The Continuing(?) Deviation Between Sunspot Number and F10.7 Activity Indices

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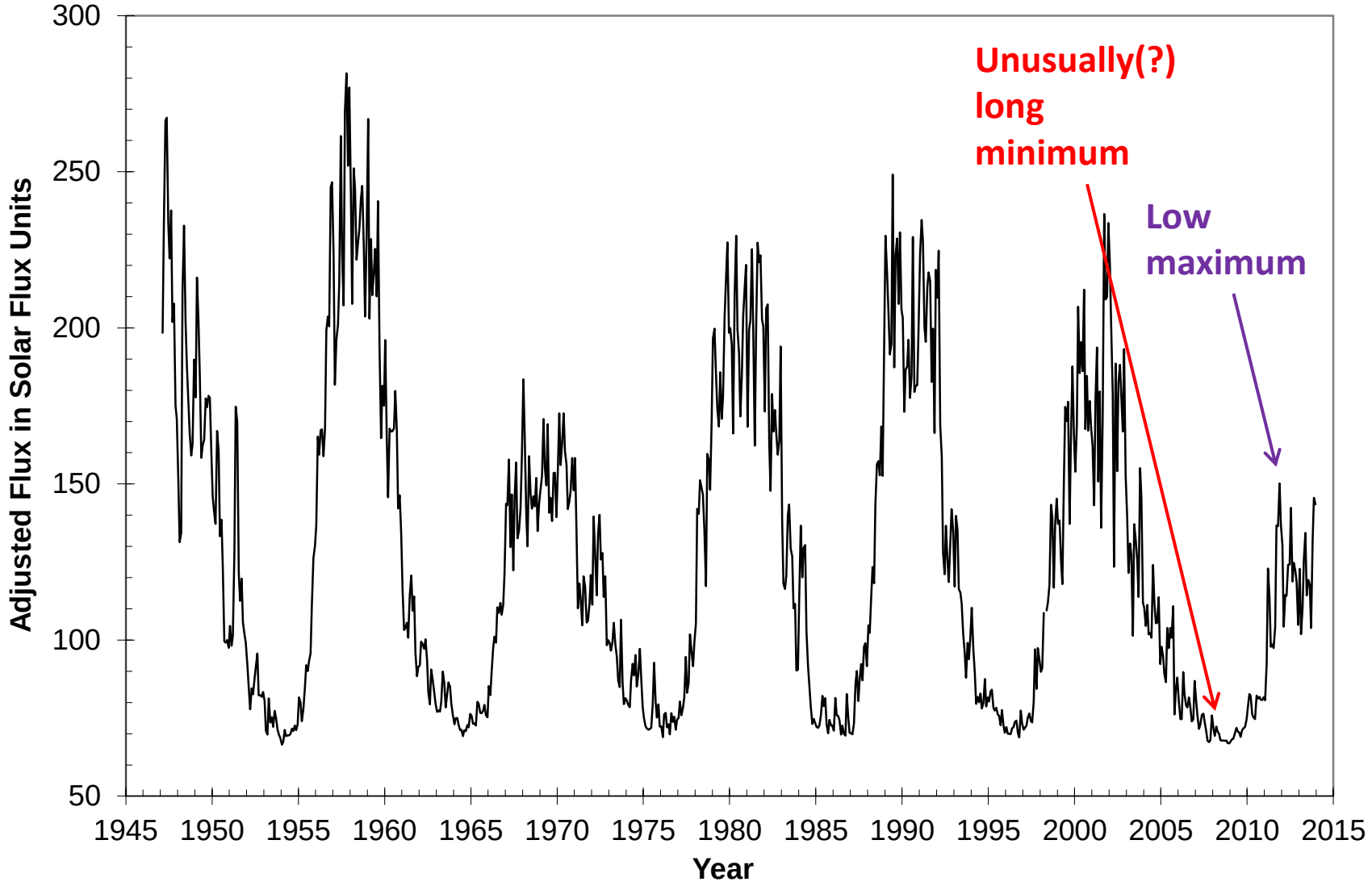
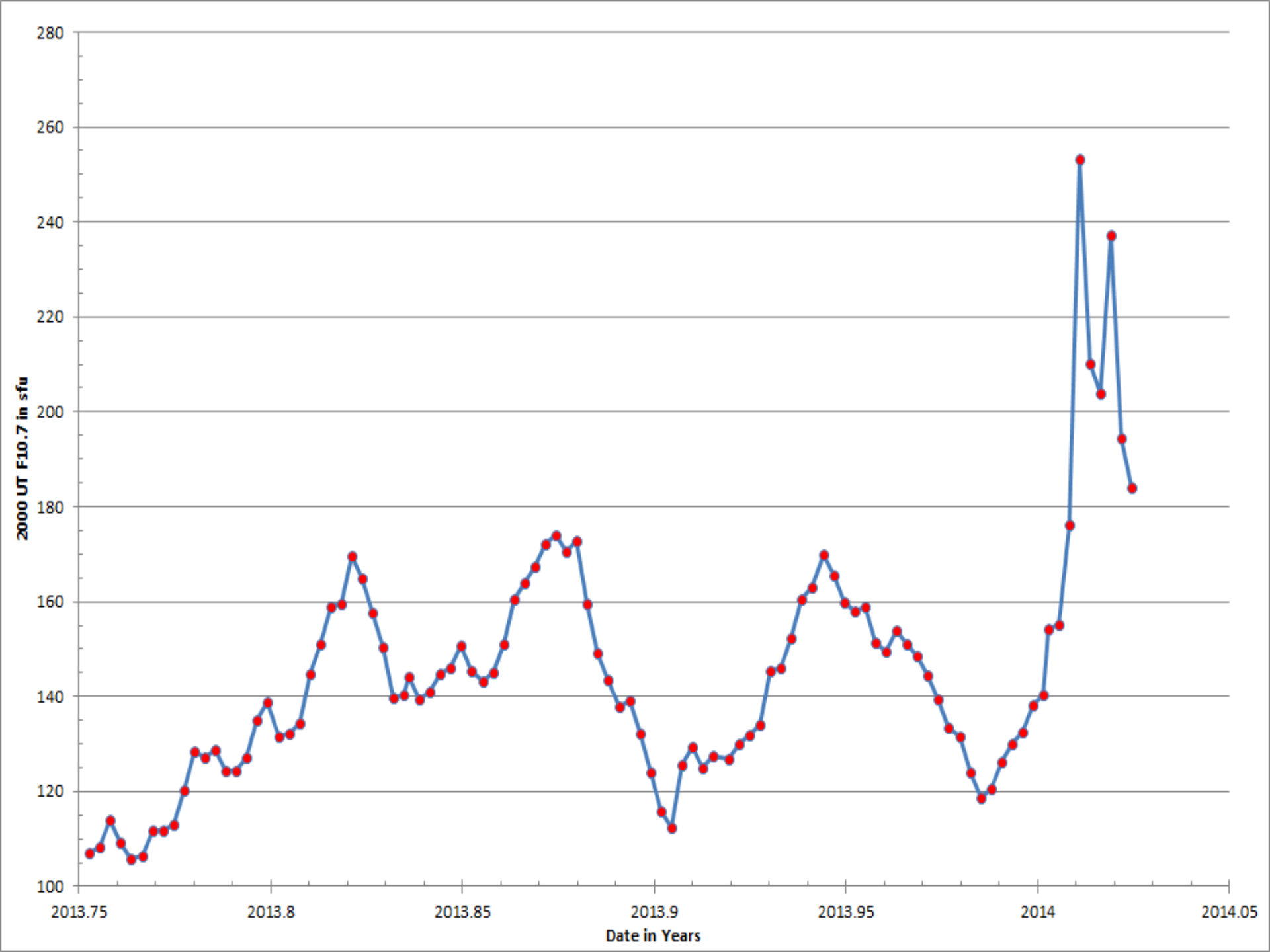

Unusually(?)
long
minimum
Low
maximum
Adjusted Flux in Solar Flux Units
300
250
200
150
100
50
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
Year


280
260
240
220
200
180
160
140
120
100
2000 UT F10.7 in sfu
2013.75
2013.8
2013.85
2013.9
2013.95
2014
2014.05
Date in Years

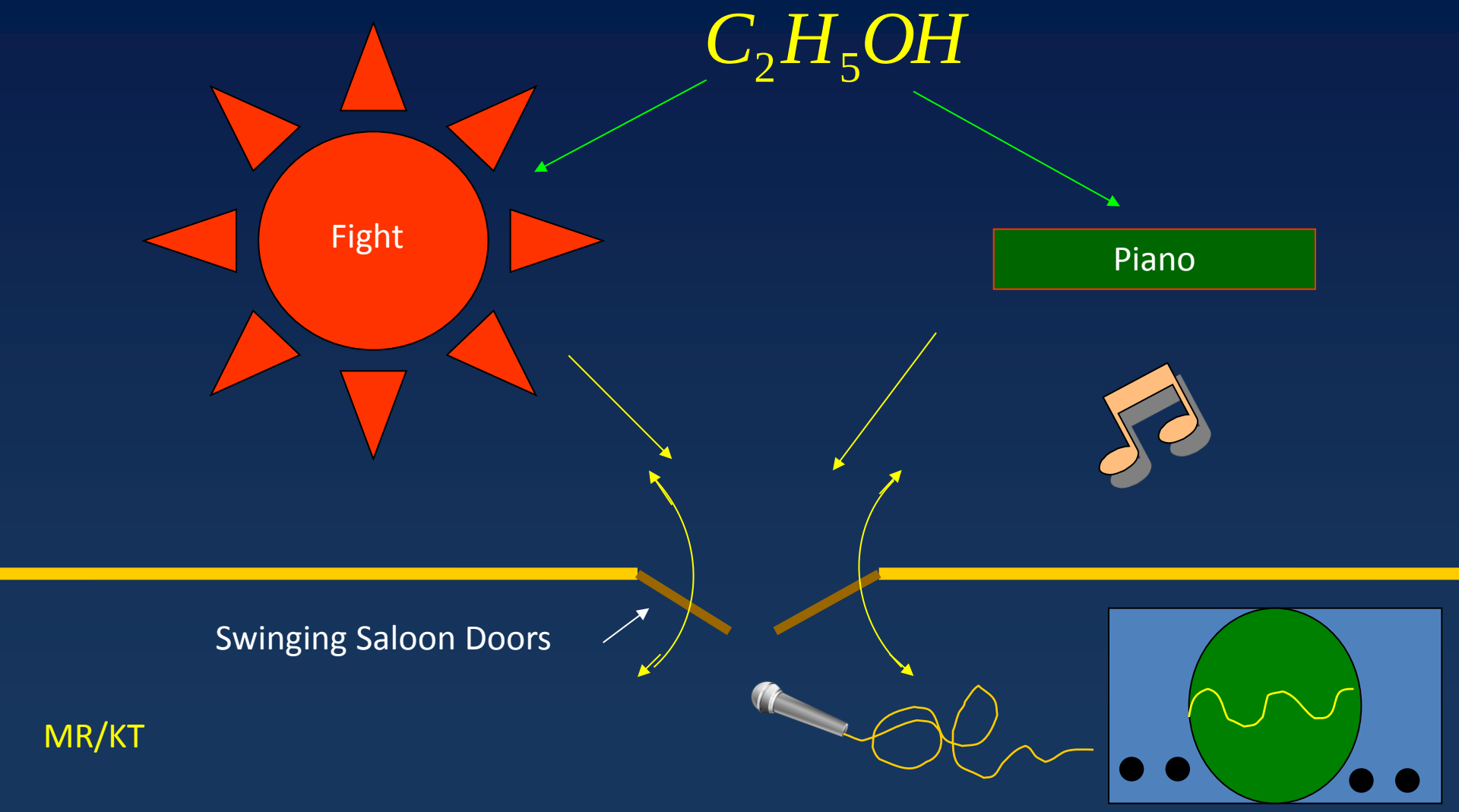
Solar Activity Indices and Proxies

- A measure of some property of some feature of the Sun integrated over the whole visible disc.
- The various indices are produced in different places by different subsets of processes.
- They vary in some useful way over the solar cycle.
- Can be measured consistently over long lengths of time (multiple activity cycles, without significant gaps).
- Easy(ish) to measure.
- Measurements are objective.
- Amenable to a consistent calibration process.
- Comparing them provides a means to see if the way solar activity manifests itself in the different locales and physical processes is changing.
- Using one index to make a proxy for another makes the two indices much easier to compare.

Statistical Homogeneity

- The three solar activity indices are produced and processed in different ways.
- Sunspot Number and Total Sunspot Area are daily averages.
- The $F_{10.7}$ data are measurements made over one hour around local noon.
- They almost certainly differ statistically.
- Imposing a 3-month running mean will produce greater statistical homogeneity.

Rose's Cantina, El Paso, Texas



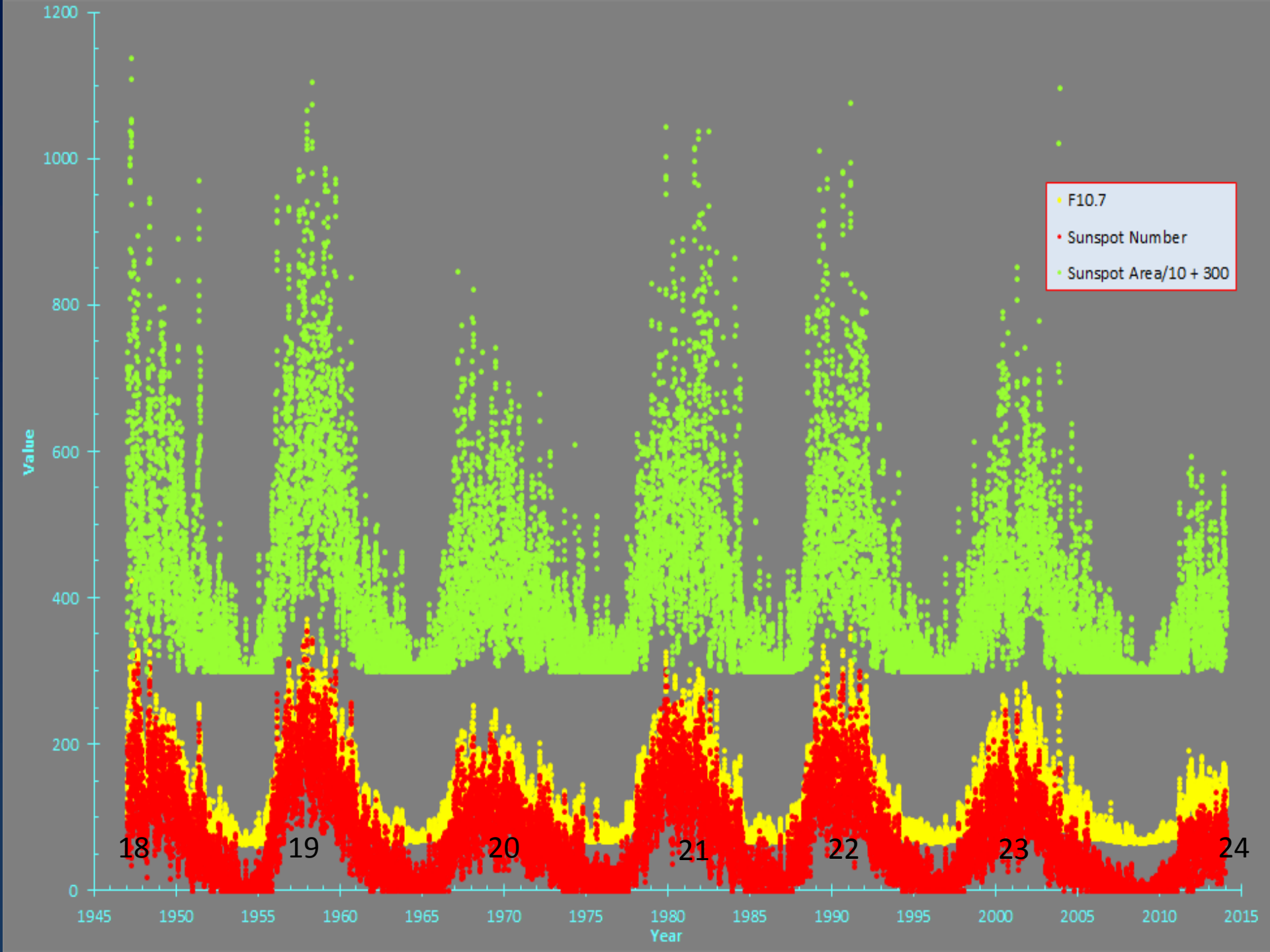
MR/KT

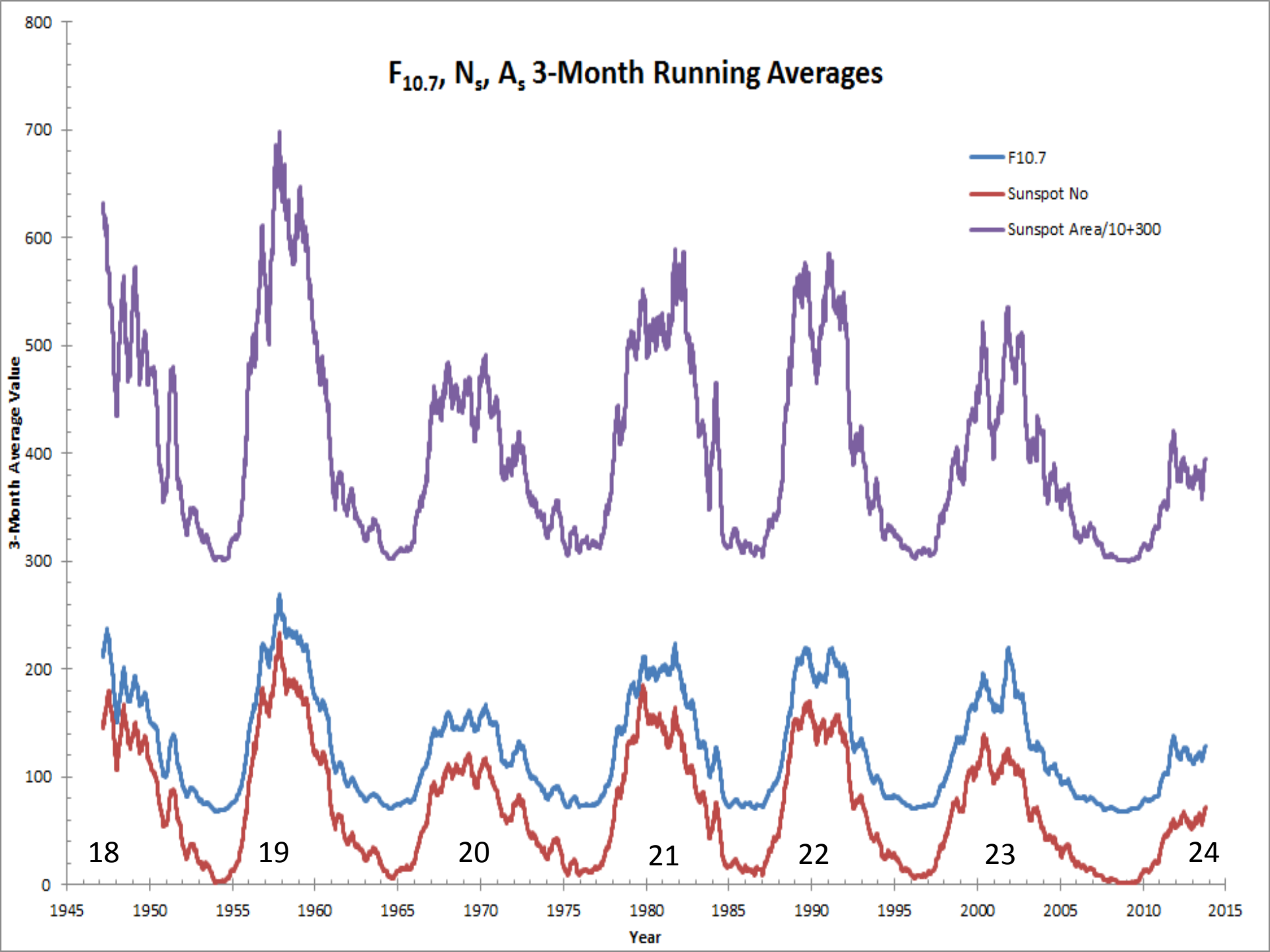
$$Volume = a(t)\left(Fight(C_2H_5OH(t)) + Piano(C_2H_5OH(t)) + \Psi(Fight, Piano)\right)$$

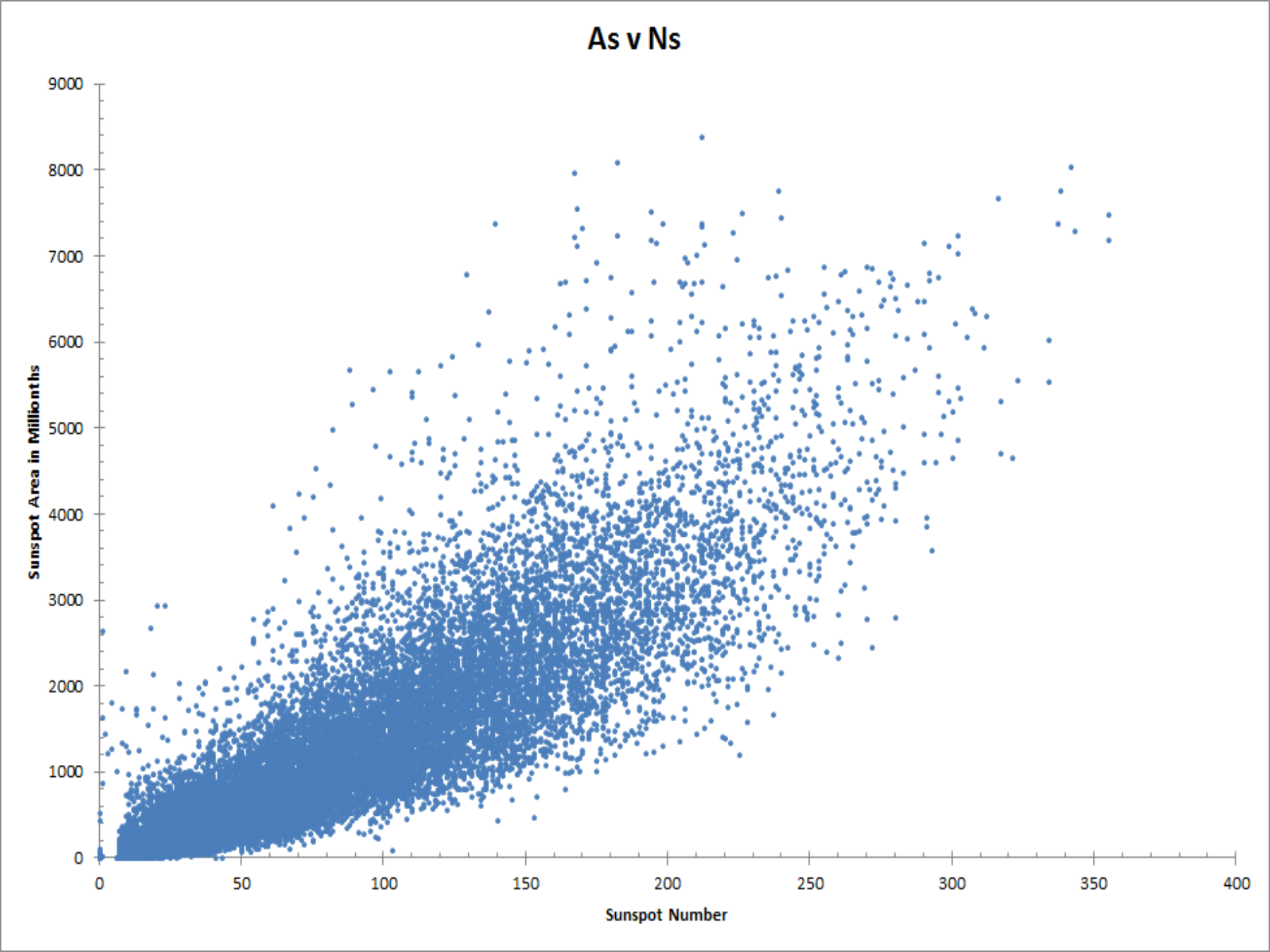
The Comparison Method

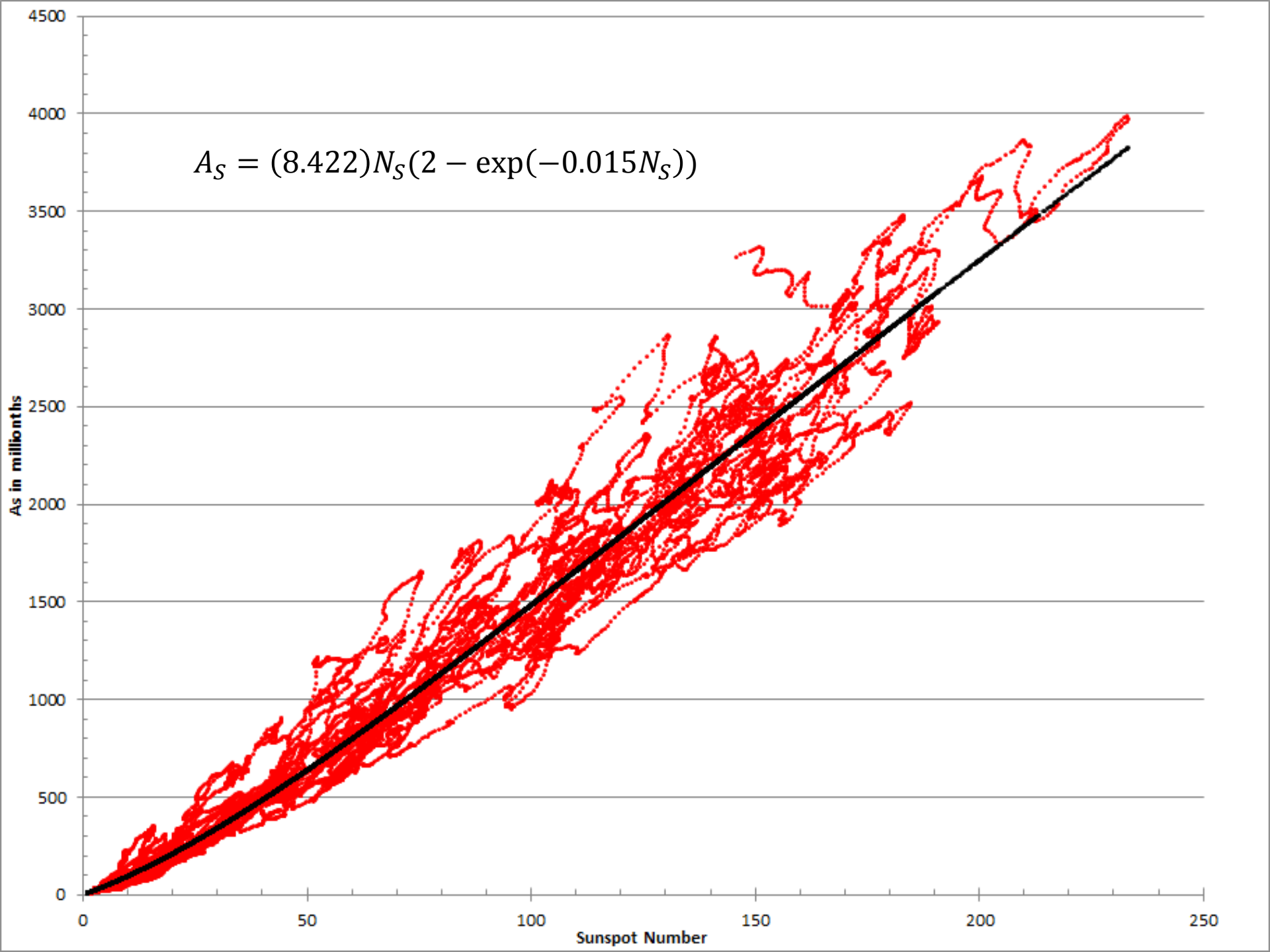
- We have two activity indices ***A*** and ***B***, which we wish to compare. ***A*** is regarded to be the "primary" index – the one that we plot on the *x*-axis.
- The best way to do a fine comparison is to make their major properties similar, which can be done by using *A* to make a proxy for B.
- Impose a heavy filter (3-month running average) to make the different data statistically similar.
- From the plot of smoothed data, obtained the empirical relationship: B = *f*(A).
- Use this with the ***A*** values to make a table of cotemporal proxy values for ***B***.
- Compare using ξ=(Obs(***B***)-Proxy(***B***))/(Obs(***B***)+Proxy(***B***)) , *i.e.*

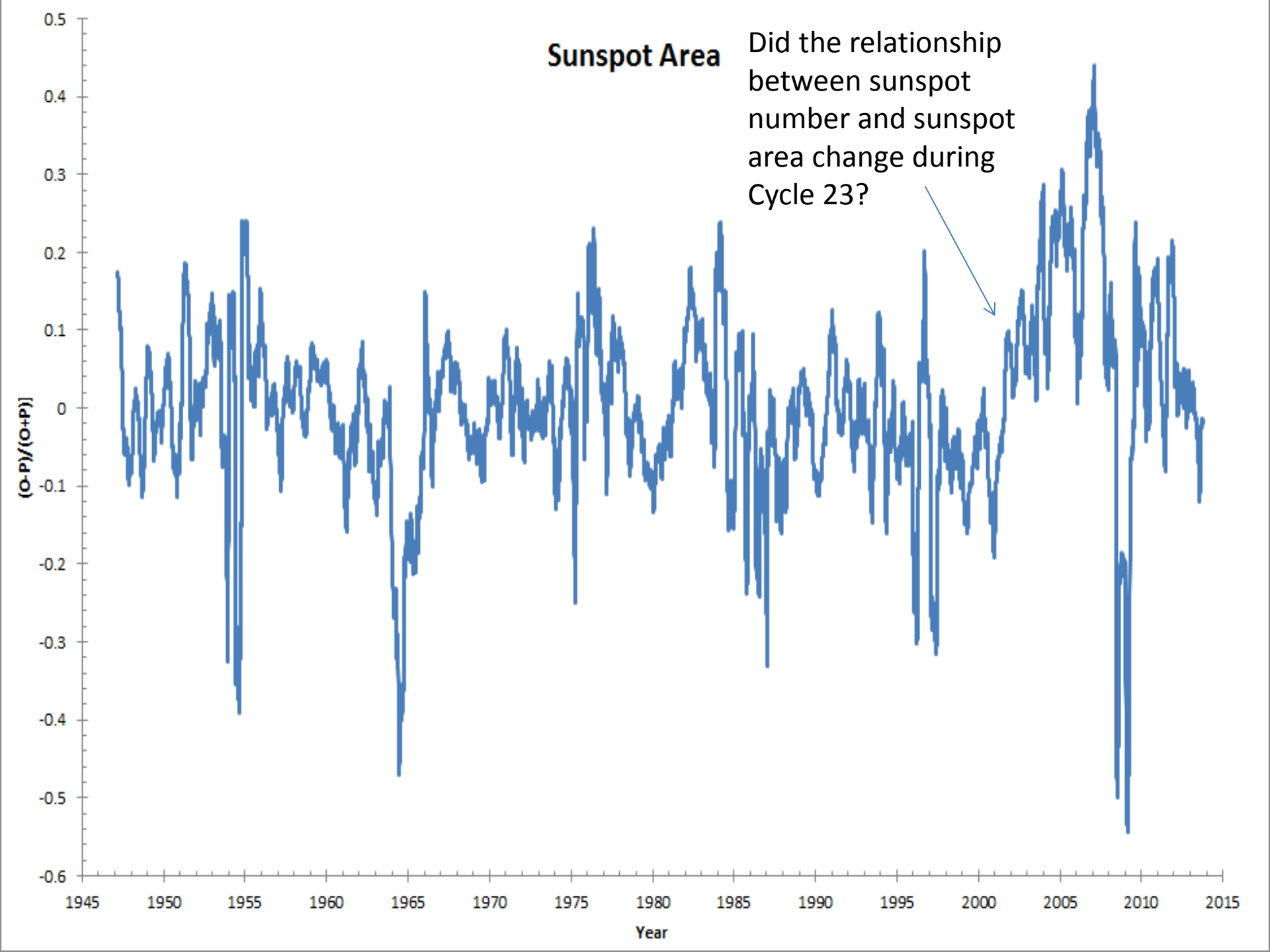
$$\xi = \frac{O - P}{O + P}$$

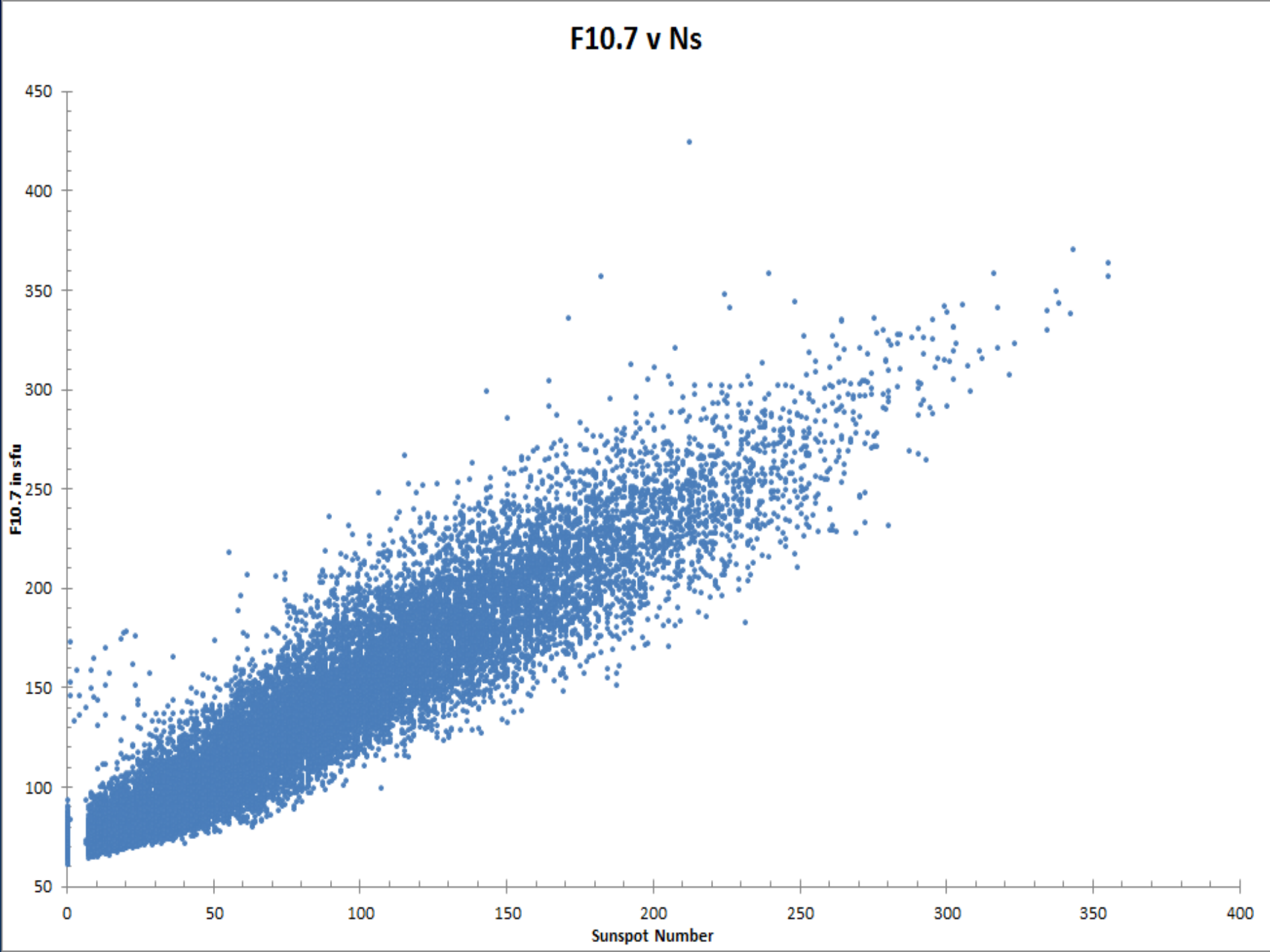

F10.7
Sunspot Number
Sunspot Area/10 + 300
Value
Year
0
200
400
600
800
1000
1200
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
18
19
20
21
22
23
24

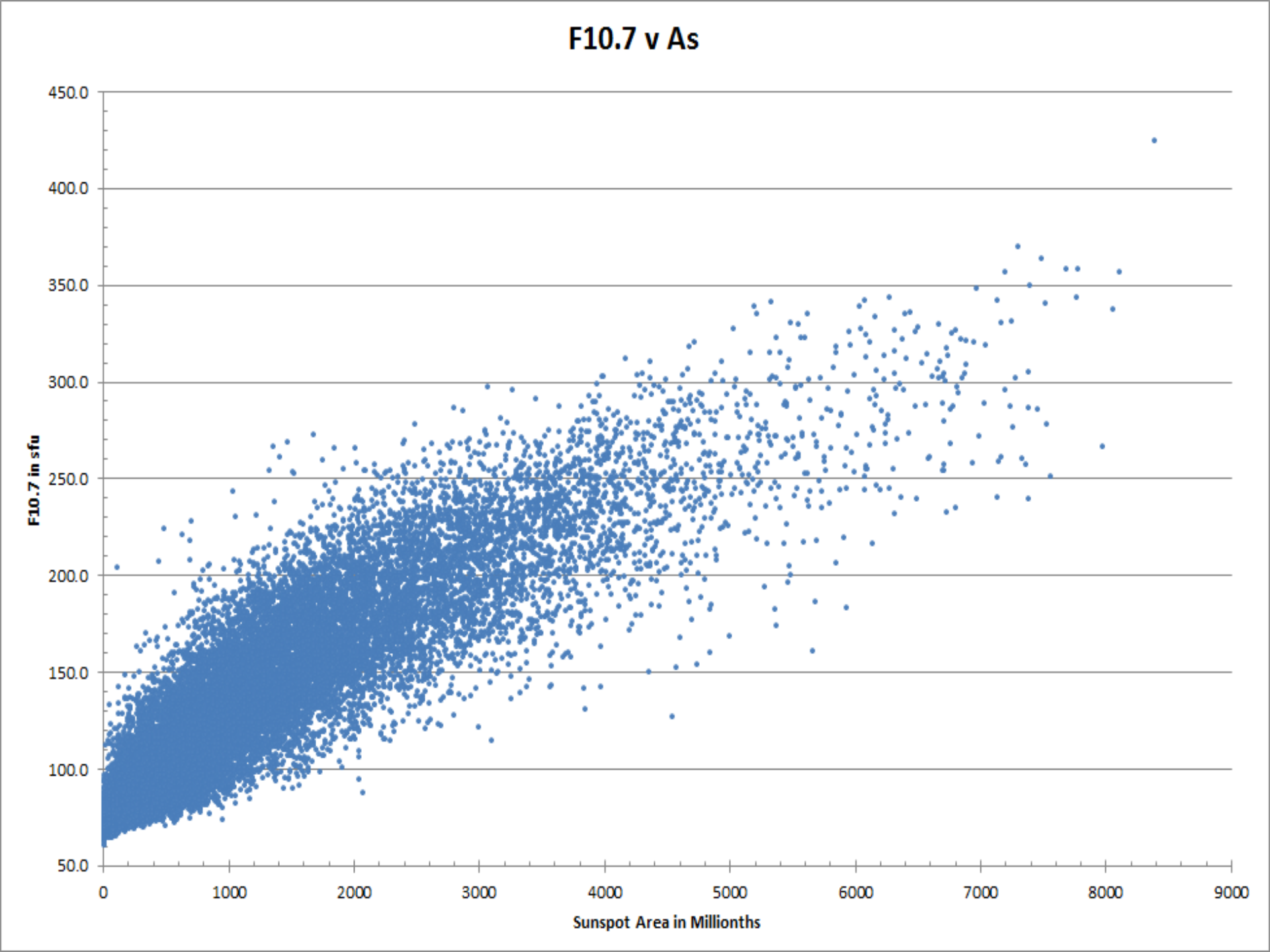

$F_{10.7}$, N_s, A_s 3-Month Running Averages
F10.7
Sunspot No
Sunspot Area/10+300
3-Month Average Value
Year
0
100
200
300
400
500
600
700
800
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
18
19
20
21
22
23
24

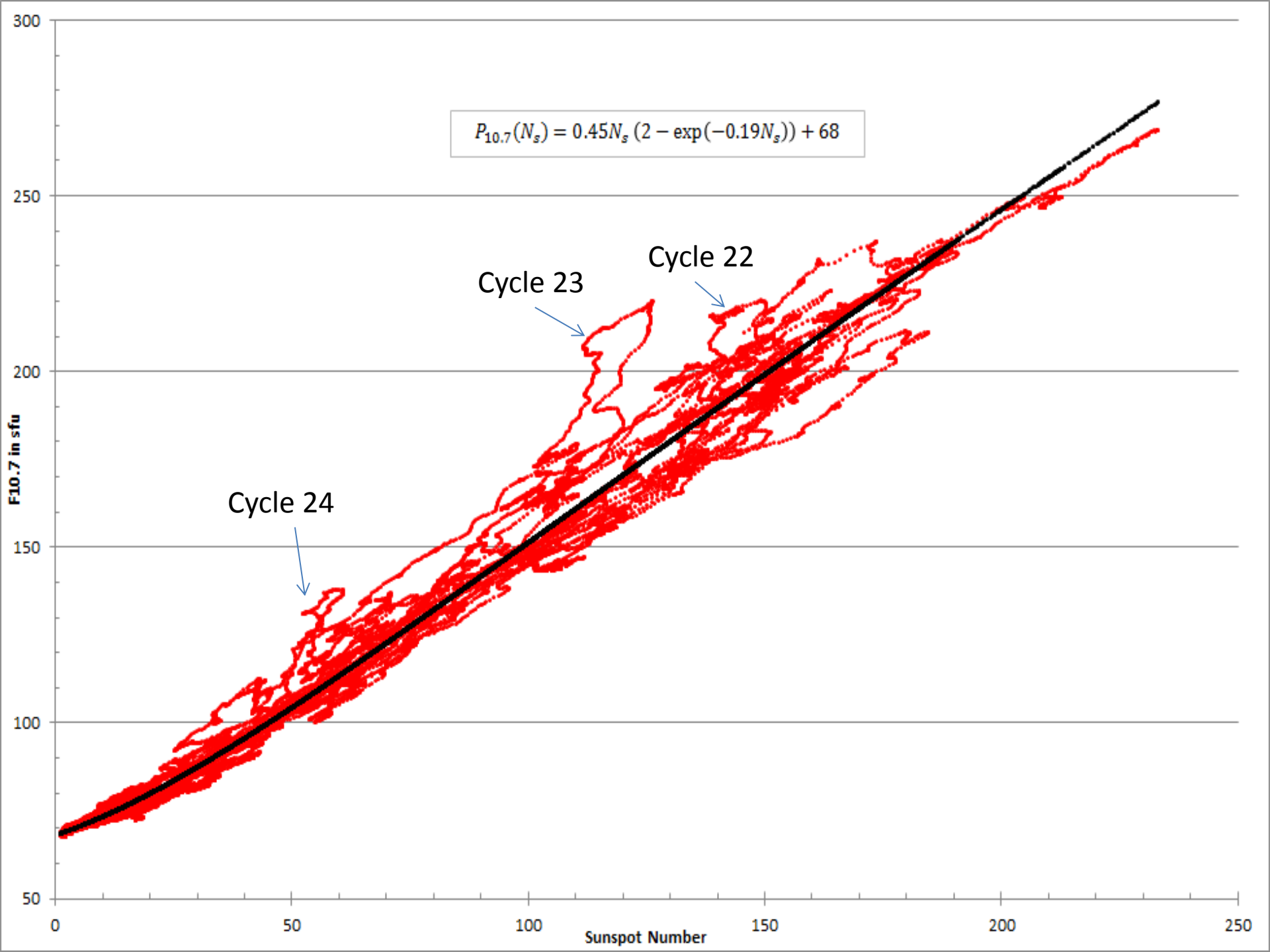

As v Ns
Sunspot Area in Millionths
Sunspot Number
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
0
50
100
150
200
250
300
350
400

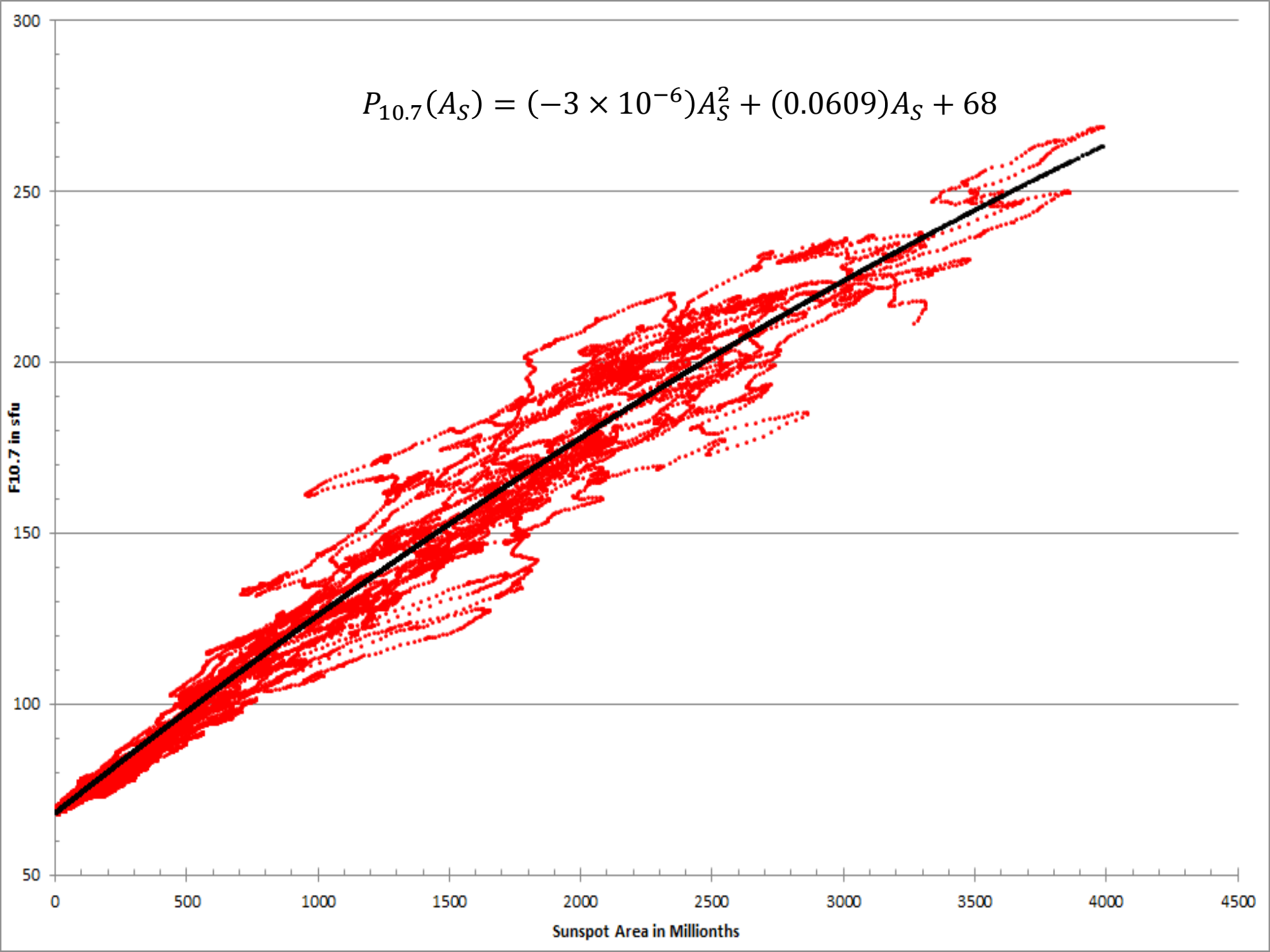

$A_S = (8.422)N_S(2 - \exp(-0.015N_S))$
As in millionths
Sunspot Number
0
500
1000
1500
2000
2500
3000
3500
4000
4500
0
50
100
150
200
250

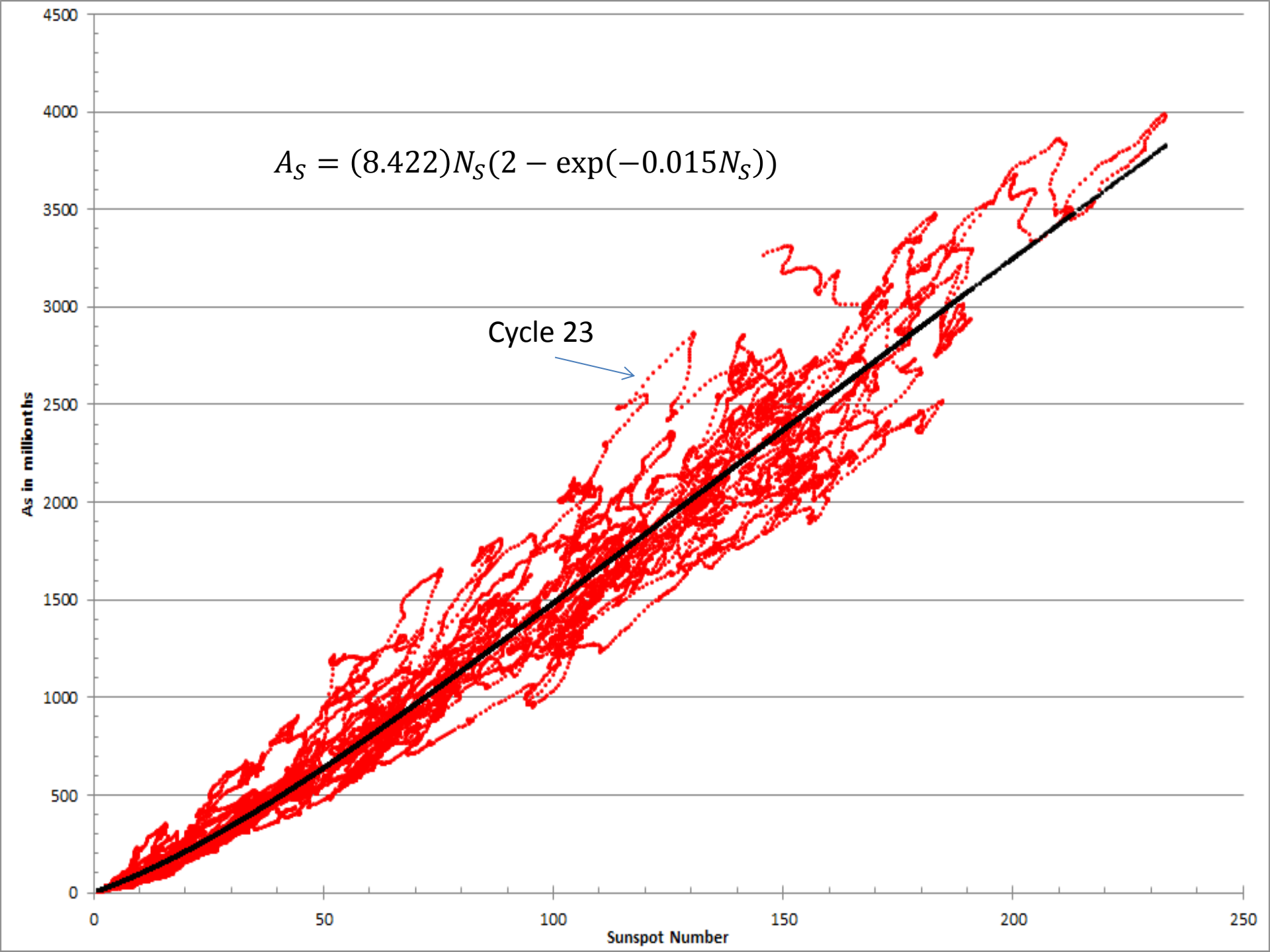

Sunspot Area
Did the relationship between sunspot number and sunspot area change during Cycle 23?
(O-P)/(O+P)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
Year

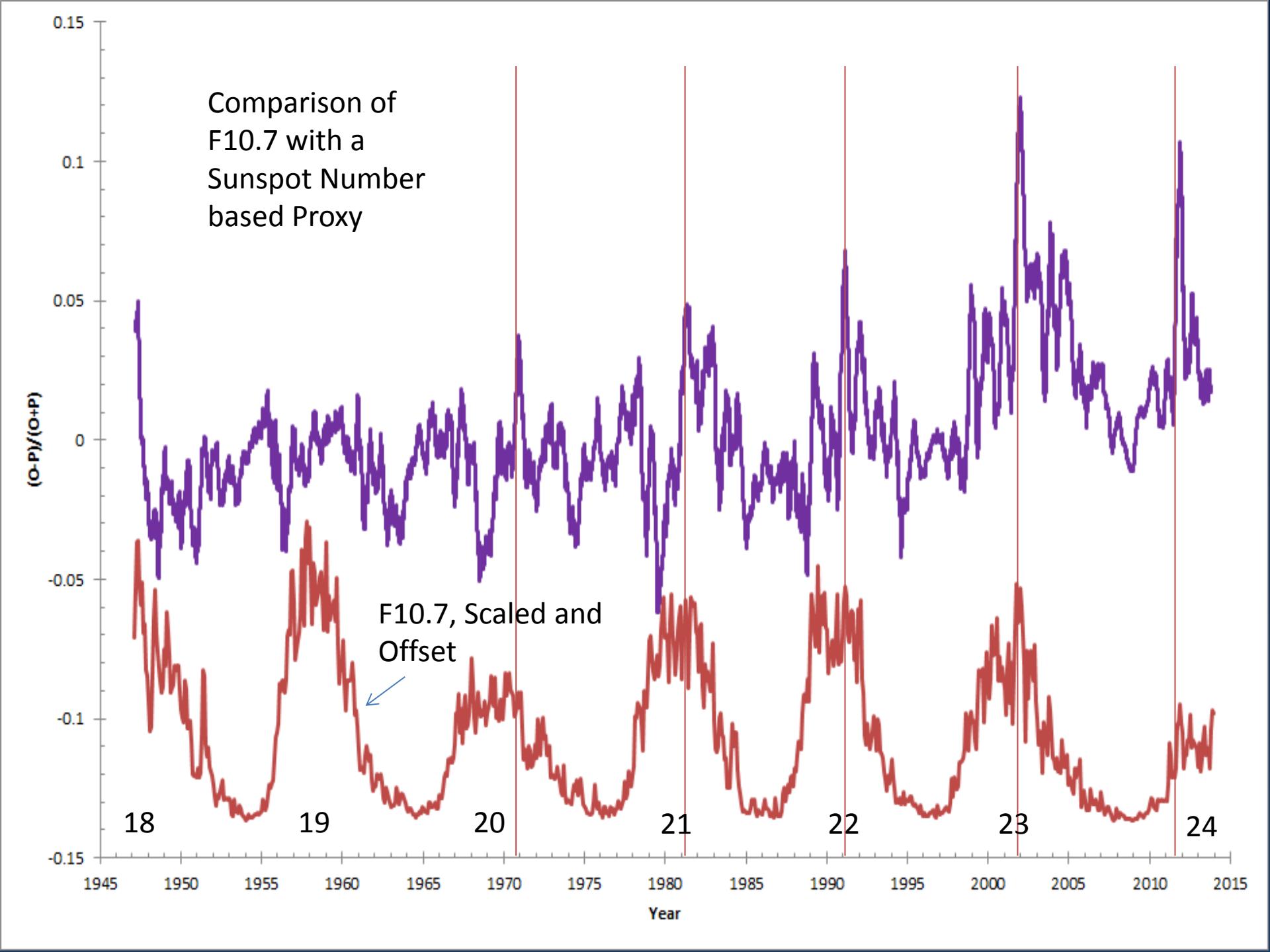

F10.7 v Ns
F10.7 in sfu
Sunspot Number
450
400
350
300
250
200
150
100
50
0
50
100
150
200
250
300
350
400

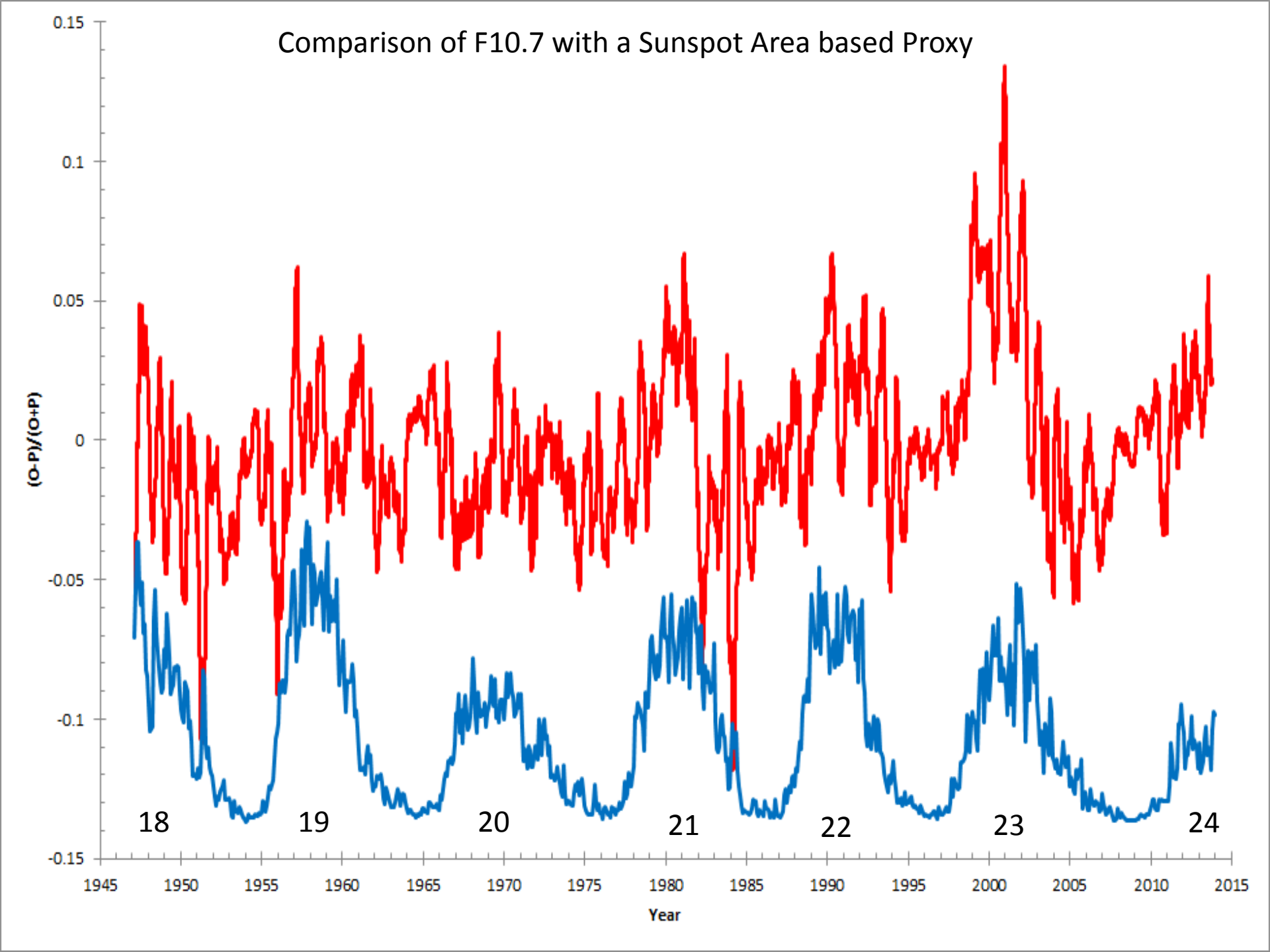

F10.7 v As
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
F10.7 in sfu
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
Sunspot Area in Millionths

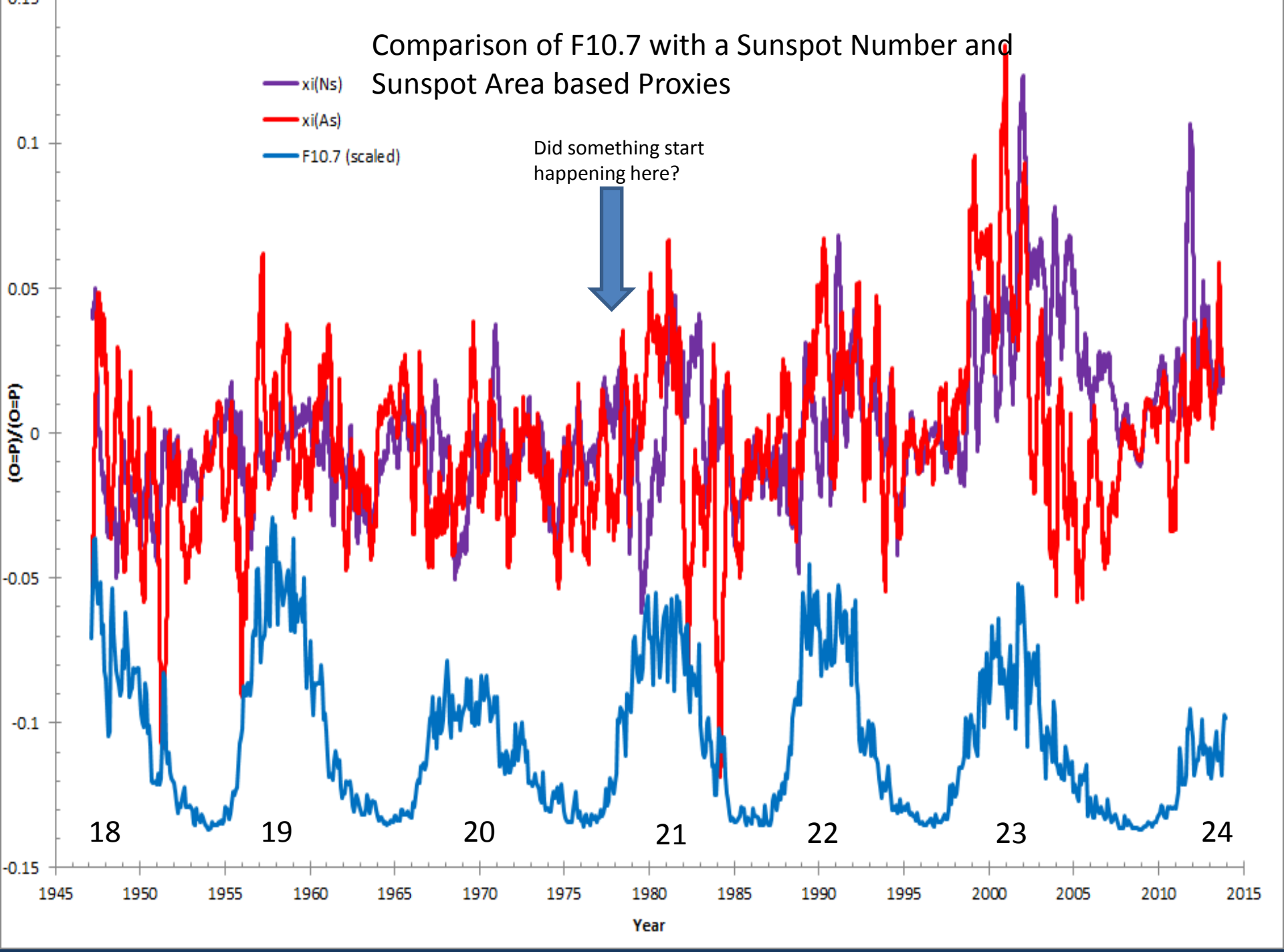

$P_{10.7}(N_s) = 0.45N_s\,(2 - \exp(-0.19N_s)) + 68$
Cycle 22
Cycle 23
Cycle 24
F10.7 in sfu
Sunspot Number
300
250
200
150
100
50
0
50
100
150
200
250

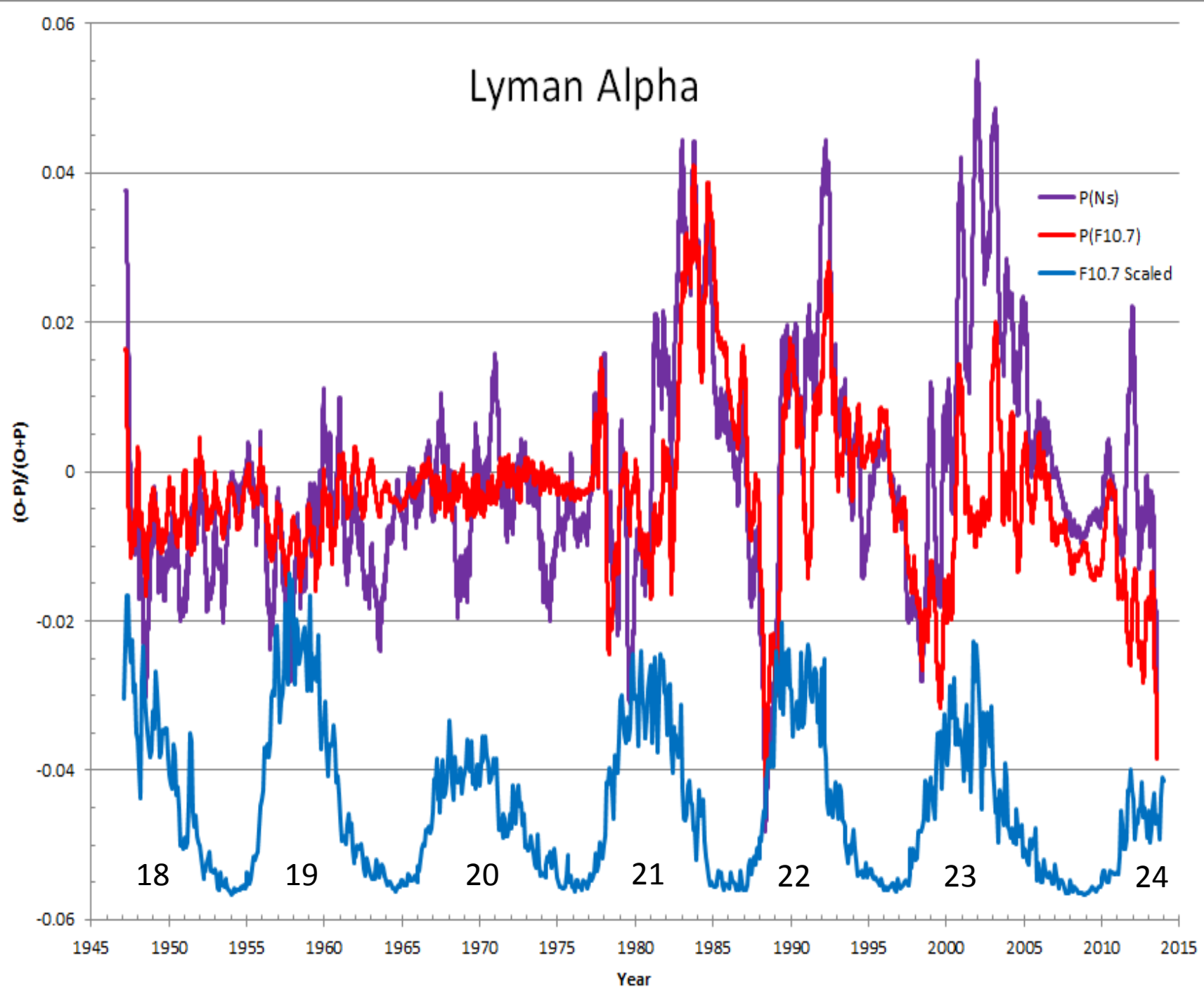

$P_{10.7}(A_S) = (-3 \times 10^{-6})A_S^2 + (0.0609)A_S + 68$
300
250
200
150
100
50
F10.7 in sfu
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Sunspot Area in Millionths

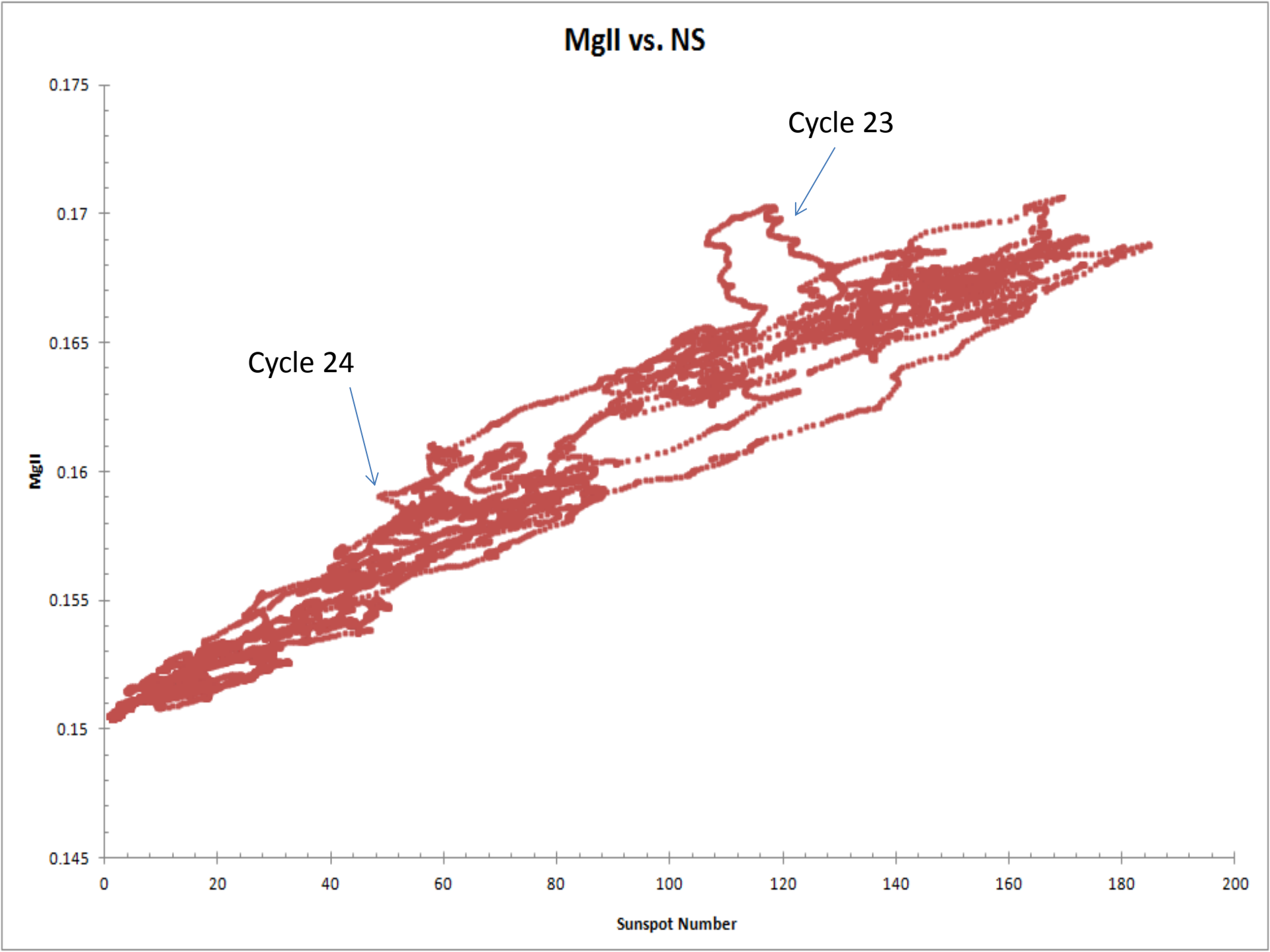

$A_S = (8.422)N_S(2 - \exp(-0.015N_S))$
Cycle 23
As in millionths
Sunspot Number
0
500
1000
1500
2000
2500
3000
3500
4000
4500
0
50
100
150
200
250

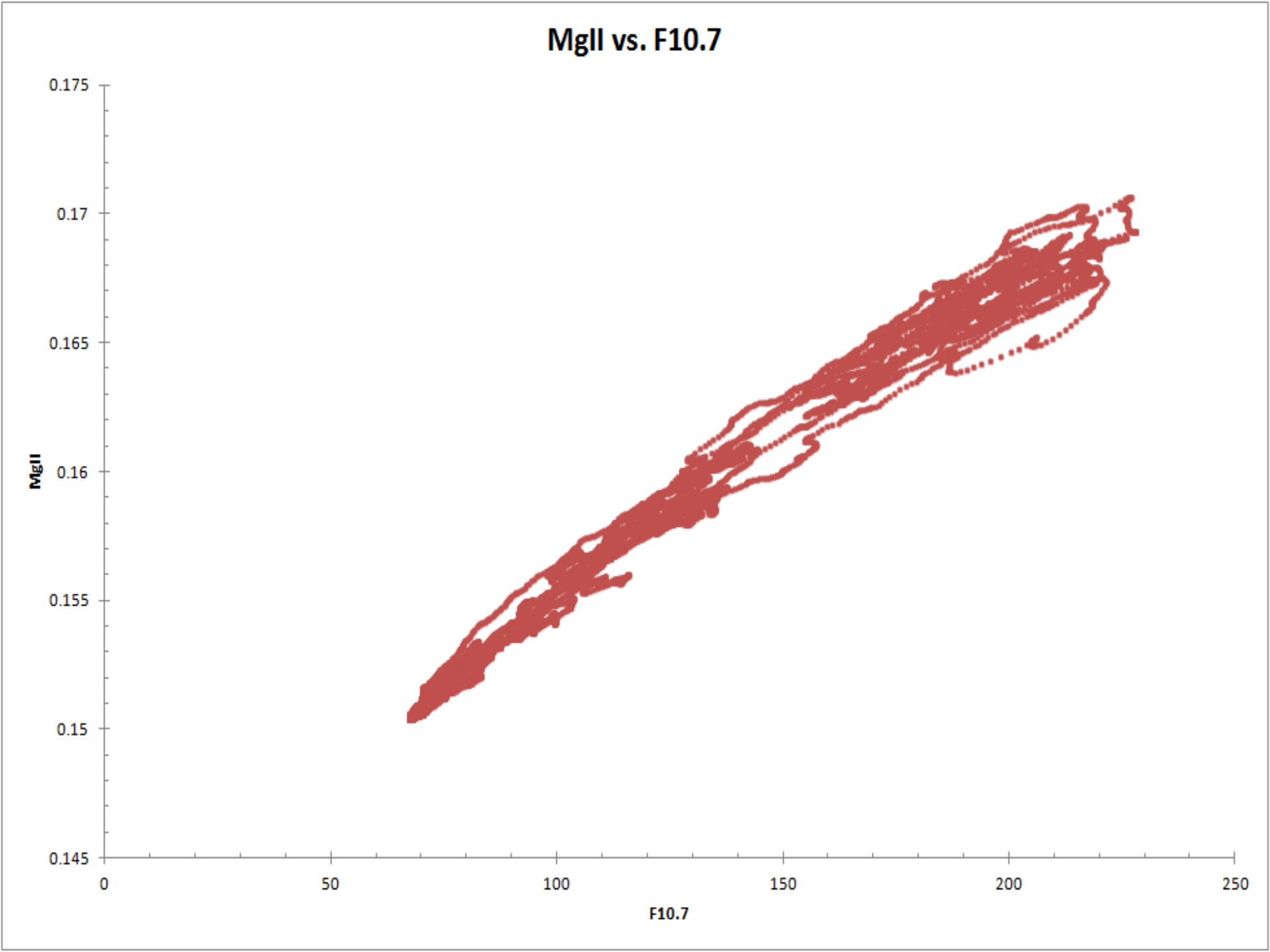

Comparison of F10.7 with a Sunspot Number based Proxy
F10.7, Scaled and Offset
18
19
20
21
22
23
24
(O-P)/(O+P)
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
Year

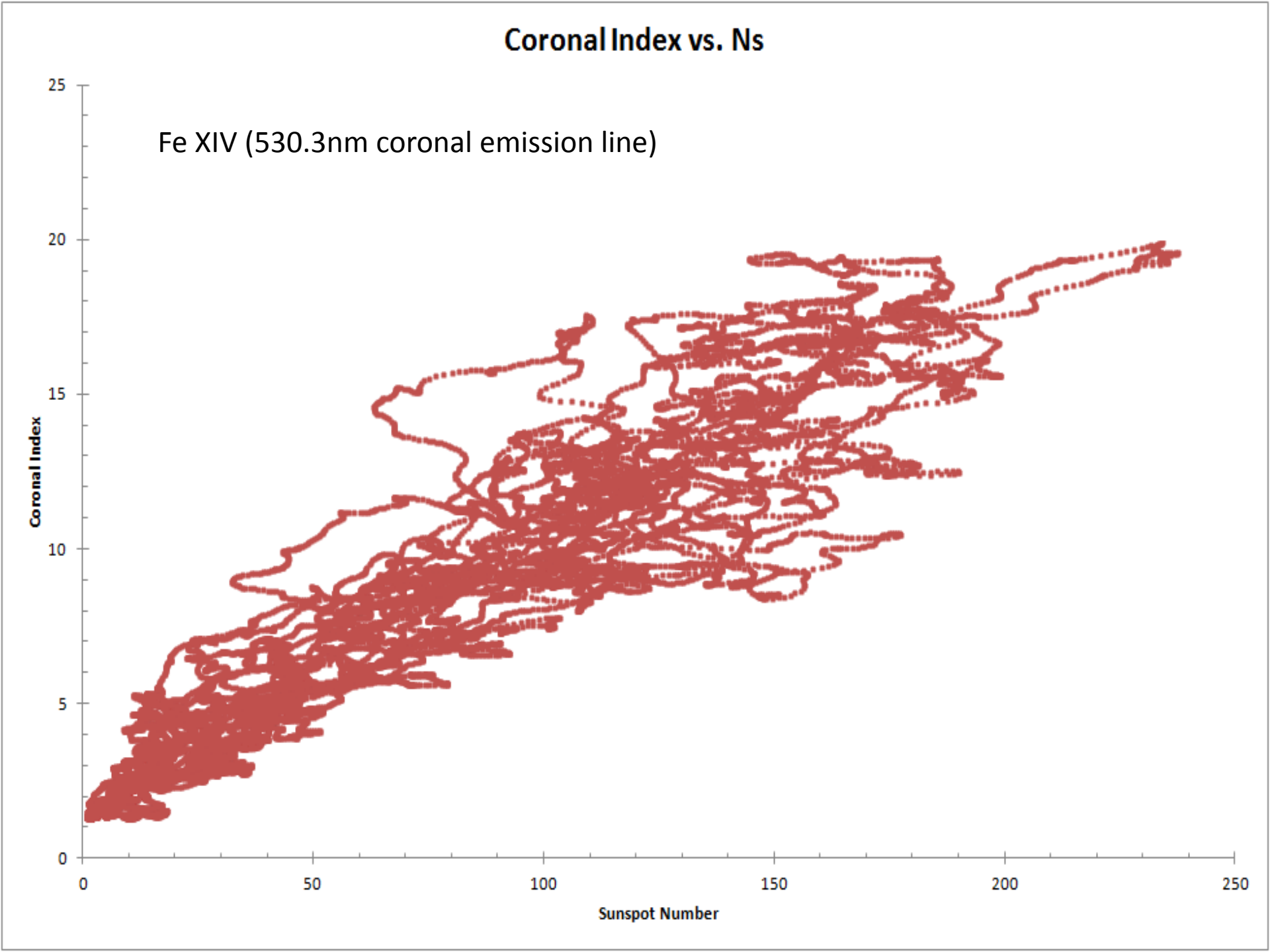

Comparison of F10.7 with a Sunspot Area based Proxy
(O-P)/(O+P)
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
18
19
20
21
22
23
24
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
Year

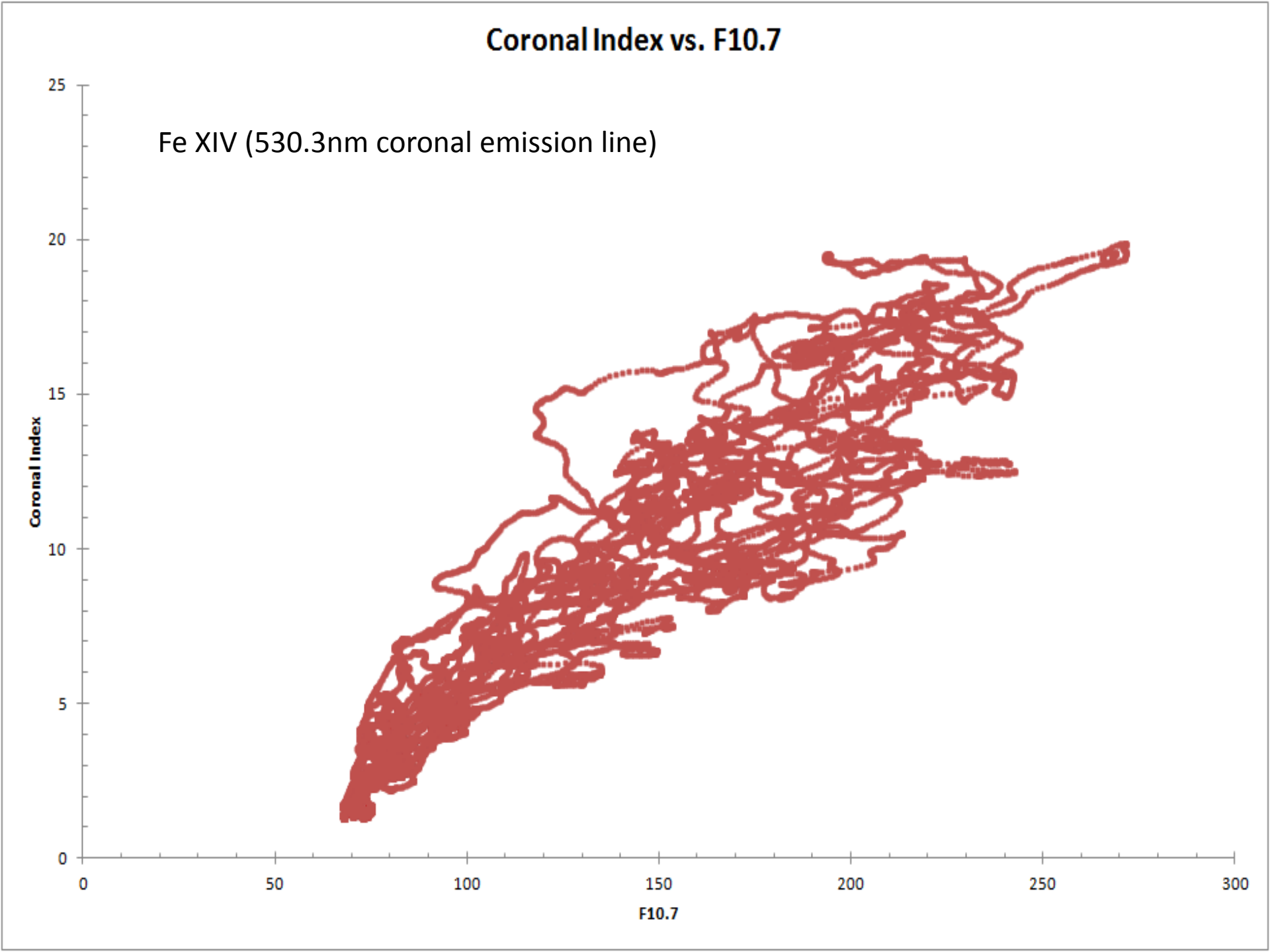

Comparison of F10.7 with a Sunspot Number and Sunspot Area based Proxies
xi(Ns)
xi(As)
F10.7 (scaled)
Did something start happening here?
(O=P)/(O=P)
0.1
0.05
0
-0.05
-0.1
-0.15
18
19
20
21
22
23
24
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
Year

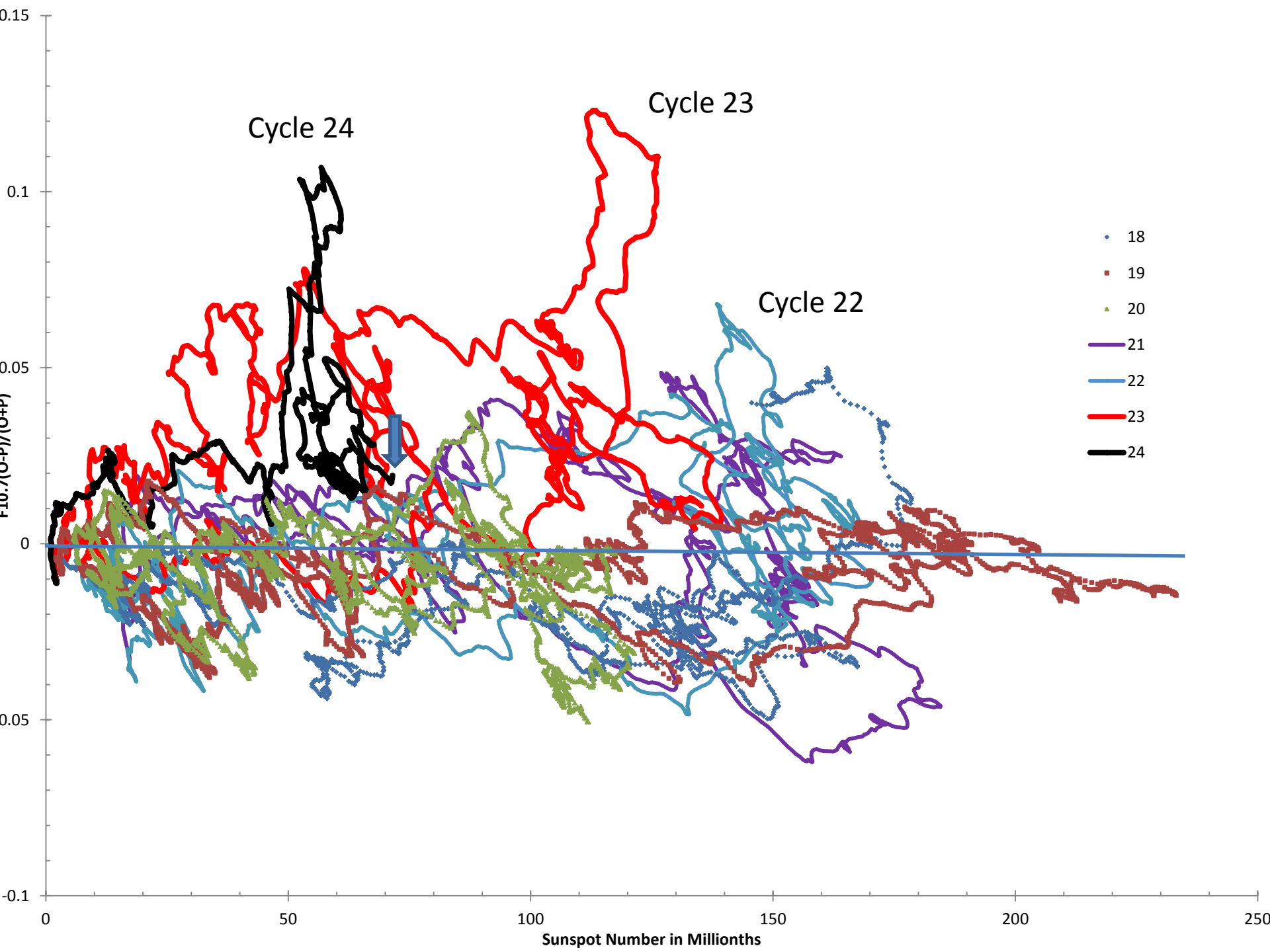

Lyman Alpha
P(Ns)
P(F10.7)
F10.7 Scaled
(O-P)/(O+P)
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
18
19
20
21
22
23
24
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
Year

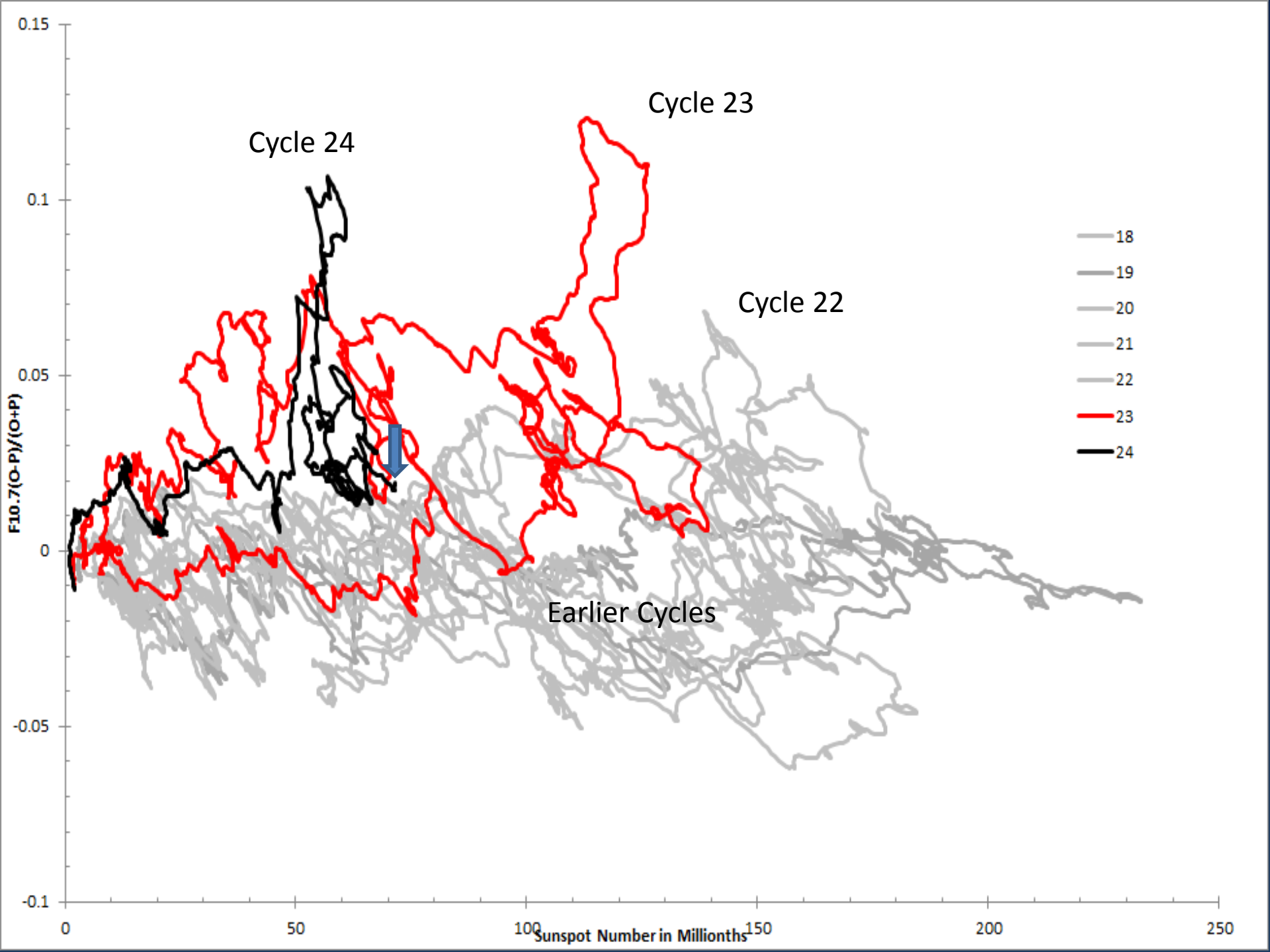

MgII vs. NS
Cycle 23
Cycle 24
MgII
0.175
0.17
0.165
0.16
0.155
0.15
0.145
0
20
40
60
80
100
120
140
160
180
200
Sunspot Number


MgII vs. F10.7
0.175
0.17
0.165
0.16
0.155
0.15
0.145
MgII
0
50
100
150
200
250
F10.7


Coronal Index vs. Ns
Fe XIV (530.3nm coronal emission line)
Coronal Index
Sunspot Number
0
5
10
15
20
25
0
50
100
150
200
250


Coronal Index vs. F10.7
Fe XIV (530.3nm coronal emission line)
Coronal Index
F10.7
0
5
10
15
20
25
0
50
100
150
200
250
300


Cycle 24
Cycle 23
Cycle 22
18
19
20
21
22
23
24
0.15
0.1
0.05
0
-0.05
-0.1
0
50
100
150
200
250
Sunspot Number in Millionths


Cycle 23
Cycle 24
Cycle 22
Earlier Cycles
18
19
20
21
22
23
24
0.15
0.1
0.05
0
-0.05
-0.1
F10.7(O-P)/(O+P)
0
50
100
150
200
250
Sunspot Number in Millionths

Conclusions

- Though intercomparison of indices, it appears that there are indications of a change in solar behaviour began just before the maximum of cycle 21.
- An increasing deviation began between photospheric and coronal activity indices, including an excess of F10.7 over a sunspot number based proxy.
- There was a spike of this excess in cycles 21, 22, 23 and 24, getting bigger each time.
- It's still not clear where cycle 24 is going.