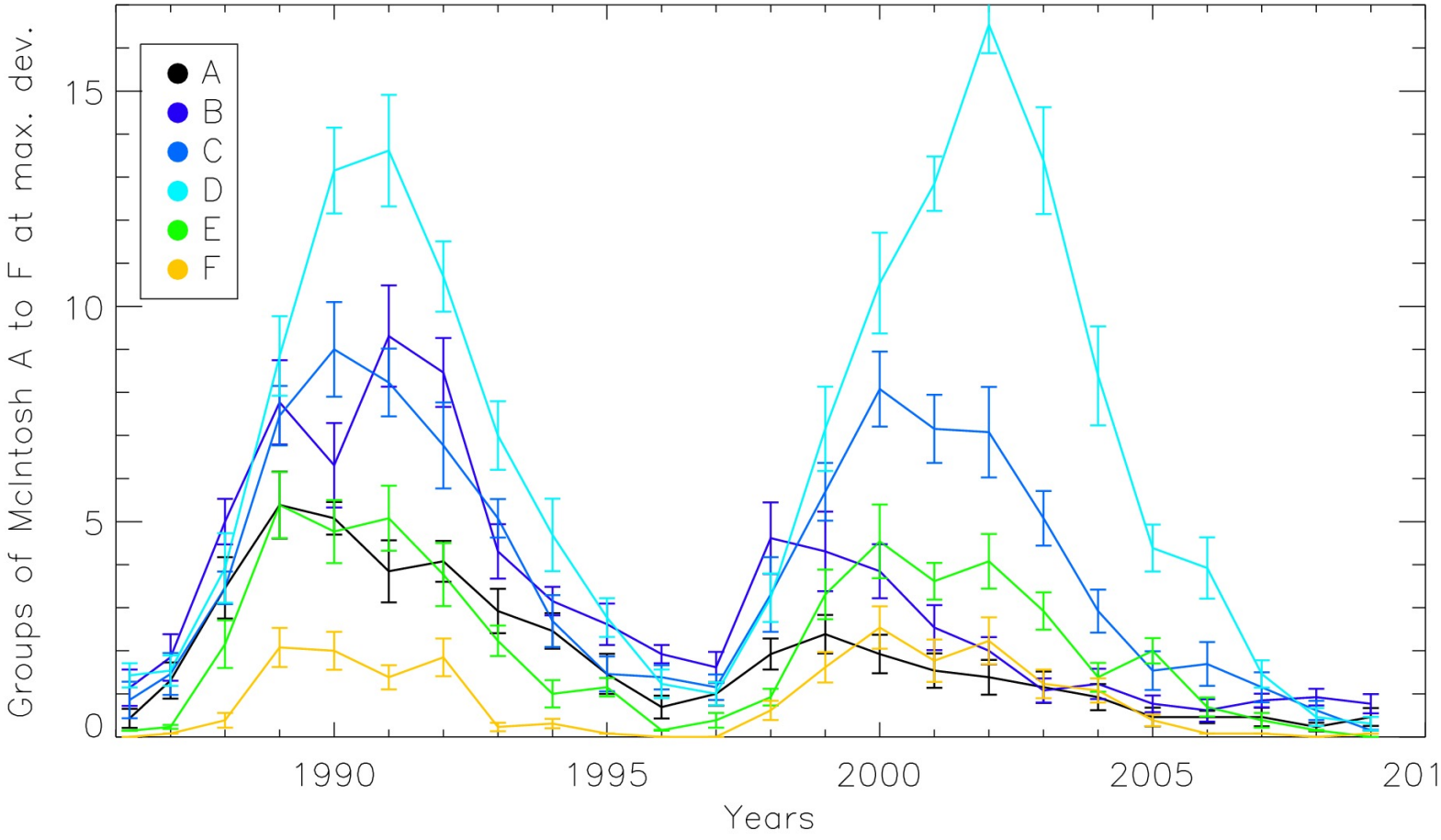
- Total : 54857 groups
- 78.8% of the groups can be matched without problems
- 13.5% are ”penumbrae without umbrae” (pores)
- 4.3% are transitory objects (short lived sunspots or pores)
- 3.4% of cases are still to be studied (mainly different group splitting)
- ➔96.5% of “real” groups are matched

Groups of each McIntosh type at maximum development (Merged catalog)



Each group is counted only once: when it reaches its maximum area. Ratios are for max22 (1989-1991) and max23 (2000-2002).

Groups of each McIntosh type at maximum development (USAF)



r_A=3±0.8

r_B= 2.8±0.6

r_C=1.1 ± 0.2

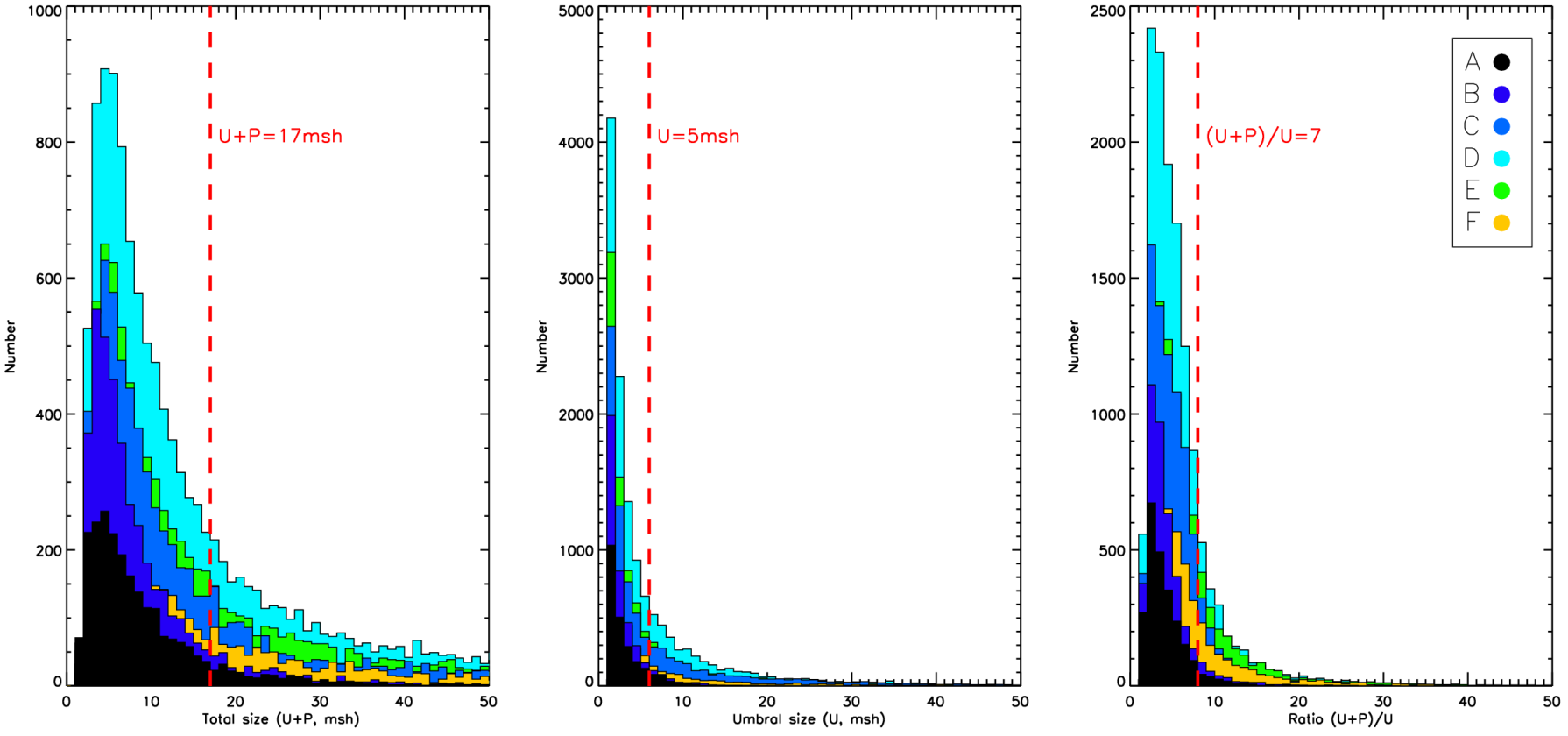
r_D=0.9±0.1

r_E=0.8±0.3

r_F=0.7 ±0.2

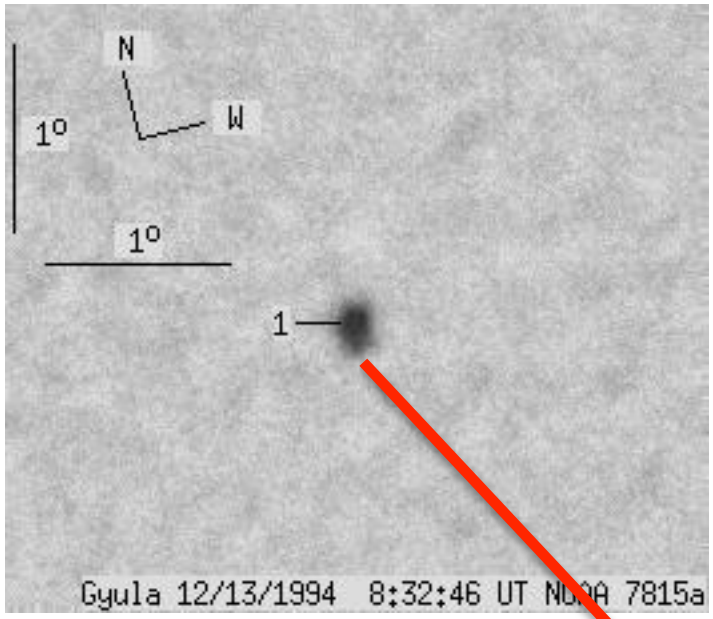
Distributions of Umbrae (U) and Penumbrae (P)

Merged / DPD catalogs



90% of A and B groups have U+P ≤ 17 msh, U ≤ 5 msh and (U+P)/U ≤ 7

DPD: (U+P)/U criterion



- (U+P)/U = 3
- U+P = 3U
- P=2U

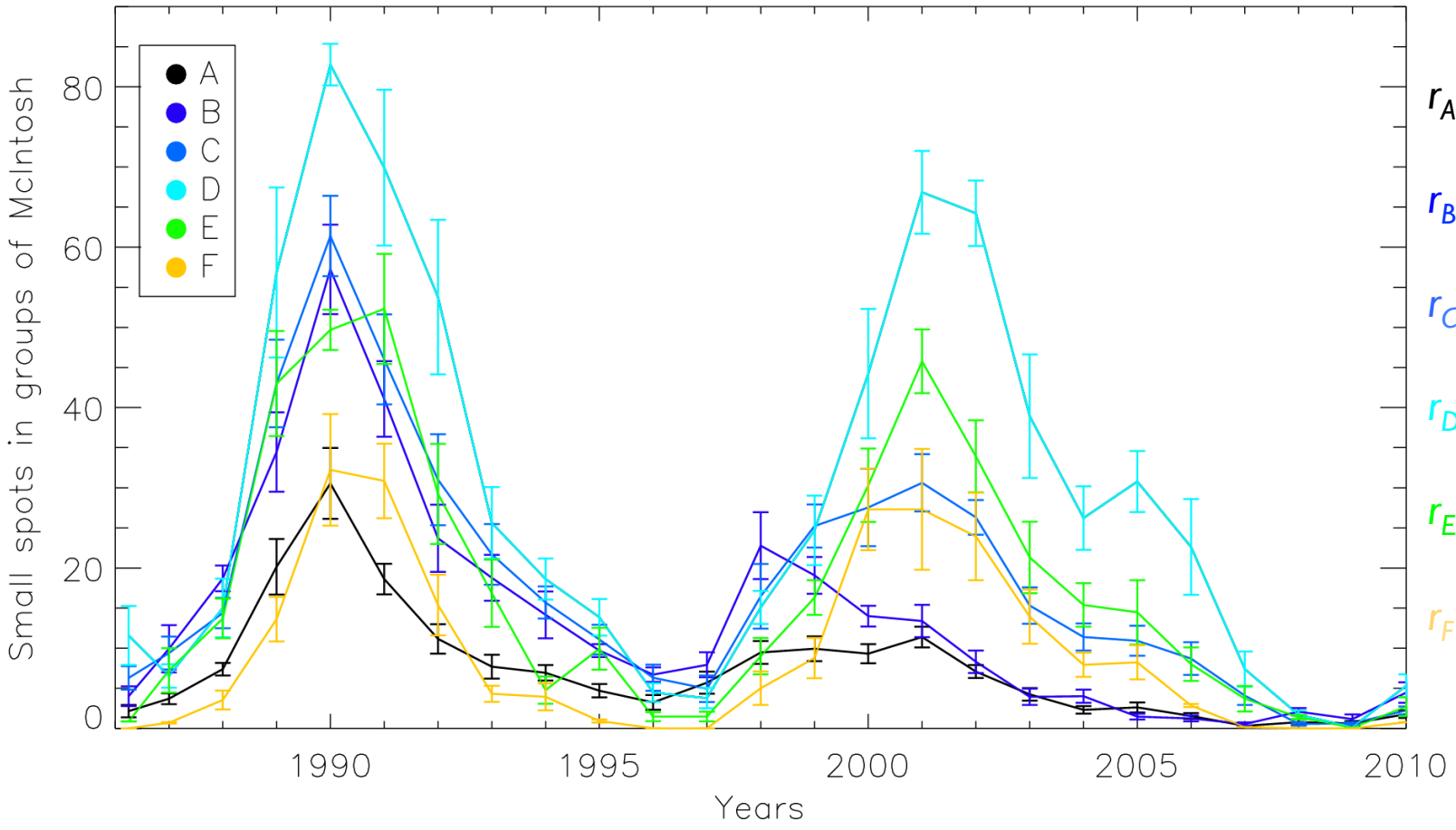
Penumbra twice the size of umbra though spot is classified AXX by USAF-ISOON catalog

Table: Description of group 7815a in the DPD catalog

	Year	mt	dy	h	mn	s	NOAA+suffix		U	U+P	U	U+P	Lat	Long	LCM	B_0	Dist from center
g	1994	12	13	08	33	29	7815a		1	6	1	3	-11.26	217.23	-17.40	122.11	0.3479
s	1994	12	13	08	33	29	7815a	1	1	6	1	3	-11.26	217.23	-17.40	122.11	0.3479

Excerpt from the DPD catalog. Columns year, mt, dy, h, mn and s correspond respectively to year, month, day, hours, minutes and seconds of observations. Lat, long and LCM are the heliographic latitude, longitude and the longitude from the central meridian. B_0 is the heliographic latitude of the center of the solar disk and the last column gives the distance from the solar disk center in units of the solar radius. Group 7815a was also observed on December 13th 1994 by the ISOON-USAF consortium and classified as McIntosh AXX.

Number of small spots in each type of group



r_A=2.9±0.7

r_B= 3.9±0.8

r_C=1.8 ± 0.4

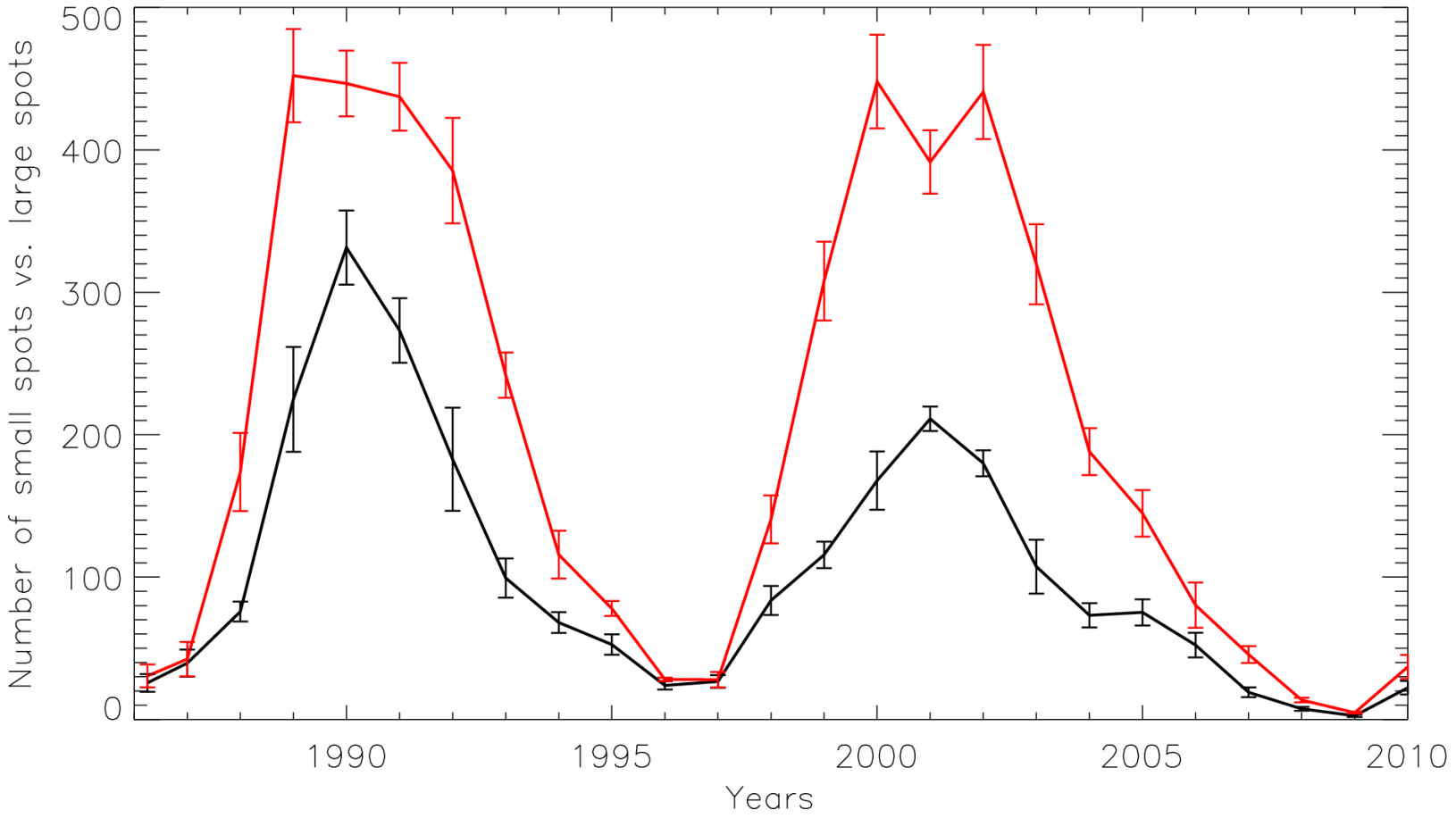
r_D=1.2±0.2

r_E=1.4±03

r_F=1.0 ±0.3

Small spots: U+P ≤ 17 msh AND (U+P)/U ≤ 7

Small spots vs. large spots

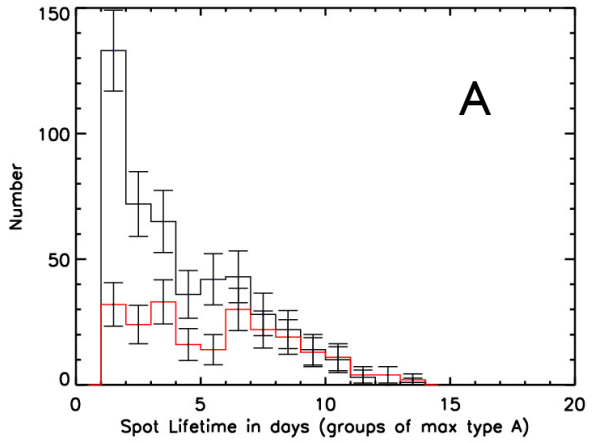


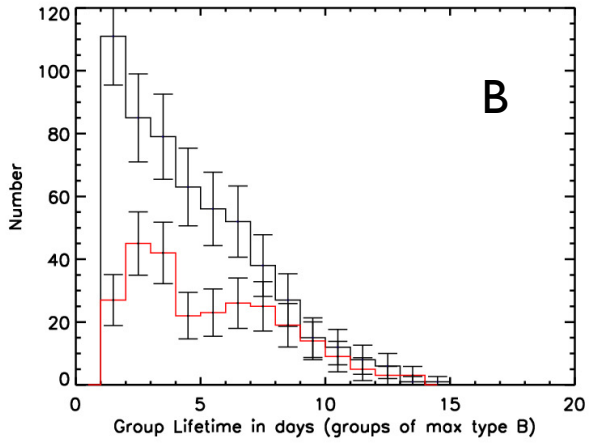
Small spots: U+P ≤ 17 msh **AND** (U+P)/U ≤ 7

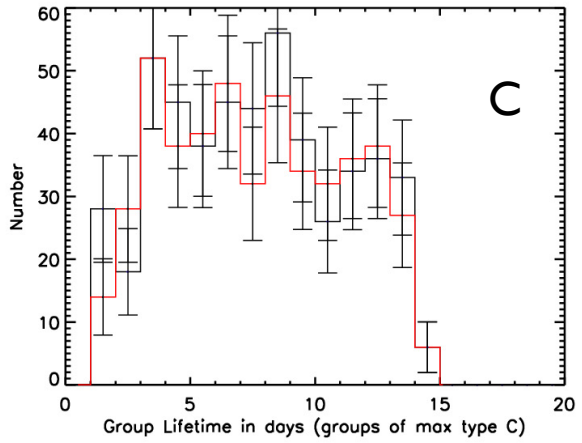
Larger spots: U+P > 17 msh **OR** (U+P)/U > 7

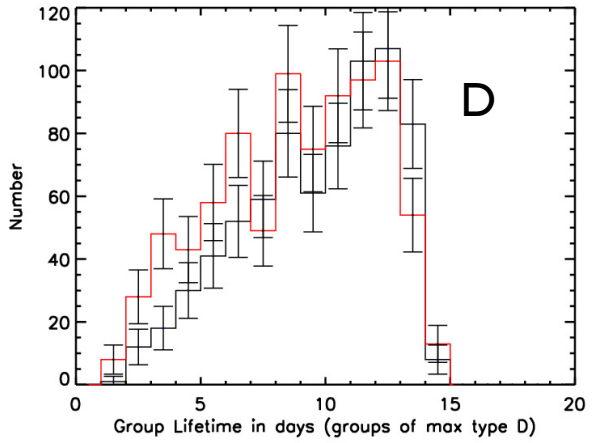
Lifetimes of the groups
Merged catalog

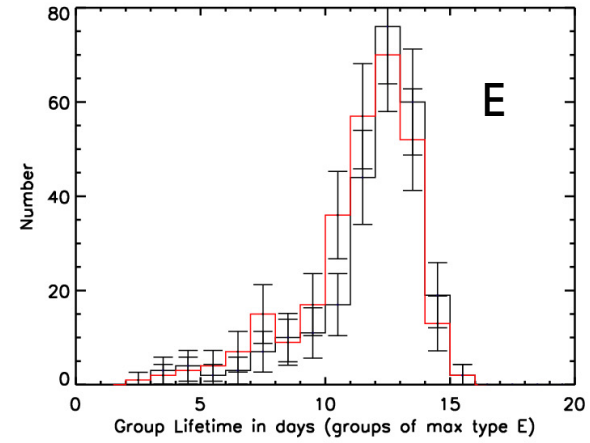
Cycle 22
Cycle 23

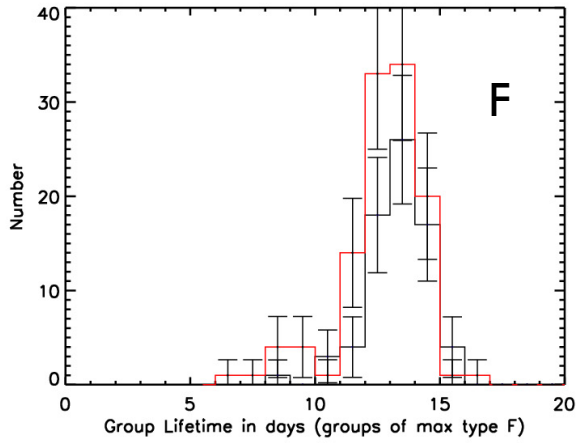












Conclusions

- Our conclusions partly match Kilcik (2011) conclusions. However it is not a SGs deficit only but a global small sunspot deficit.
- The small sunspot deficit naturally explains the discrepancies between R_i and other indices that put less weight on the smallest magnetic features.
- The disappearance of small spots = same time as those discrepancies.
- It reveals an anomaly in cycle 23, begun long before the new cycle, that suggests the Sun switched to a new regime.

New issues

- The scale dependence of the observed change implies the existence of two different dynamos: deep and superficial (Schatten, 2005).

New issues

- Cycle 23 shares properties with cycles of the 19th and early 20th century. Did such a small spot deficit occur for those cycles ? Can it explain some enduring discrepancies between historical index series (R_i vs. R_G, Sunspot area, aa) ?
- NB: the transition to large solar cycles seems to coincide with the *Waldmeier transition*… (1945)