Long-term Trends in Sunspot Magnetic Field Strengths

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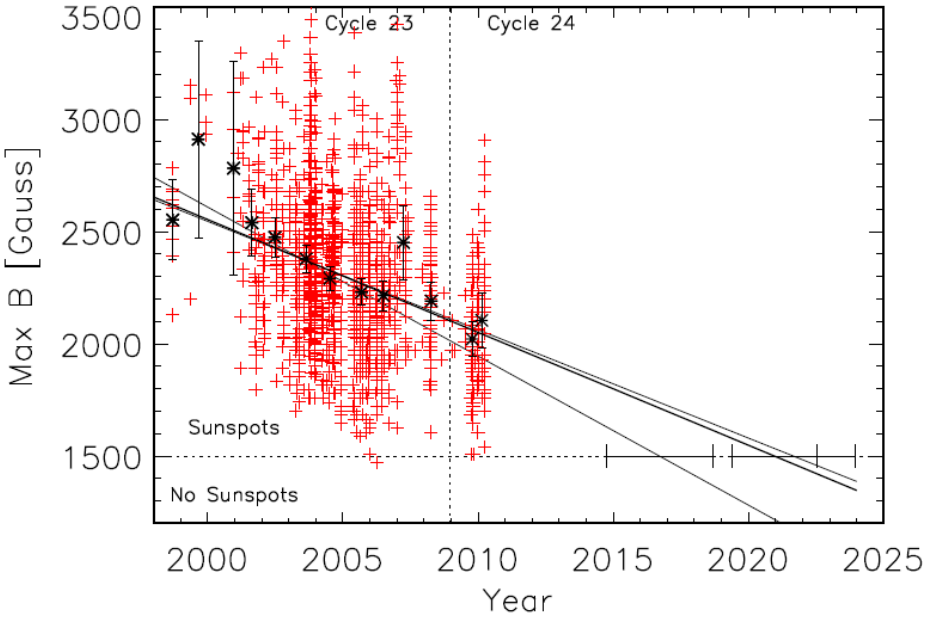
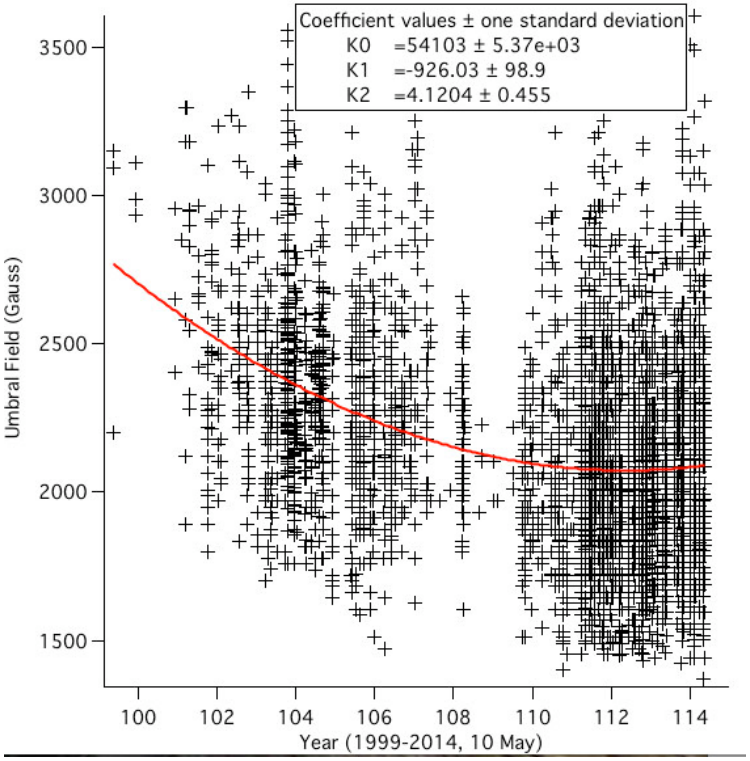
Acknowledge fruitful discussions with Livingston, W.C., Cliver, E., Bertello, L., Nagovitsyn, Yu. A., Tlatov, A.G., Watson, F., Penn, M.

- Past attitude: "Sunspots are forever"



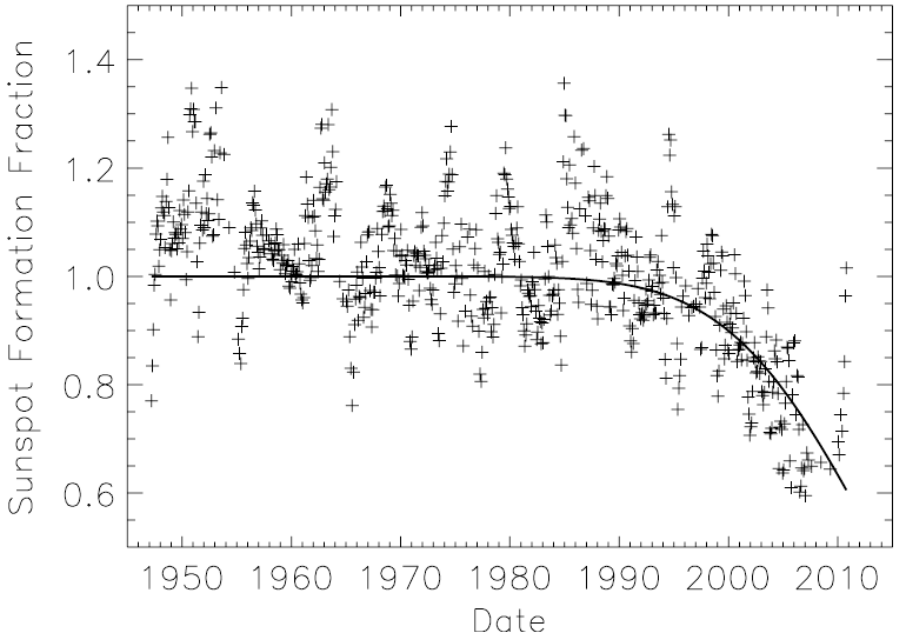
Penn and Livingston (2011)

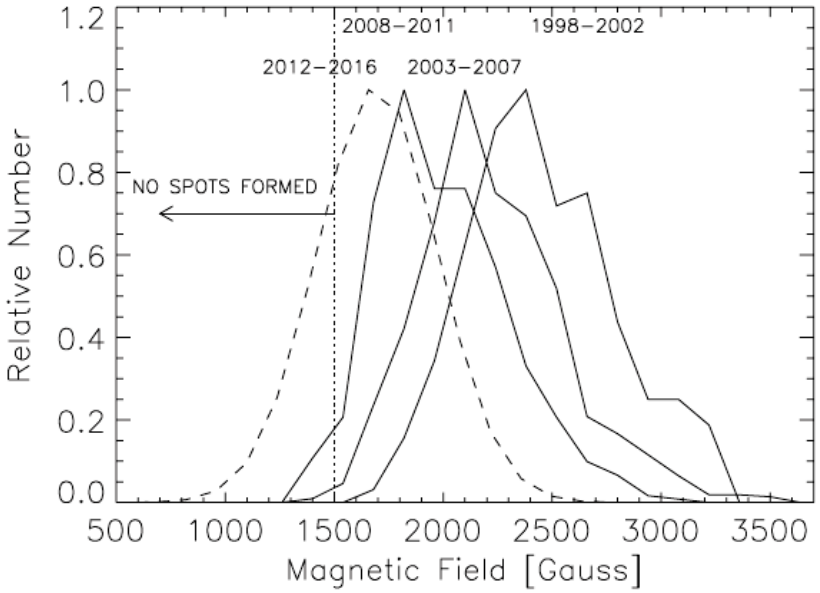


Livingston (2014, private communication)

Penn & Livingston (2006): decline in field strengths –52 G/year
Watson et al (2011) –70 G/year

Sunspot Field Strength and 10.7 cm Radio Flux

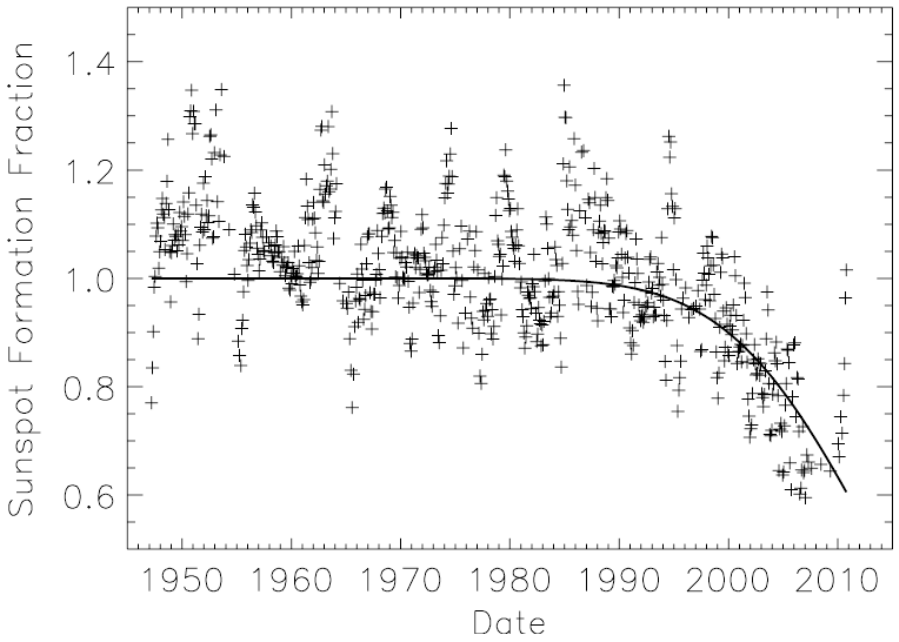


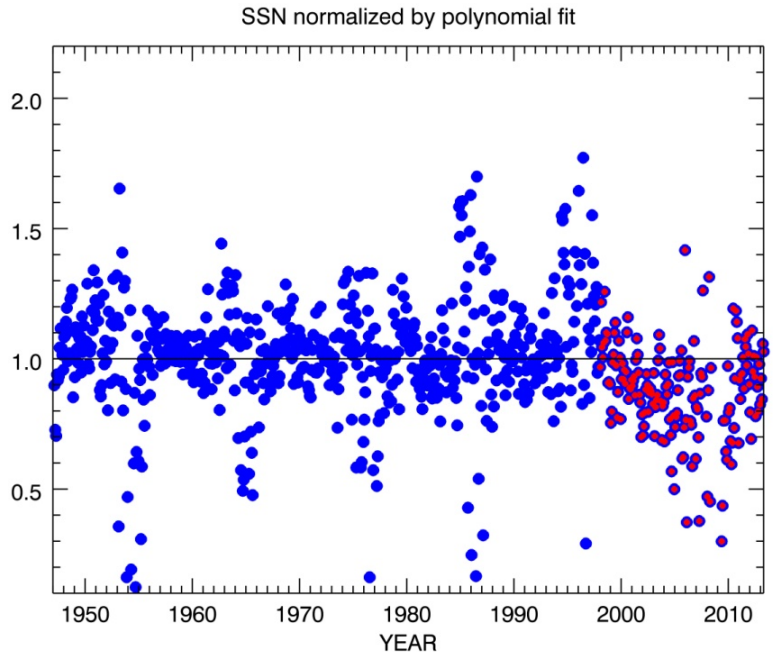


Livingston, Penn, Svalgaard (2012)

- PDF retains shape, mean shifting 46 G yr^{-1}
- Ratio of spots field strength to 10.7 cm flux anomaly consistent

Sunspot Field Strength and 10.7 cm Radio Flux





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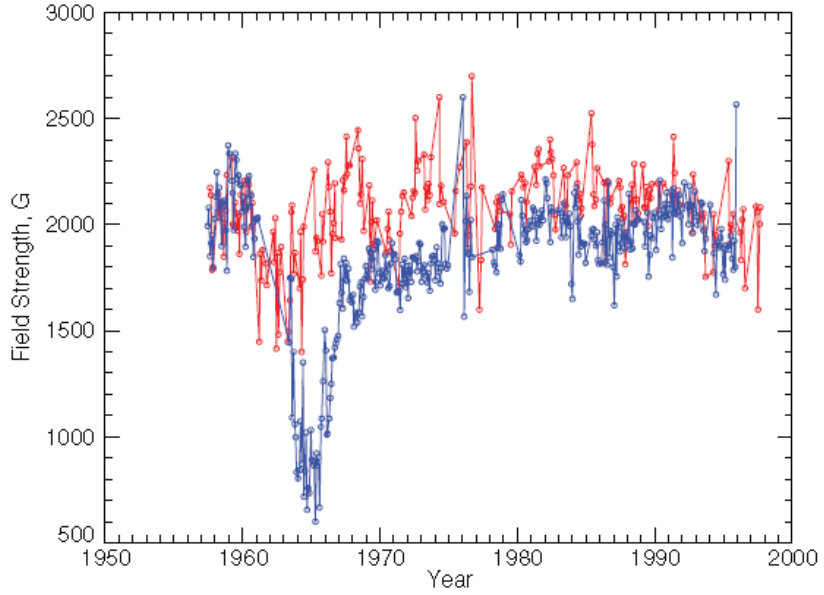
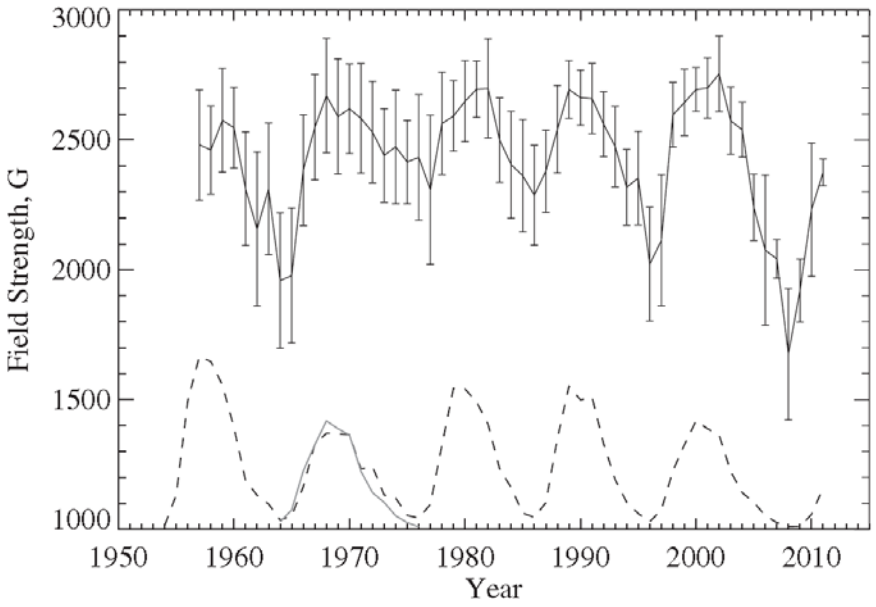
“Russian” Data Set





- Long-term trends may appear due to inclusion of smaller/weaker field features
- Strong fields show only variations with solar cycle, and no secular trend
- Penn & Livingston (2006): decline in field strengths –52 G/year
- Watson et al (2011) –70 G/year
- -83.5 G/yr (C19), -47.1 (C20), -97.9 (C21), -85.1 (C22), -118.7 G/yr (C23)

Pevtsov et al (2011)

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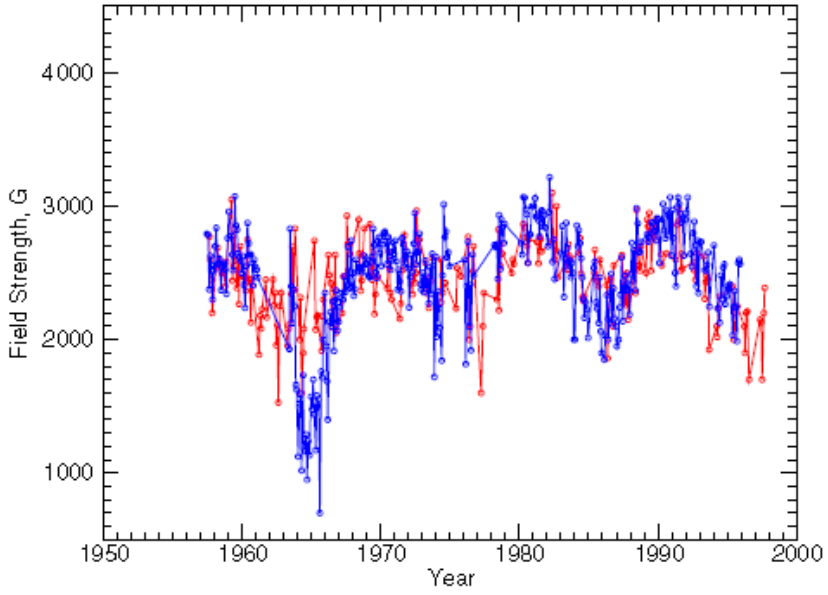

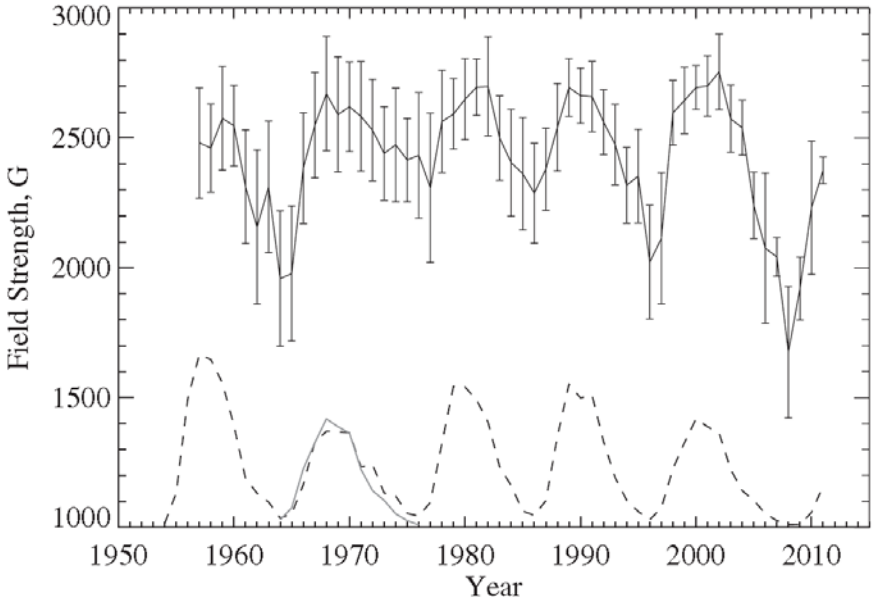

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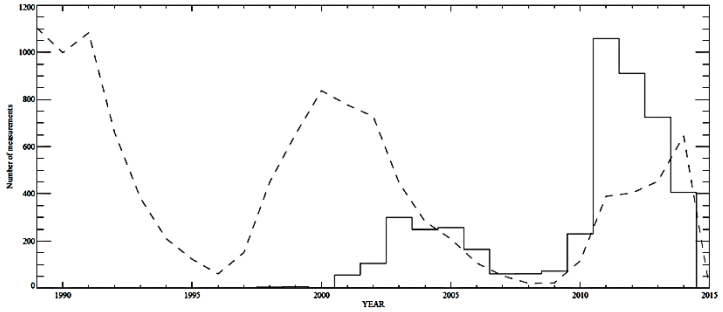
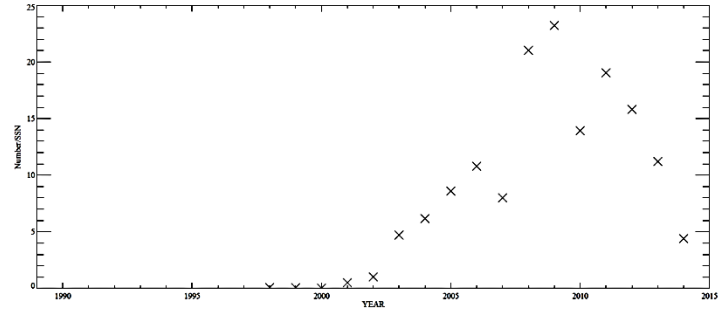
Pevtsov et al (2011)

Changing statistics?

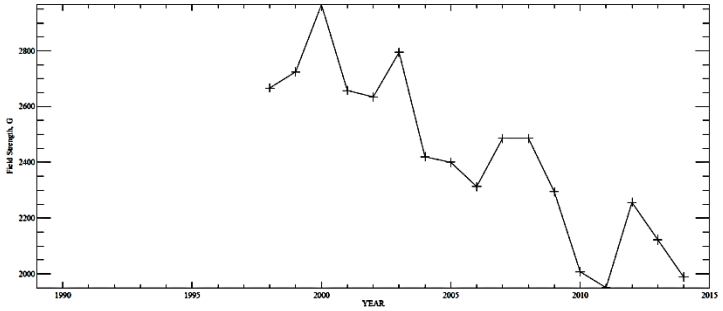
Number of measurements



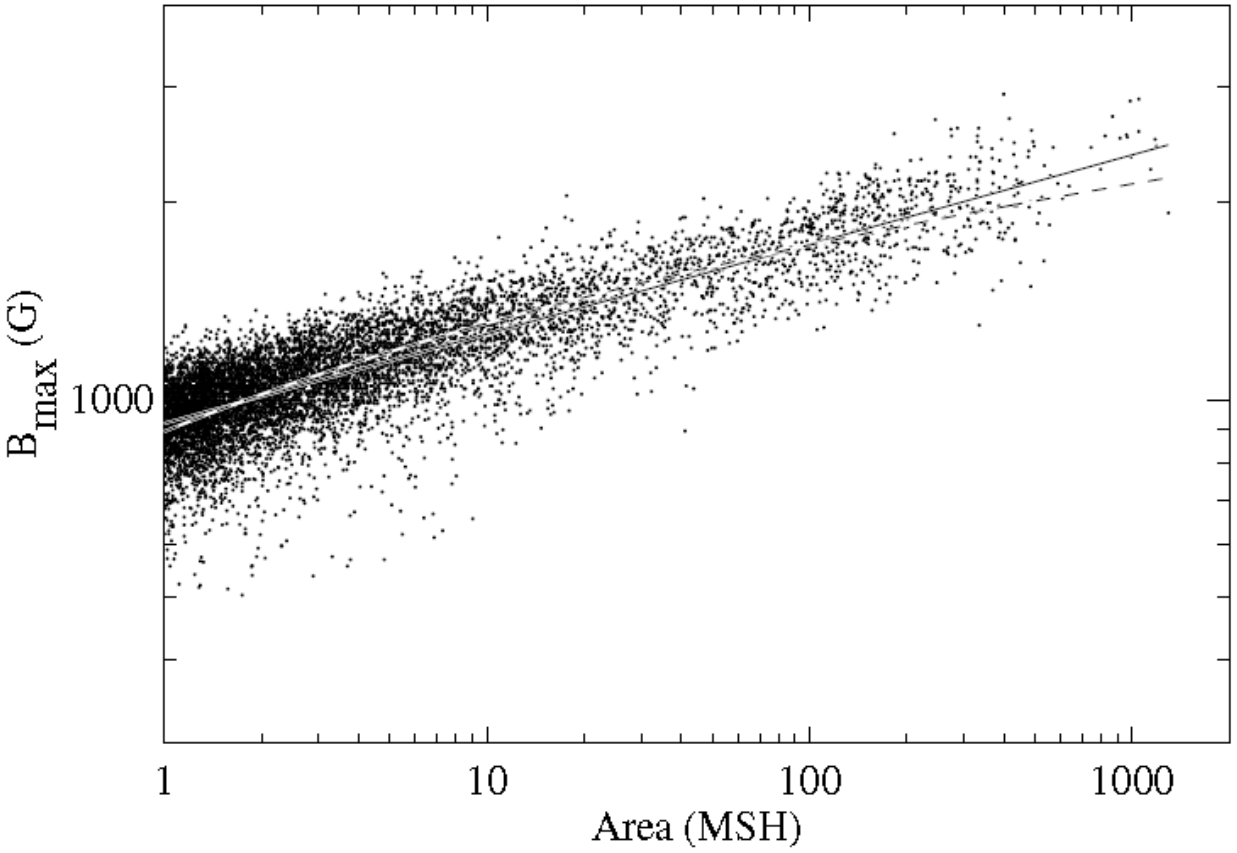
Number of measurements/SSN



Mean field strength



Area – B_{max} relation

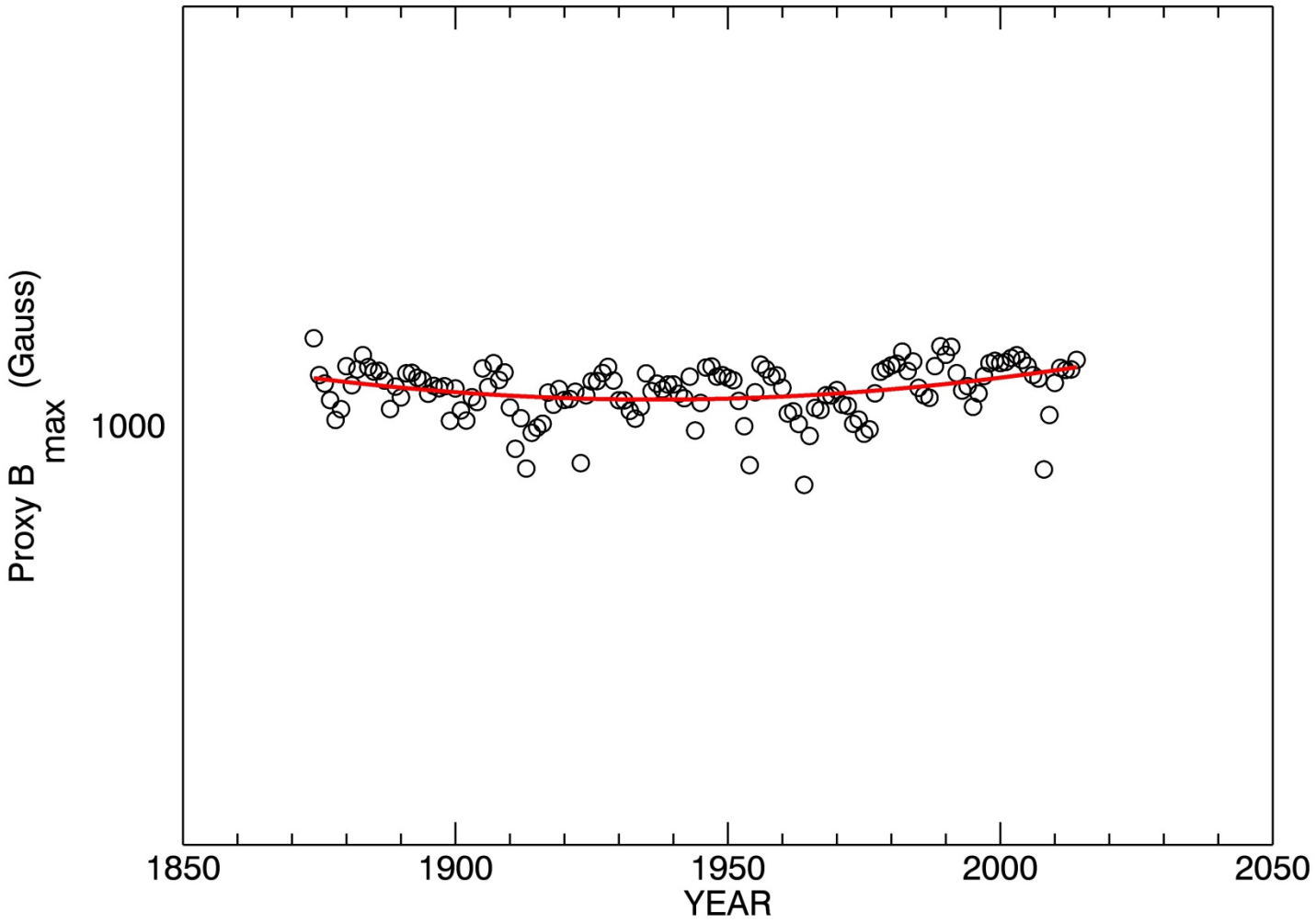


Tlatov & Pevtsov (2014)

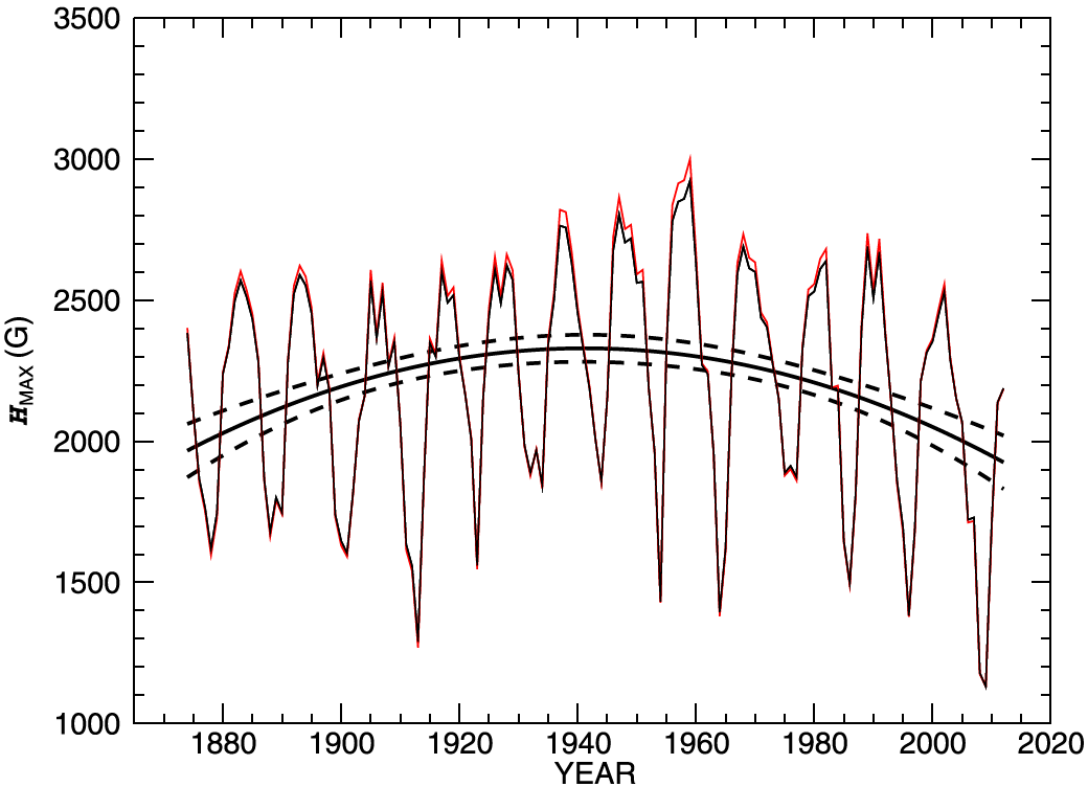
$$B_{MAX} = (894.7640 \pm 2.1067) + (414.1450 \pm 2.458) \times \log(A)$$

Ringnes & Jensen (1960)

All sunspots

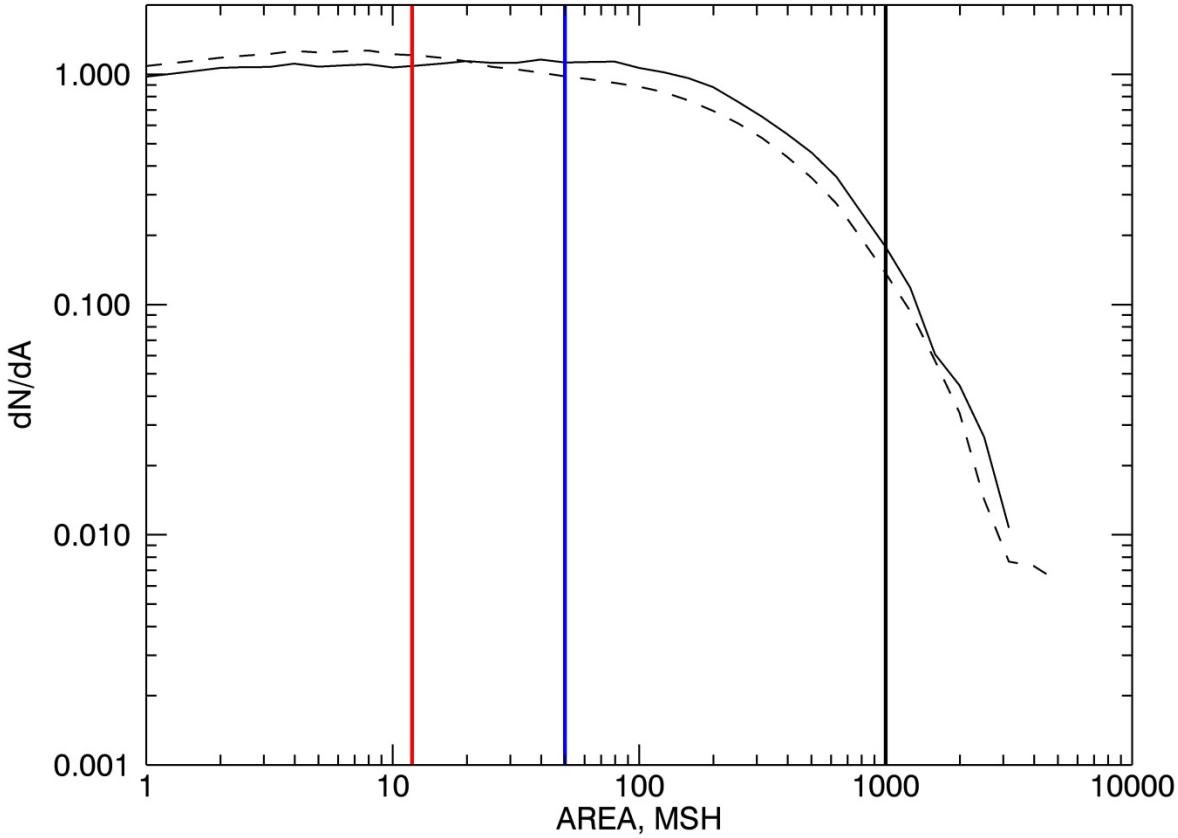


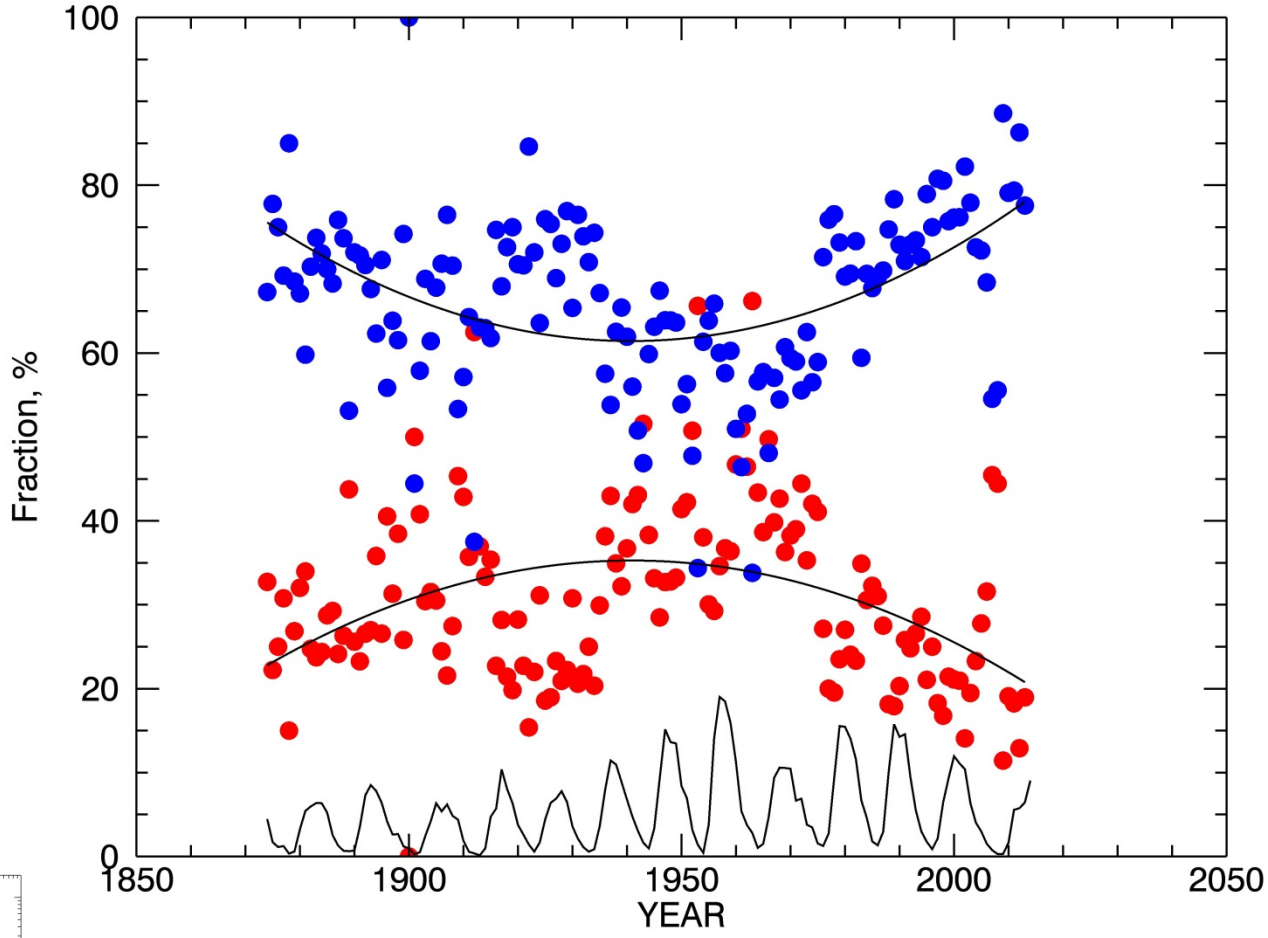
Daily largest sunspots

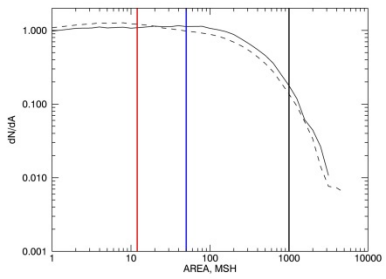


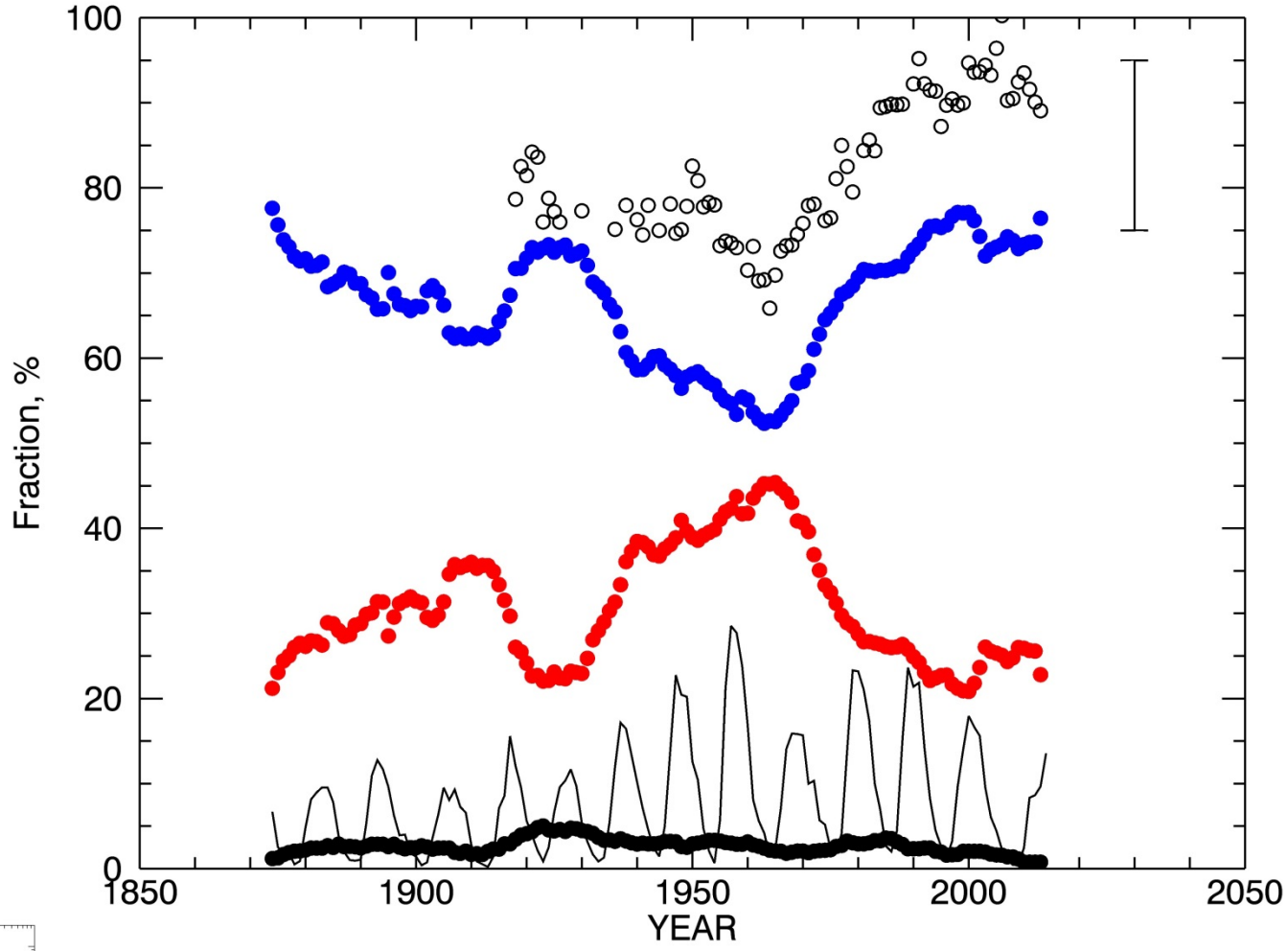
Pevtsov et al (2014)

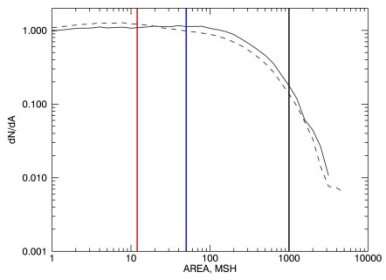
- Solar cycle variations with amplitude about 1000 G
- Magnetic field proxy shows variations with solar cycle
- Much weaker secular trend (300 G increase-decrease) with a broad maximum in 1950th – Gleissberg Cycle?

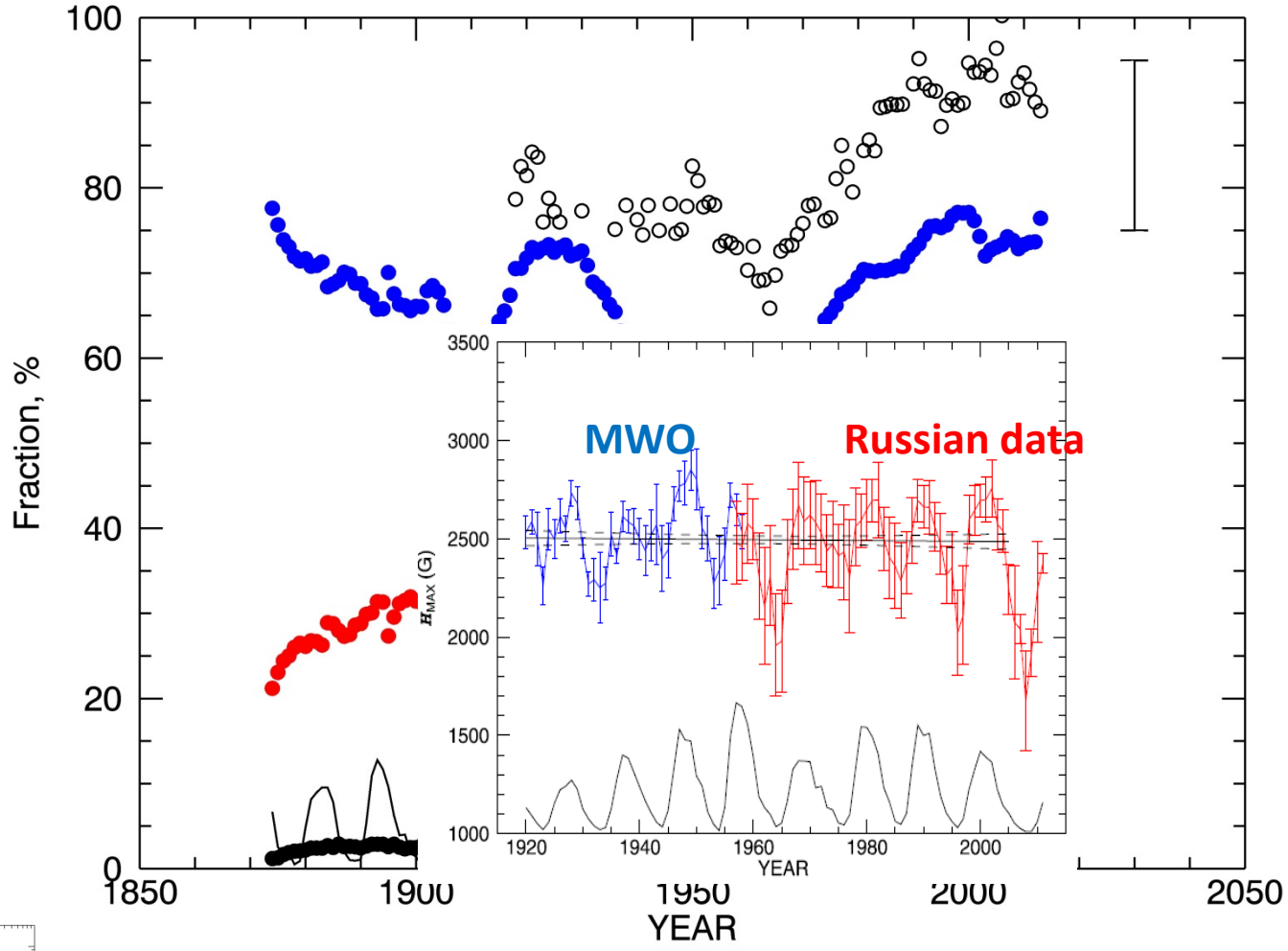

1.000
0.100
0.010
0.001
dN/dA
1
10
100
1000
10000
AREA, MSH

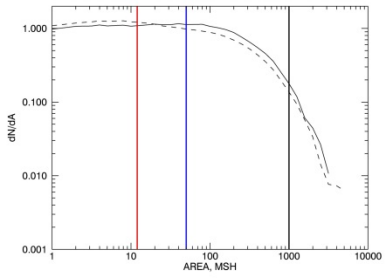

100
80
60
40
20
0
Fraction, %
1850
1900
1950
2000
2050
YEAR

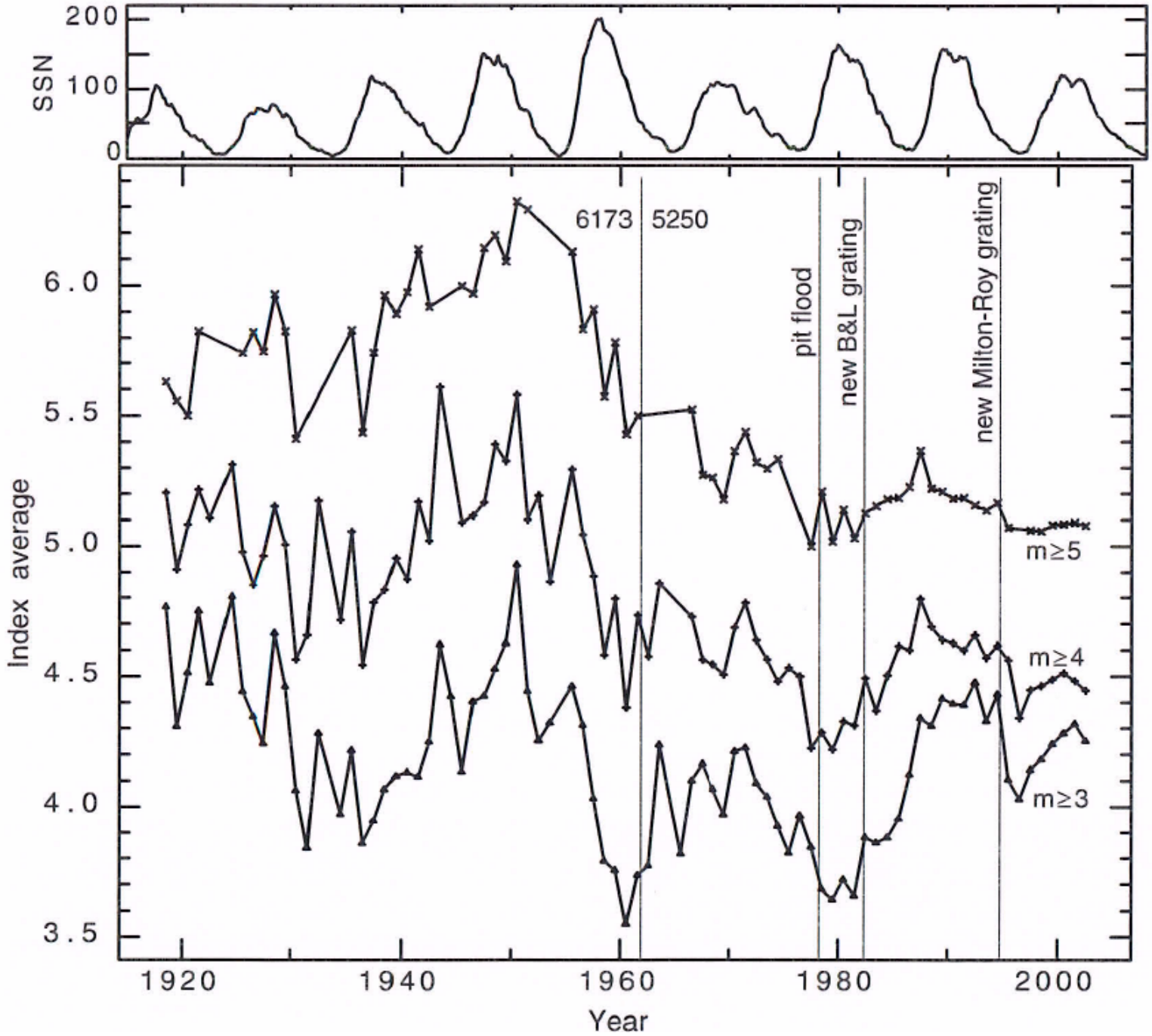

1.000
0.100
0.010
0.001
dN/dA
1
10
100
1000
10000
AREA, MSH


100
80
60
40
20
0
Fraction, %
1850
1900
1950
2000
2050
YEAR

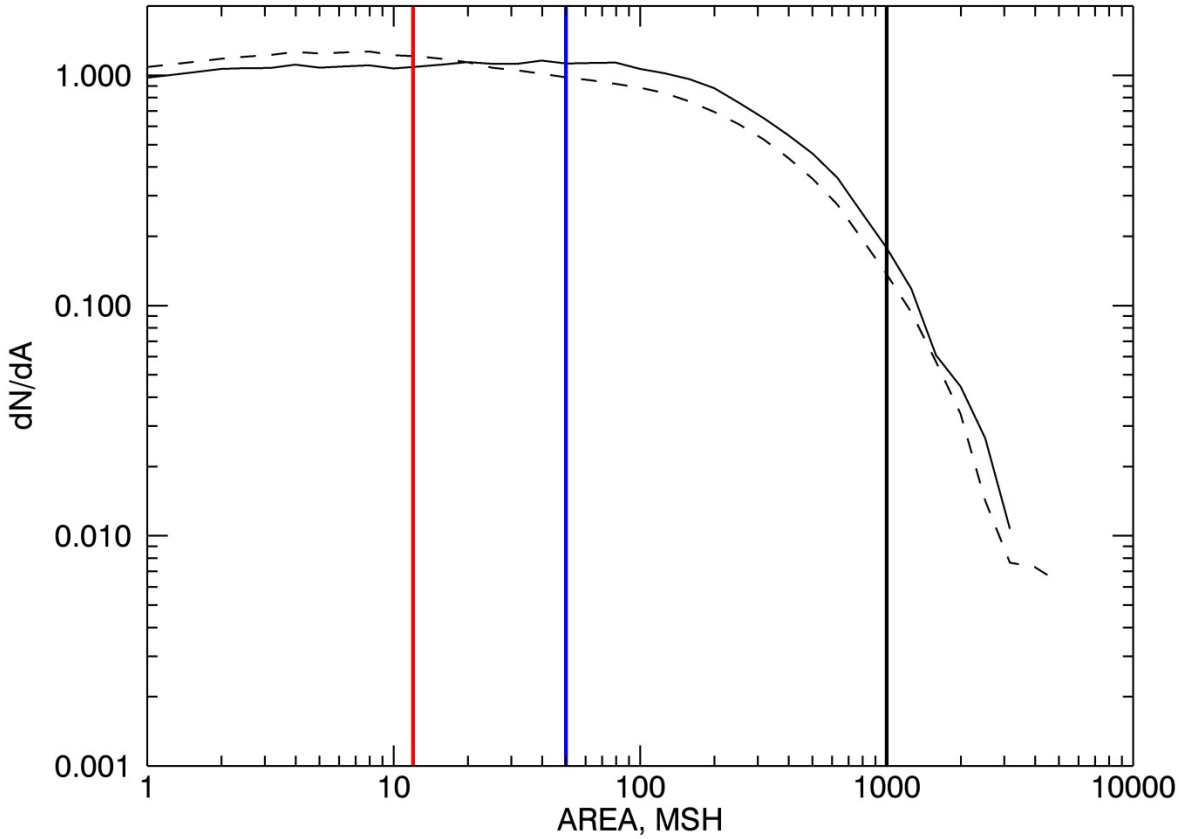

1.000
0.100
0.010
0.001
dN/dA
1
10
100
1000
10000
AREA, MSH

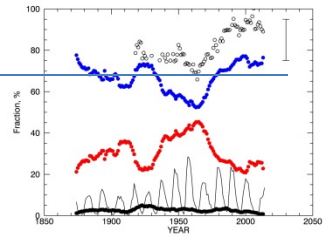

Fraction, %
YEAR
MWO
Russian data
B_{MAX} (G)
YEAR


dN/dA
AREA, MSH

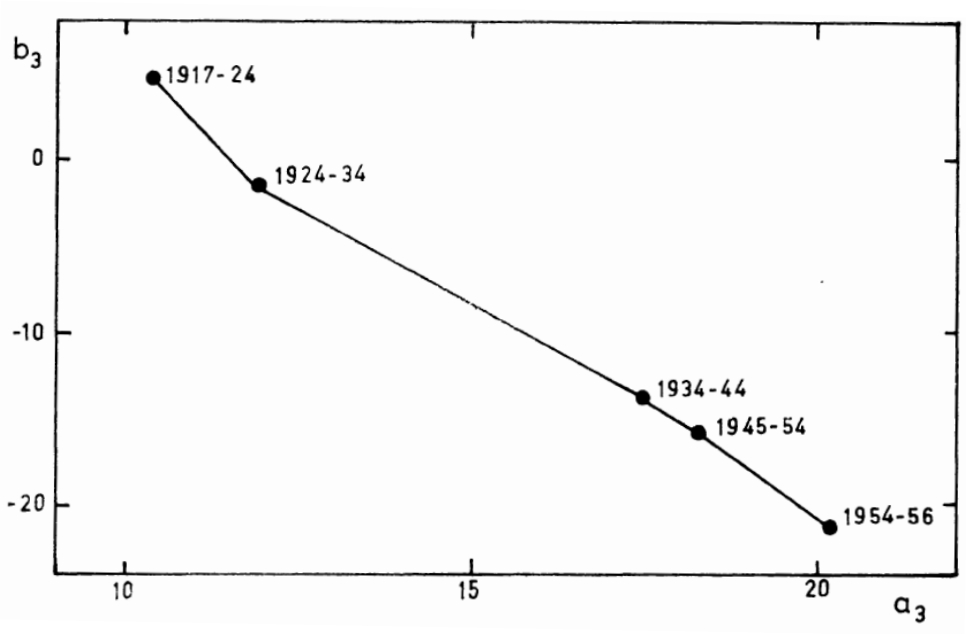

SSN
200
100
0
6173
5250
pit flood
new B&L grating
new Milton-Roy grating
m≥5
m≥4
m≥3
Index average
6.0
5.5
5.0
4.5
4.0
3.5
1920
1940
1960
1980
2000
Year

Change in distribution of sunspots





Changes in Area-Field Relation

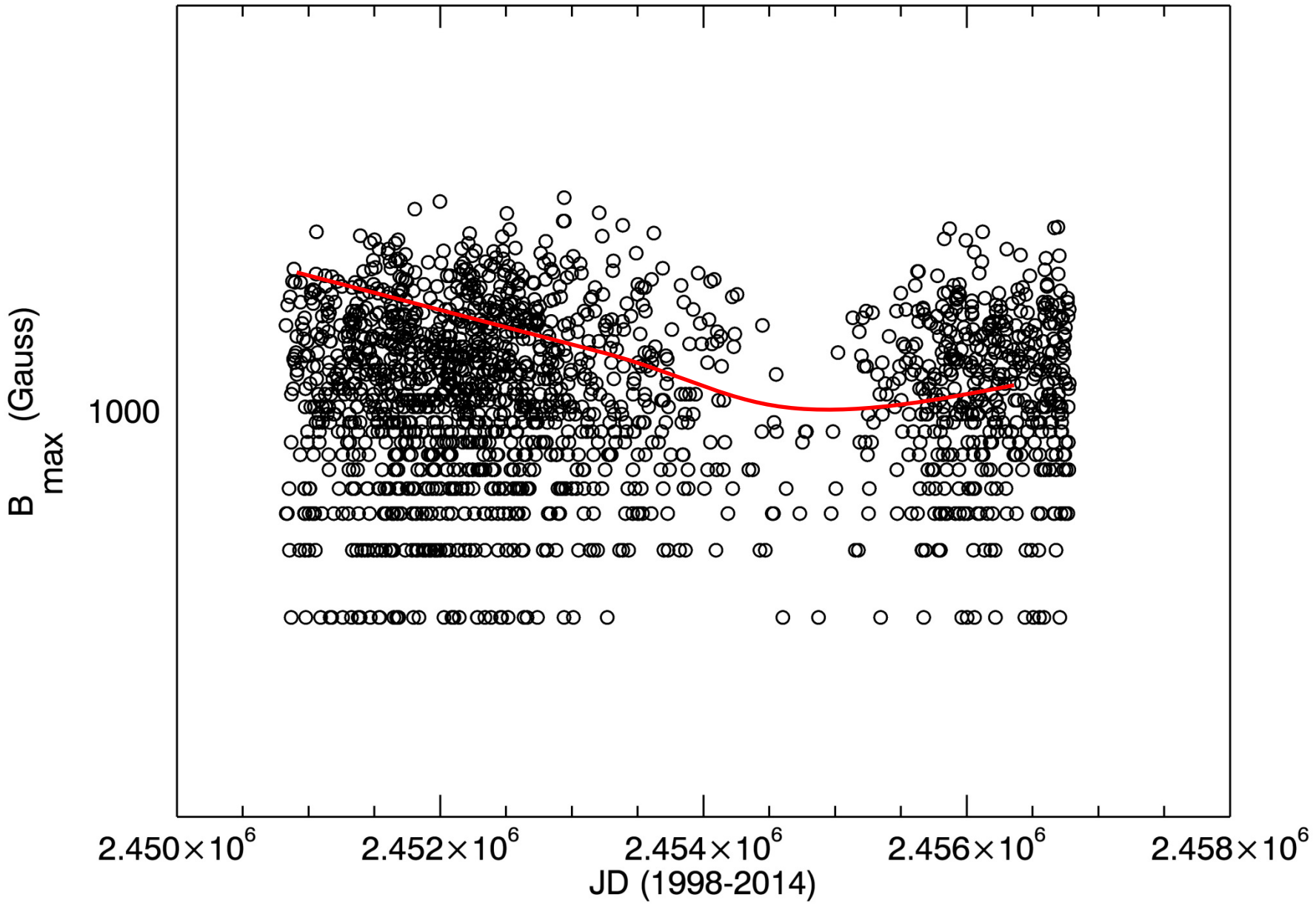


Ringnes & Jensen (1960): $H=a_3 \log A_p + b_3$

Cycle No.	*A*	*B*
Cycle 15	-274.1 ± 177.6	507.3 ± 40.2
Cycle 16	-475.1 ± 63.4	514.9 ± 13.9
Cycle 17	-771.0 ± 59.9	523.2 ± 13.2
Cycle 18	-1106.9 ± 78.9	609.2 ± 16.9
Cycle 19	-800.4 ± 69.5	495.4 ± 14.9
All cycles	-774.2 ± 35.6	536.0 ± 7.7
Cycles 16–18	-806.3 ± 41.0	551.7 ± 8.9

Pevtsov et al (2014)

- Can be explained by changes in fraction of small or large sunspots

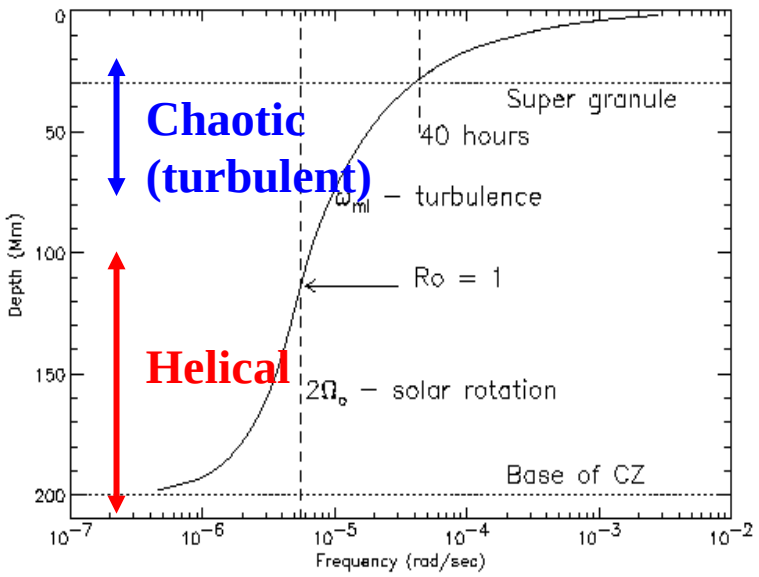

B max (Gauss)
1000
2.450×10^6
2.452×10^6
2.454×10^6
2.456×10^6
2.458×10^6
JD (1998-2014)

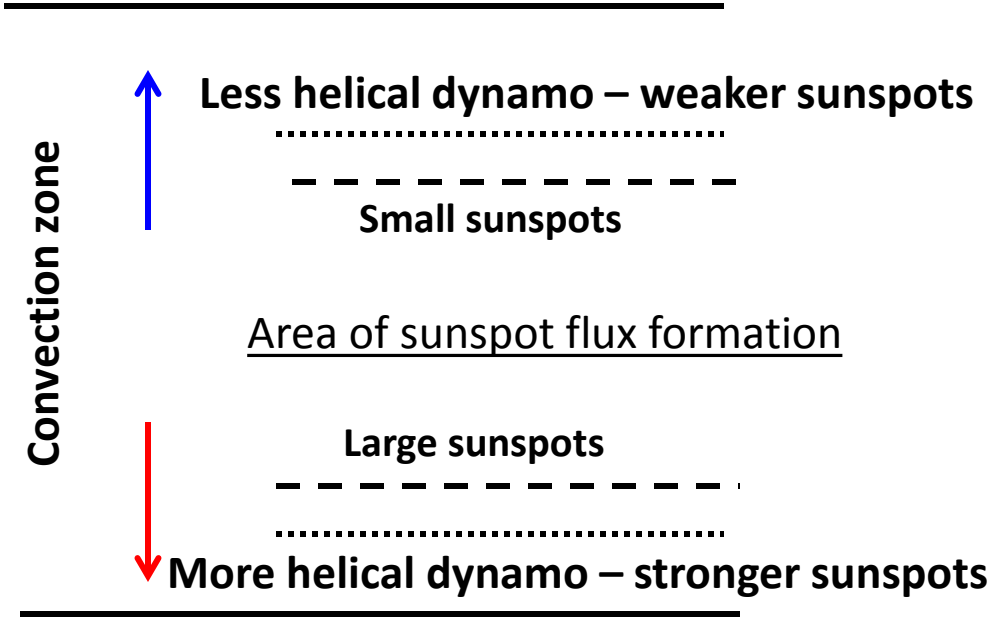
Conclusions

- No indication of significant long-term variations in sunspot field strength (and their proxies)
- Long-term variations in distribution of sunspots by area and changes in B=f(A) suggest changes in fractional contribution of small/large sunspots
- The latter may explain long-term (small amplitude) long-term changes in proxies of sunspot field strength

…(2 more slides)

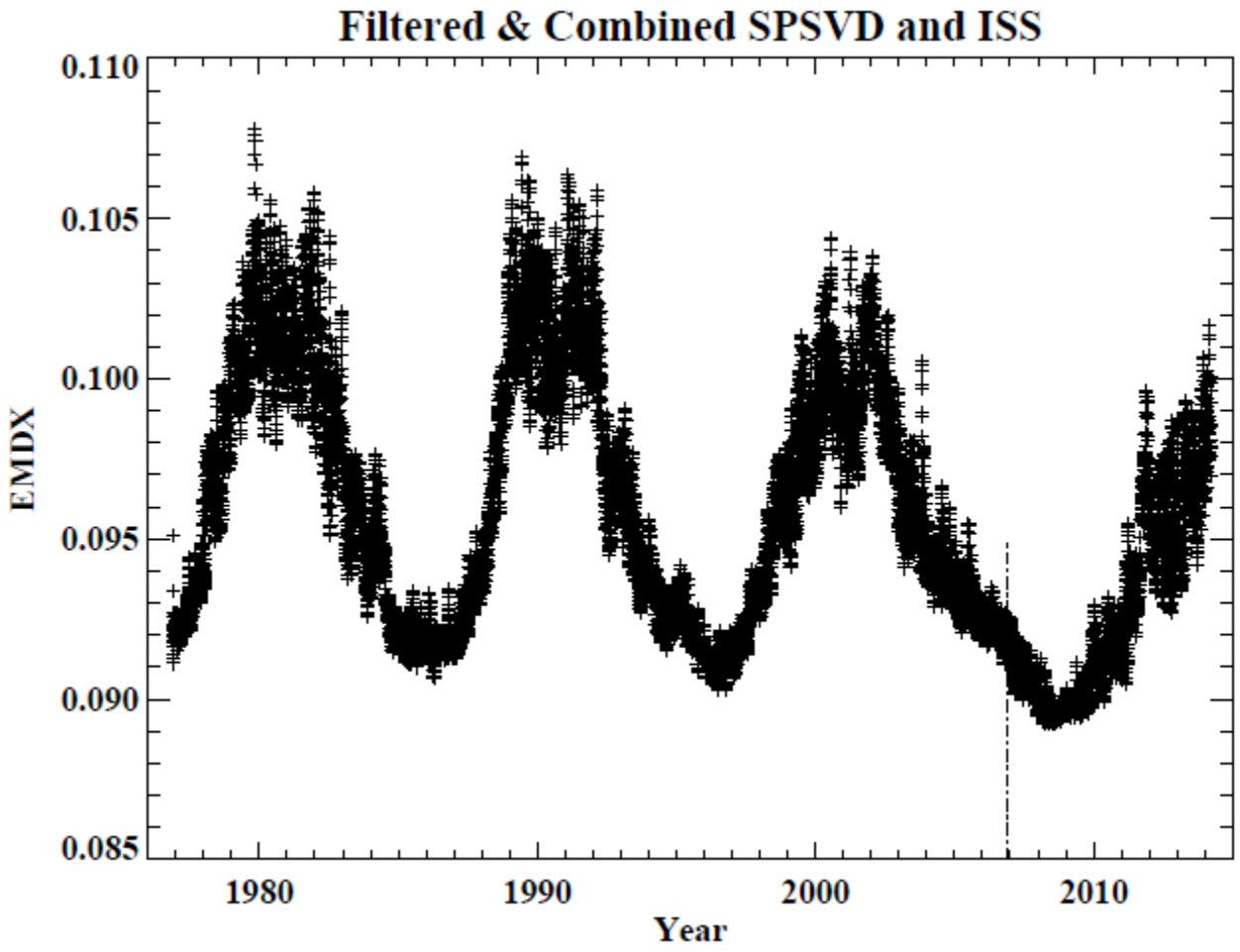
What does it all mean?





• Changes in depth of sunspot flux formation may increase/decrease fraction of sunspots with stronger/weaker field strength.

Pevtsov el at (2011)


Filtered & Combined SPSVD and ISS
0.110
0.105
0.100
0.095
0.090
0.085
EMDX
1980
1990
2000
2010
Year