Cycles and Anti-Cycles of Solar Activity and the basis for their prediction

M.I.Ryabov, A.L. Sukcharev

Odessa observatory «URAN-4» Radio-astronomical Institute NASU

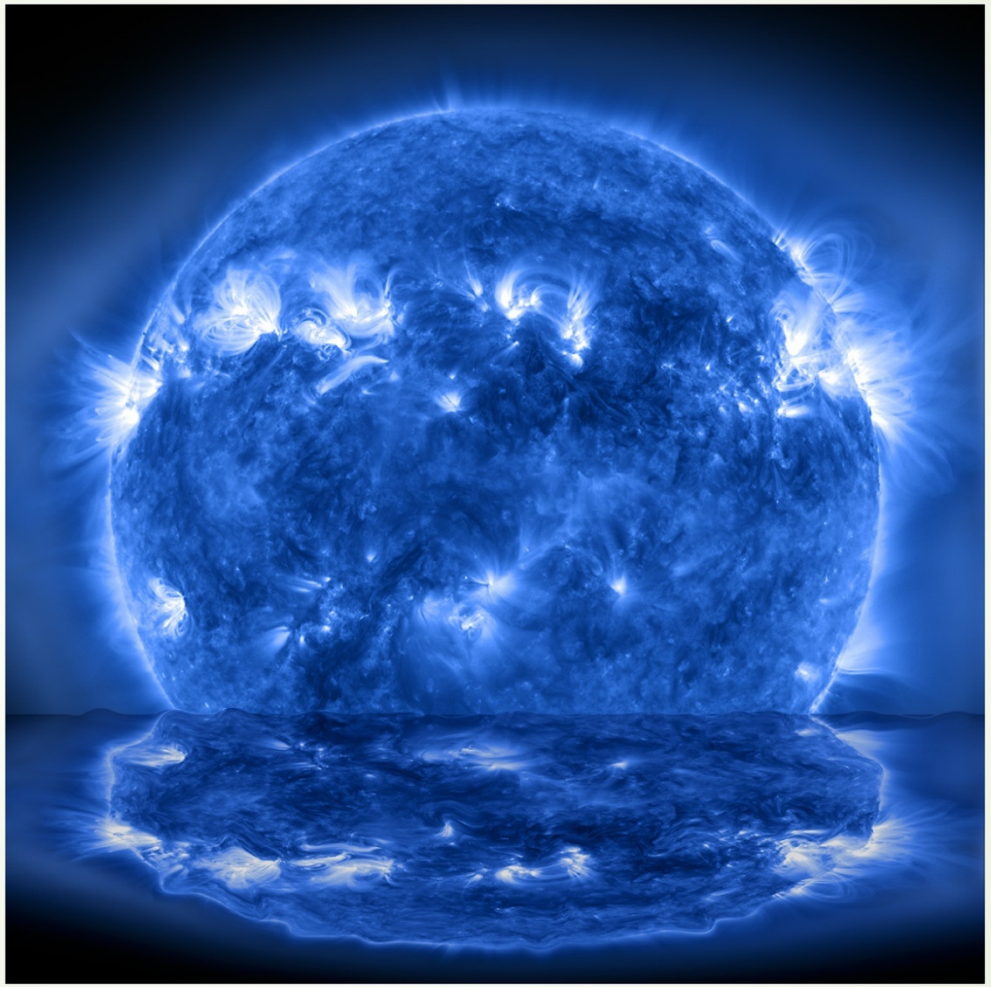
Solar Influences on the Magnetosphere, Ionosphere and Atmosphere

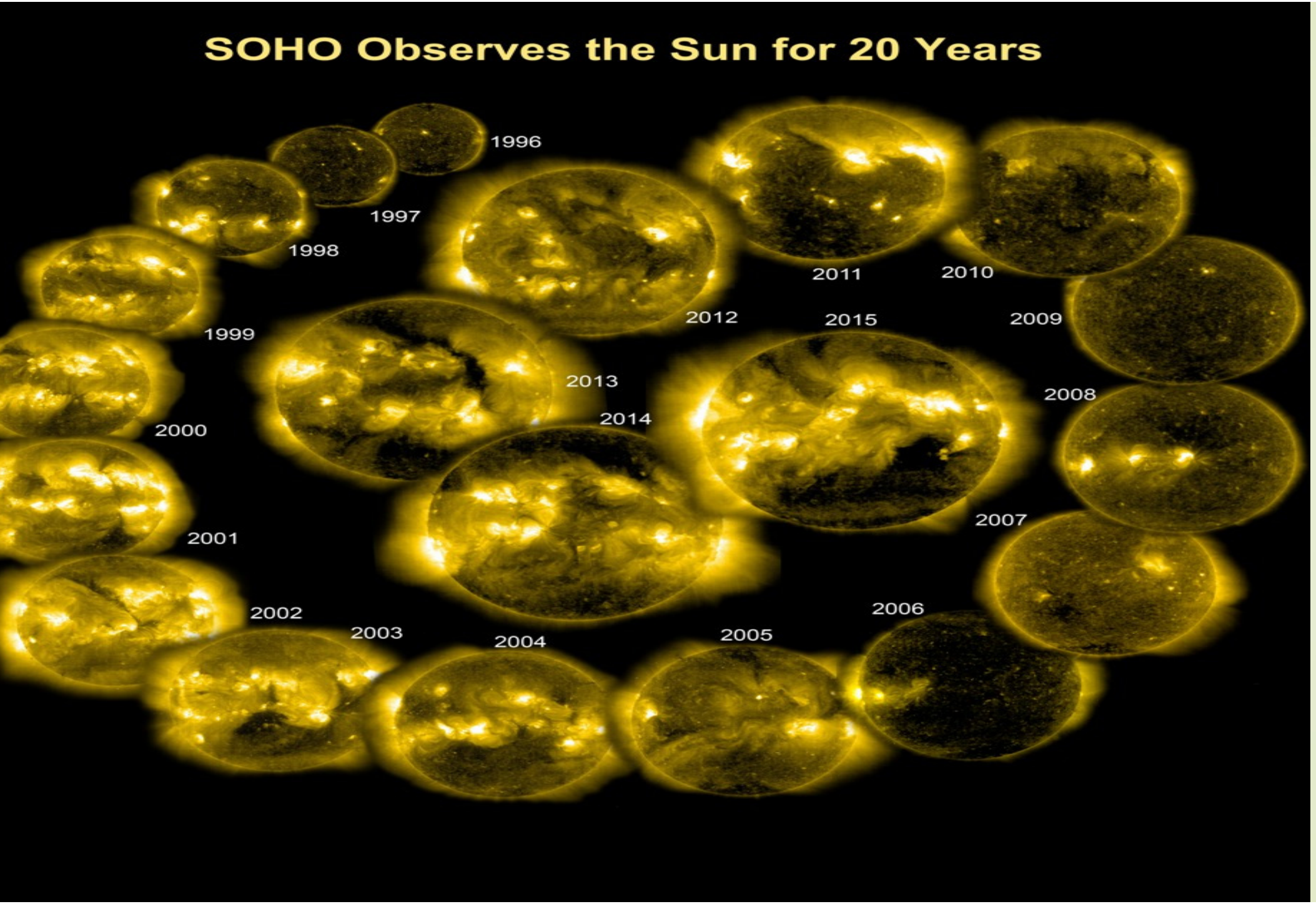
Sunny Beach, Bulgaria, May 30 - June 3, 2017

Abstract

- In previous works it was shown that the periodicity of the manifestation of solar activity in the Northern and Southern hemispheres of the Sun is essentially different and form the N and S cycles of activity.
- Among the detected differences of N and S cycles: the start and end time, the discreteness properties, the dynamics of the main periods, the time of the maxima, the periods of "faults" and "synchronization".

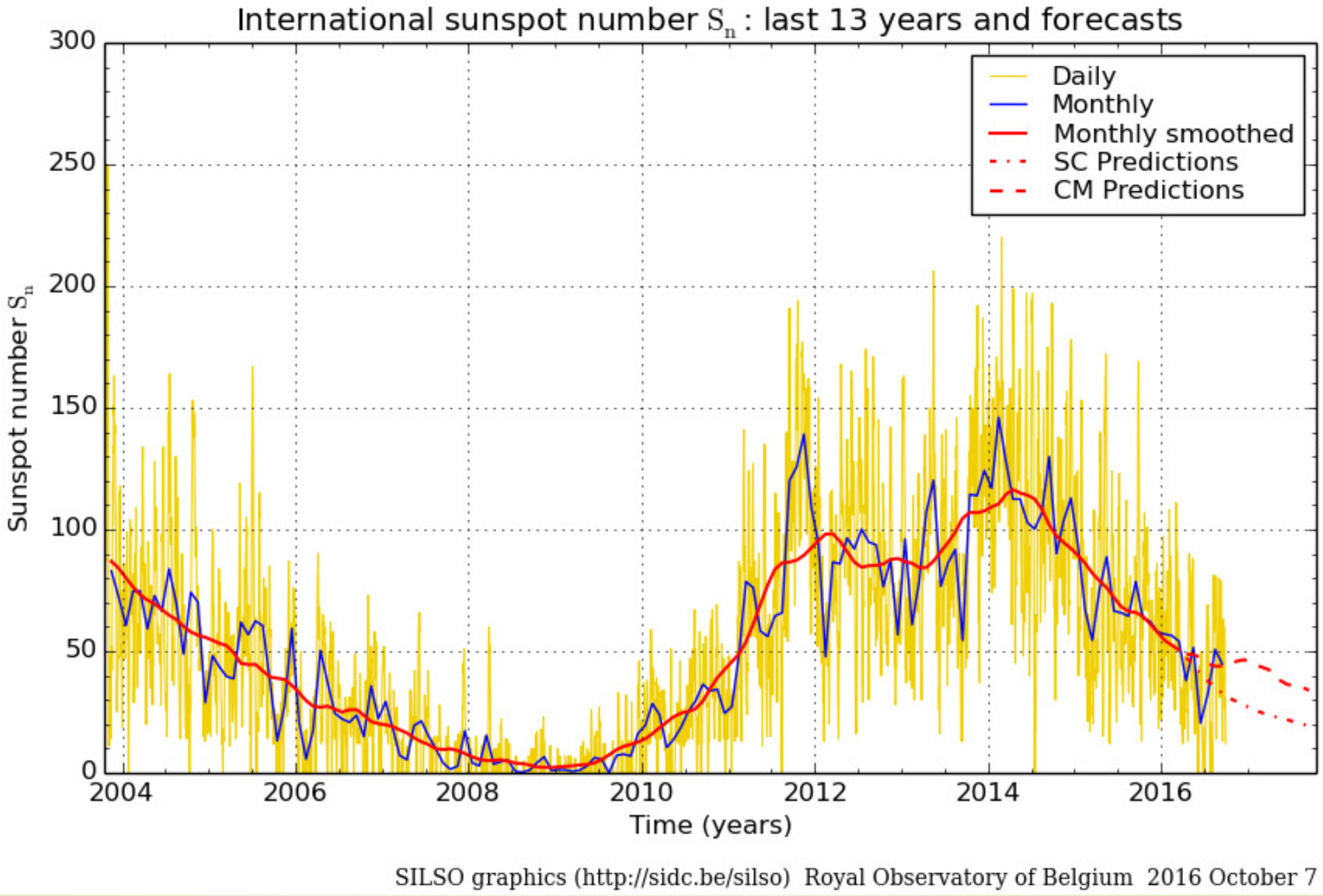
N and S activity on the Sun

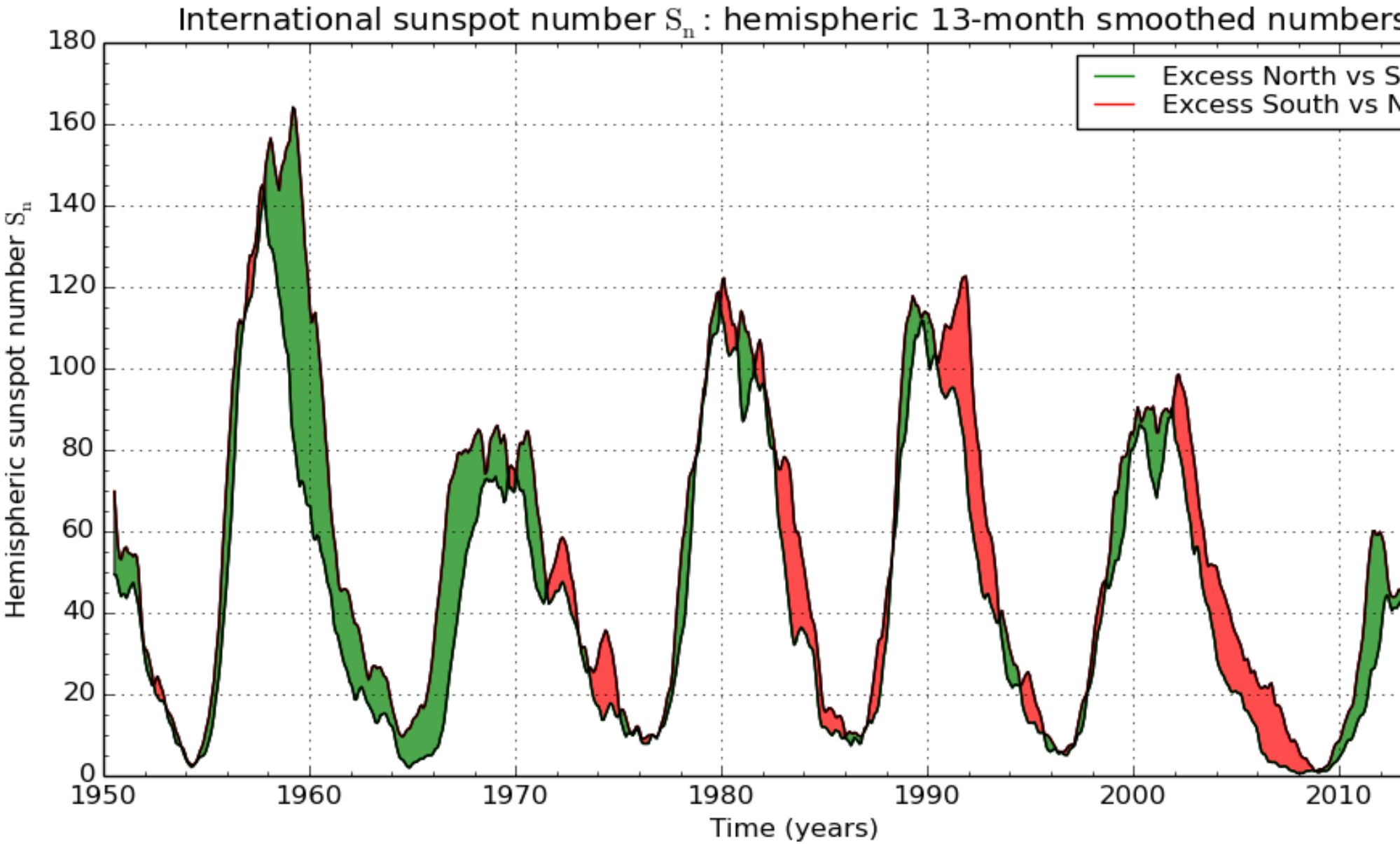


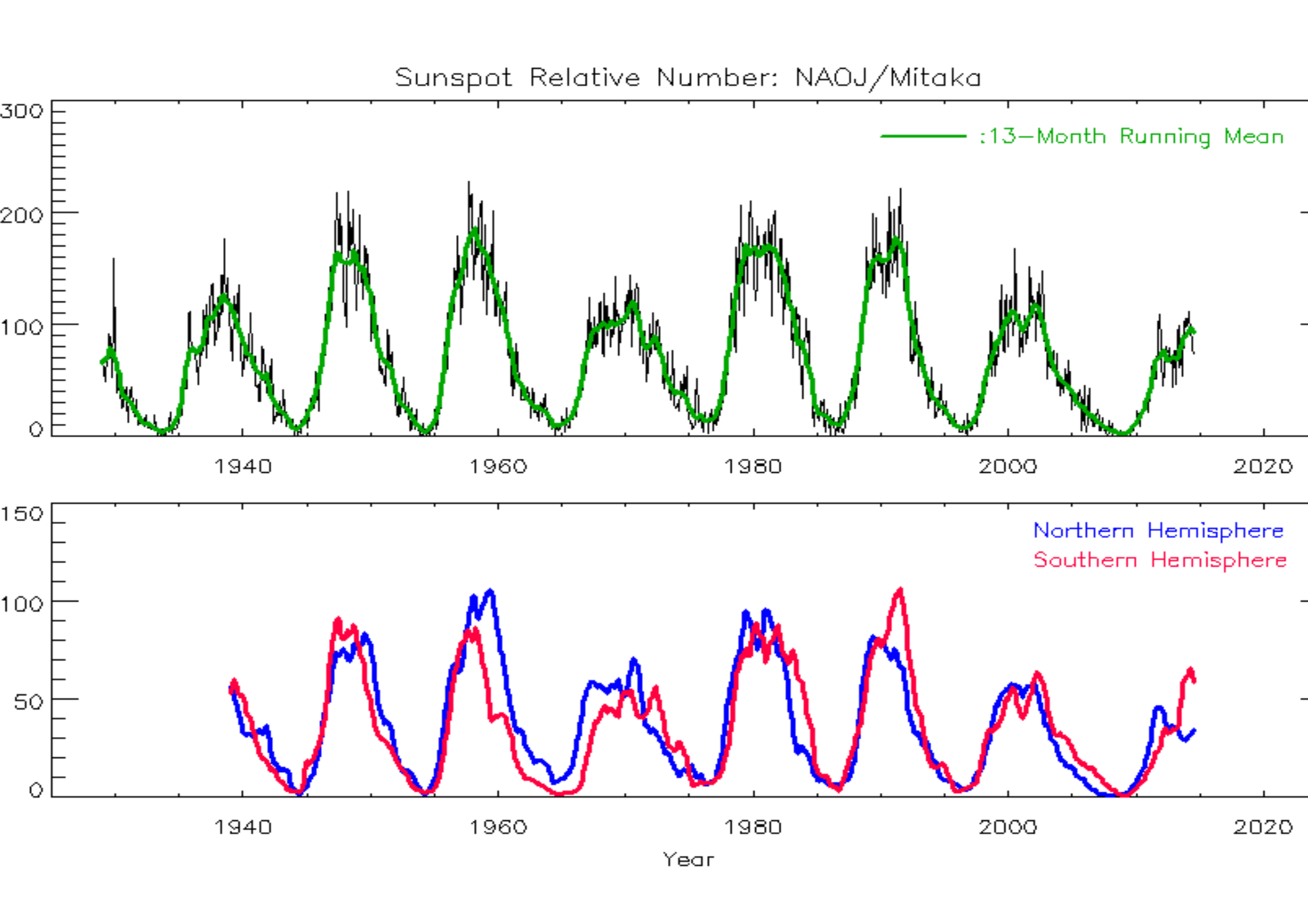

SOHO Observes the Sun for 20 Years
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015

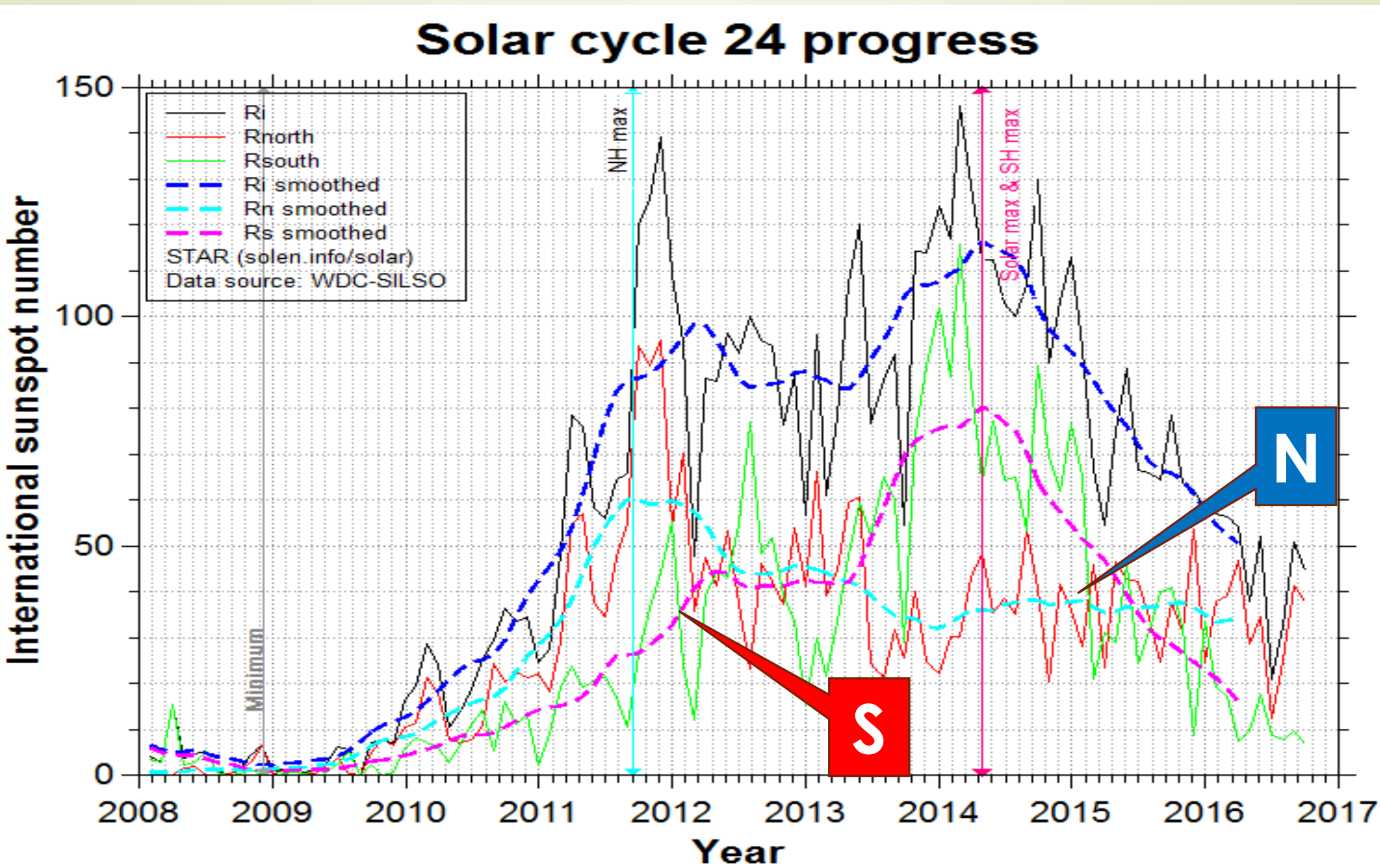
Introduction

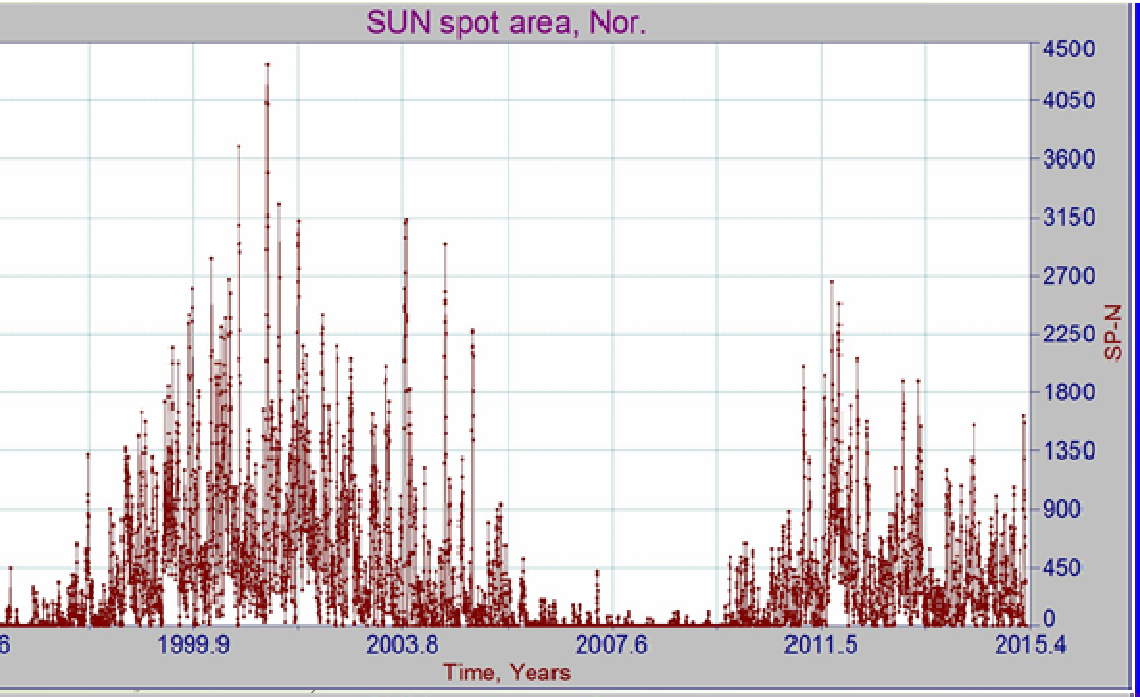
- Currently, solar cycles view prevails using mean monthly values of the various indices and their annual smoothed values for the entire solar disk.
- This view creates an illusion of monotony changes major indices at all phases of the solar cycle.

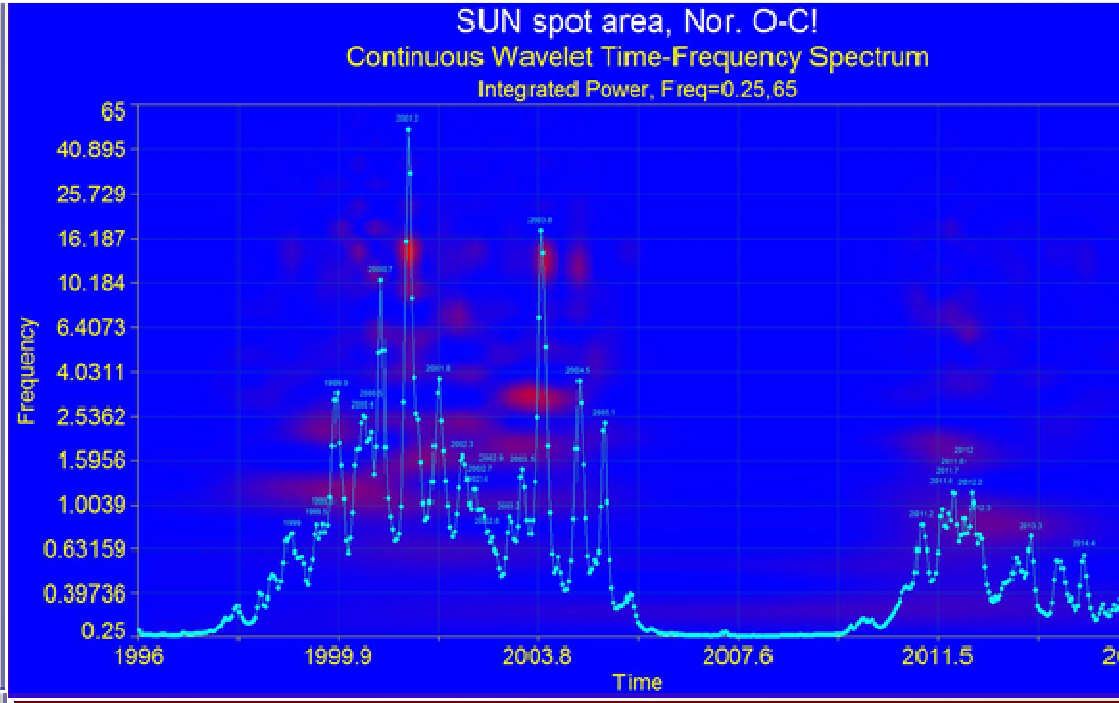

International sunspot number S_n : last 13 years and forecasts
Daily
Monthly
Monthly smoothed
SC Predictions
CM Predictions
Sunspot number S_n
Time (years)
300
250
200
150
100
50
0
2004
2006
2008
2010
2012
2014
2016
SILSO graphics (http://sidc.be/silso) Royal Observatory of Belgium 2016 October 7

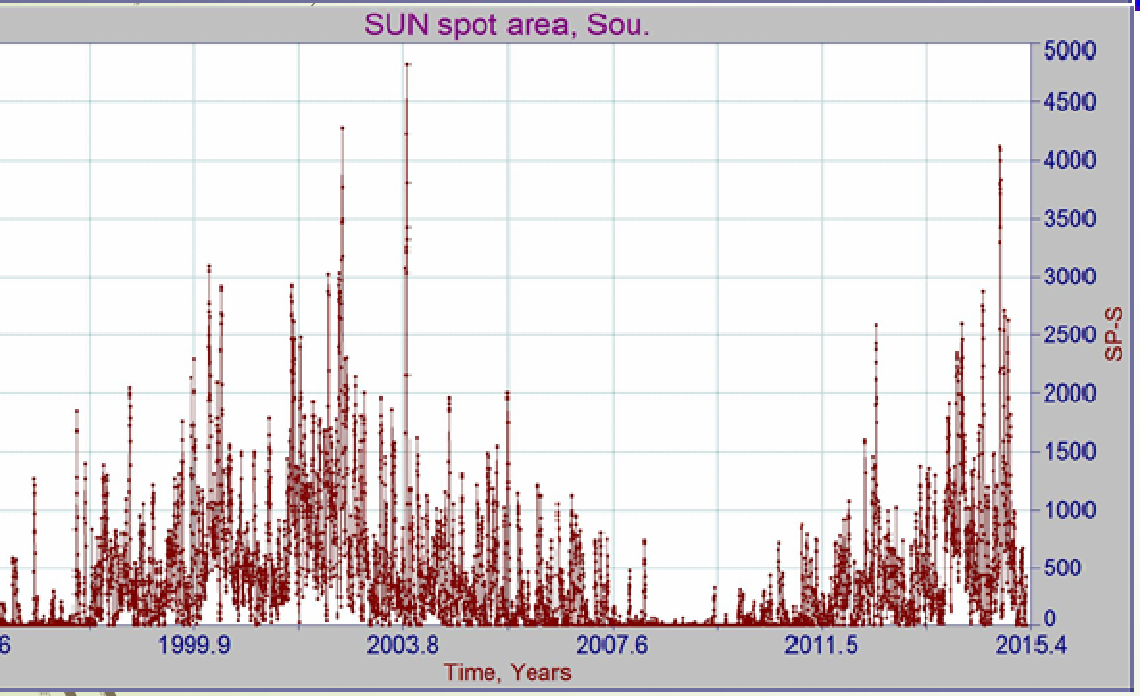

International sunspot number S_n : hemispheric 13-month smoothed numbers
Excess North vs S
Excess South vs N
Hemispheric sunspot number S_n
180
160
140
120
100
80
60
40
20
0
1950
1960
1970
1980
1990
2000
2010
Time (years)
SILSO graphics (http://sidc.be/silso) Royal Observatory of Belgium 2016 Oc

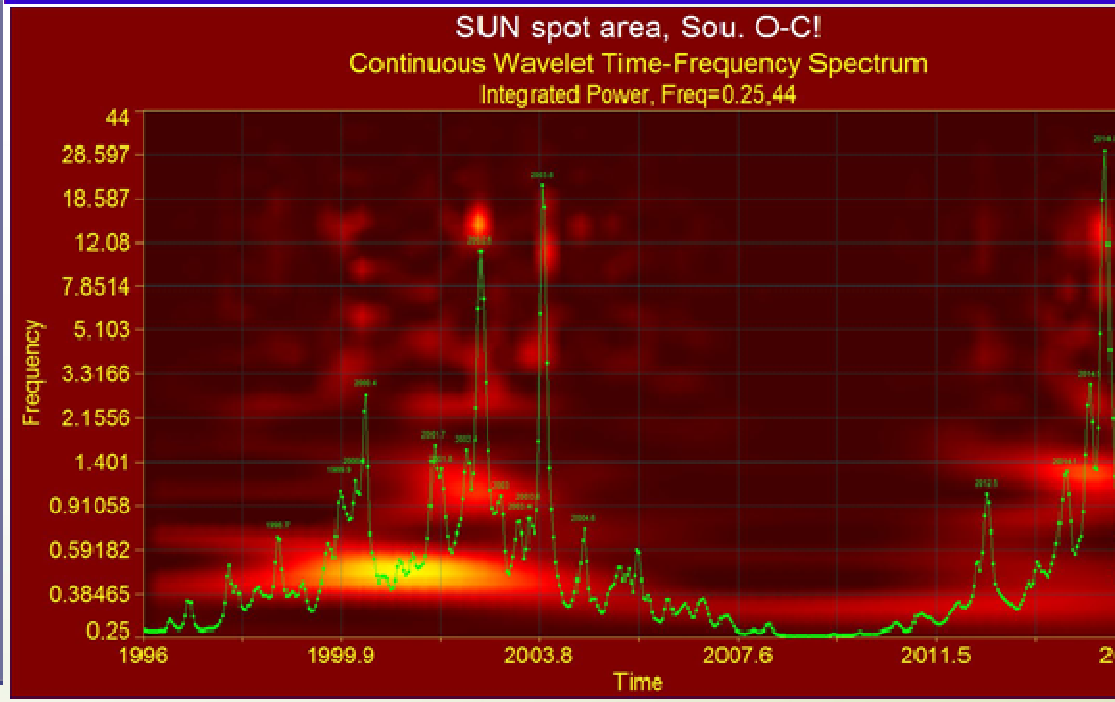

Sunspot Relative Number: NAOJ/Mitaka
:13-Month Running Mean
300
200
100
0
1940
1960
1980
2000
2020
Northern Hemisphere
Southern Hemisphere
150
100
50
0
1940
1960
1980
2000
2020
Year

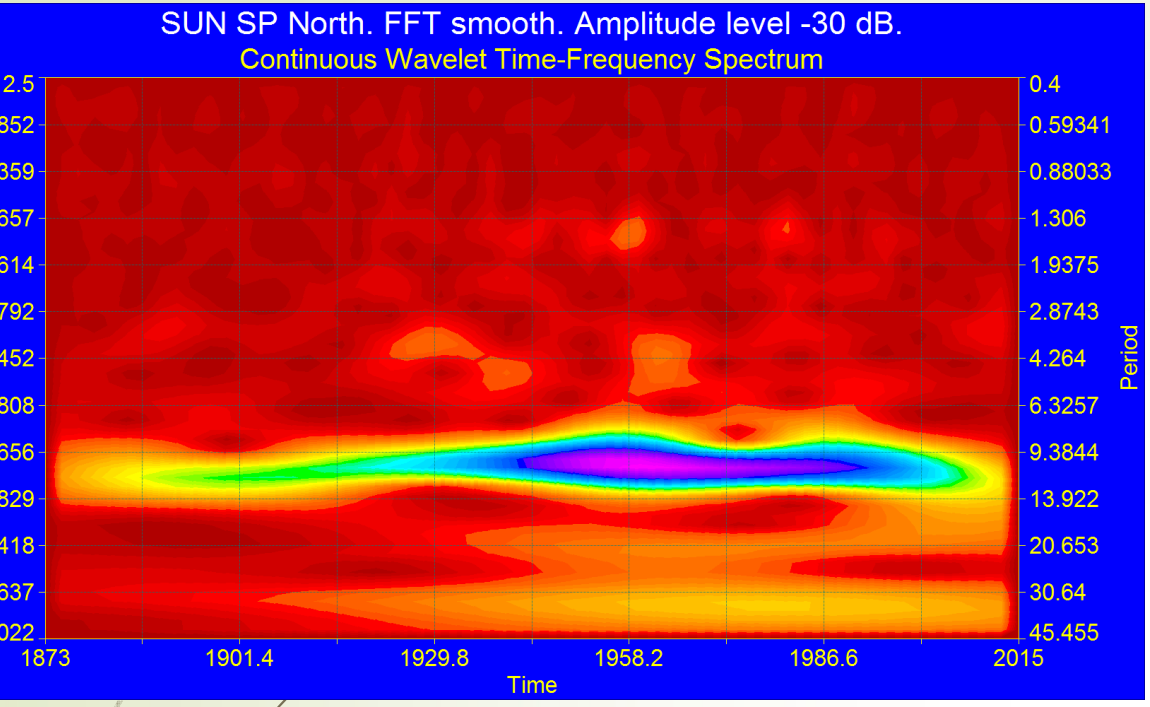

Solar cycle 24 progress
Ri
Rnorth
Rsouth
Ri smoothed
Rn smoothed
Rs smoothed
STAR (solen.info/solar)
Data source: WDC-SILSO
NH max
Solar max & SH max
Minimum
N
S
International sunspot number
Year
150
100
50
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017

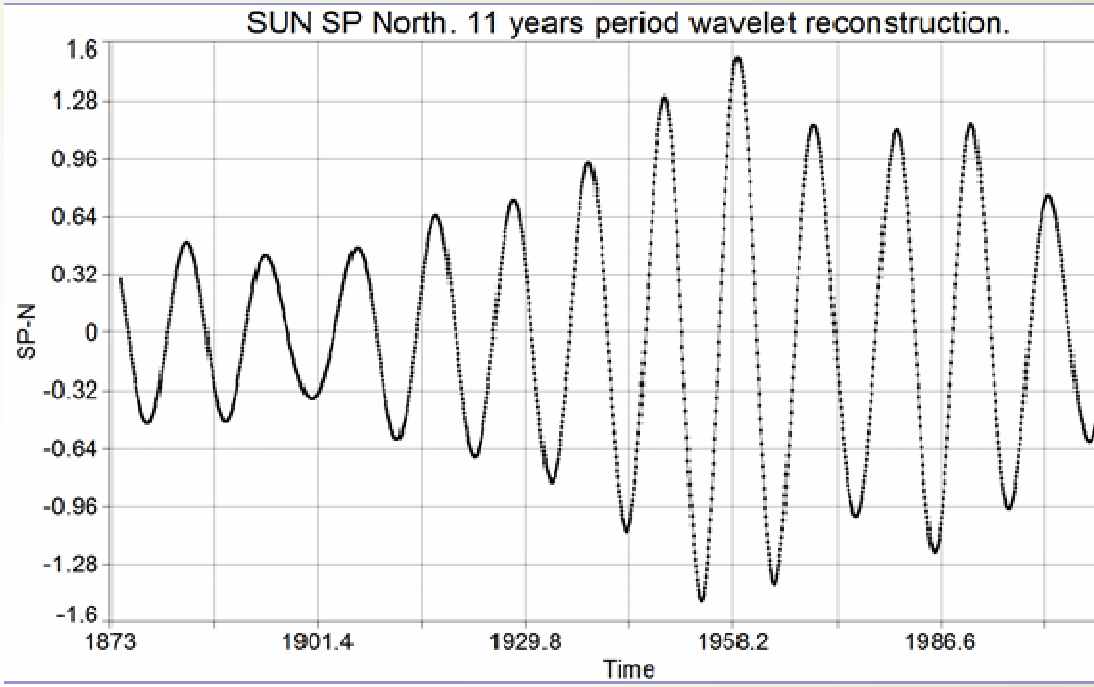

SUN spot area, Nor.
4500
4050
3600
3150
2700
2250
1800
1350
900
450
0
SP-N
1999.9
2003.8
2007.6
2011.5
2015.4
Time, Years

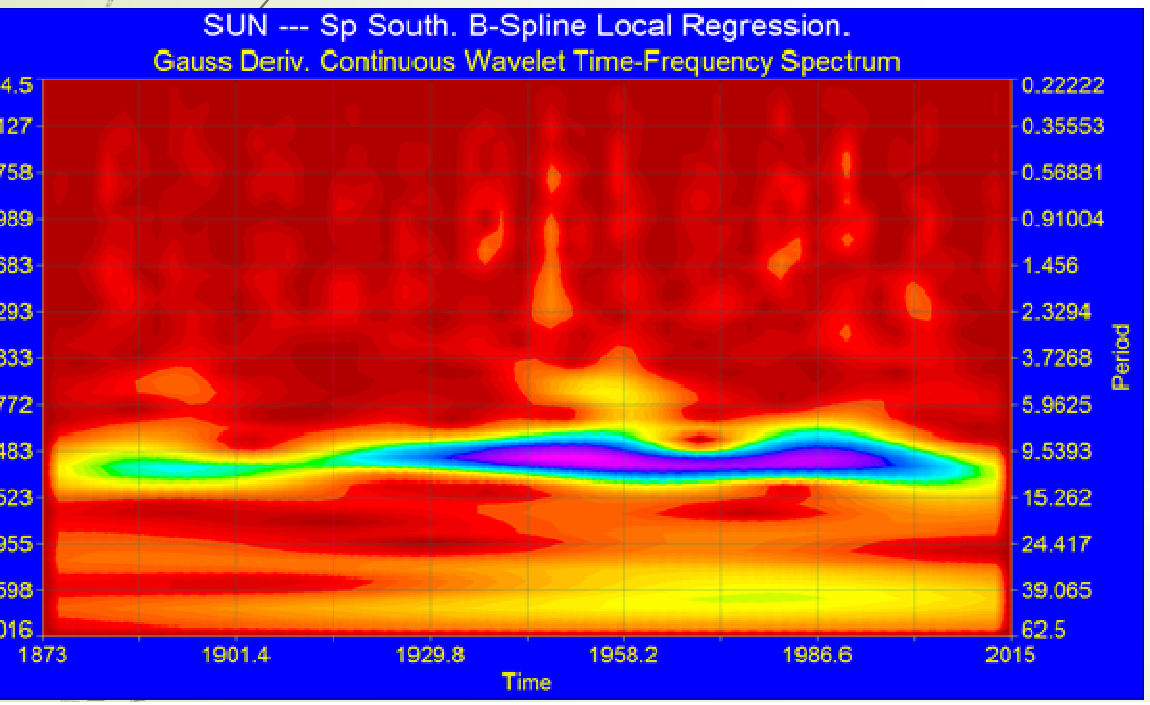

SUN spot area, Nor. O-C!
Continuous Wavelet Time-Frequency Spectrum
Integrated Power, Freq=0.25,65
65
40.895
25.729
16.187
10.184
6.4073
4.0311
2.5362
1.5956
1.0039
0.63159
0.39736
0.25
Frequency
1996
1999.9
2003.8
2007.6
2011.5
Time

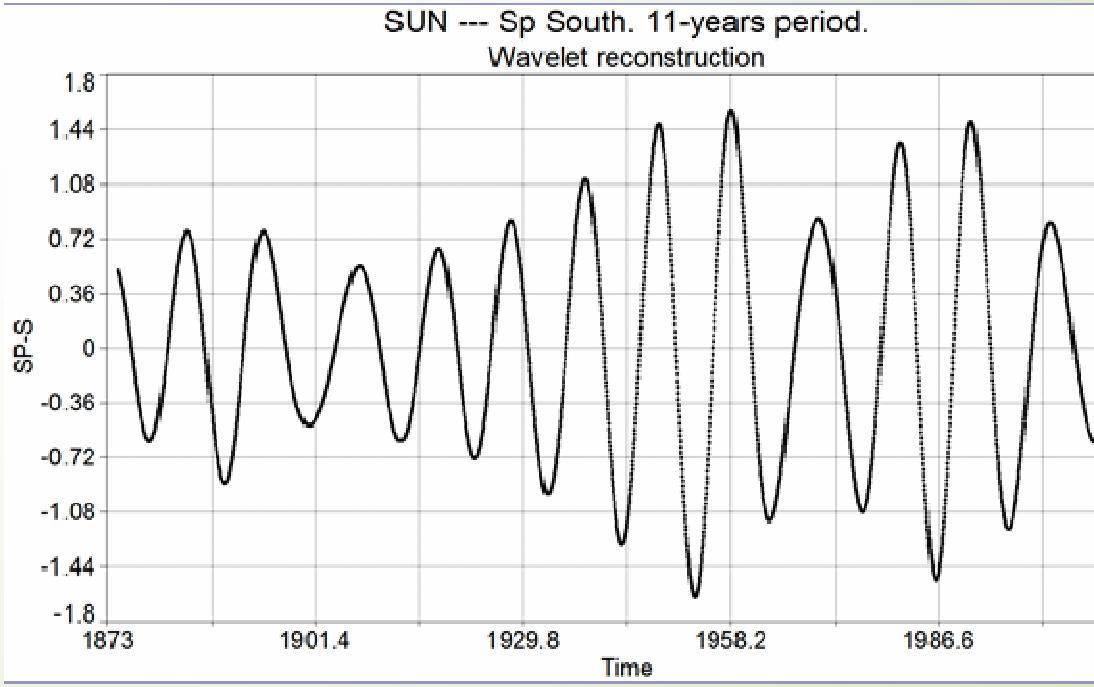

SUN spot area, Sou.
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
SP-S
1999.9
2003.8
2007.6
2011.5
2015.4
Time, Years

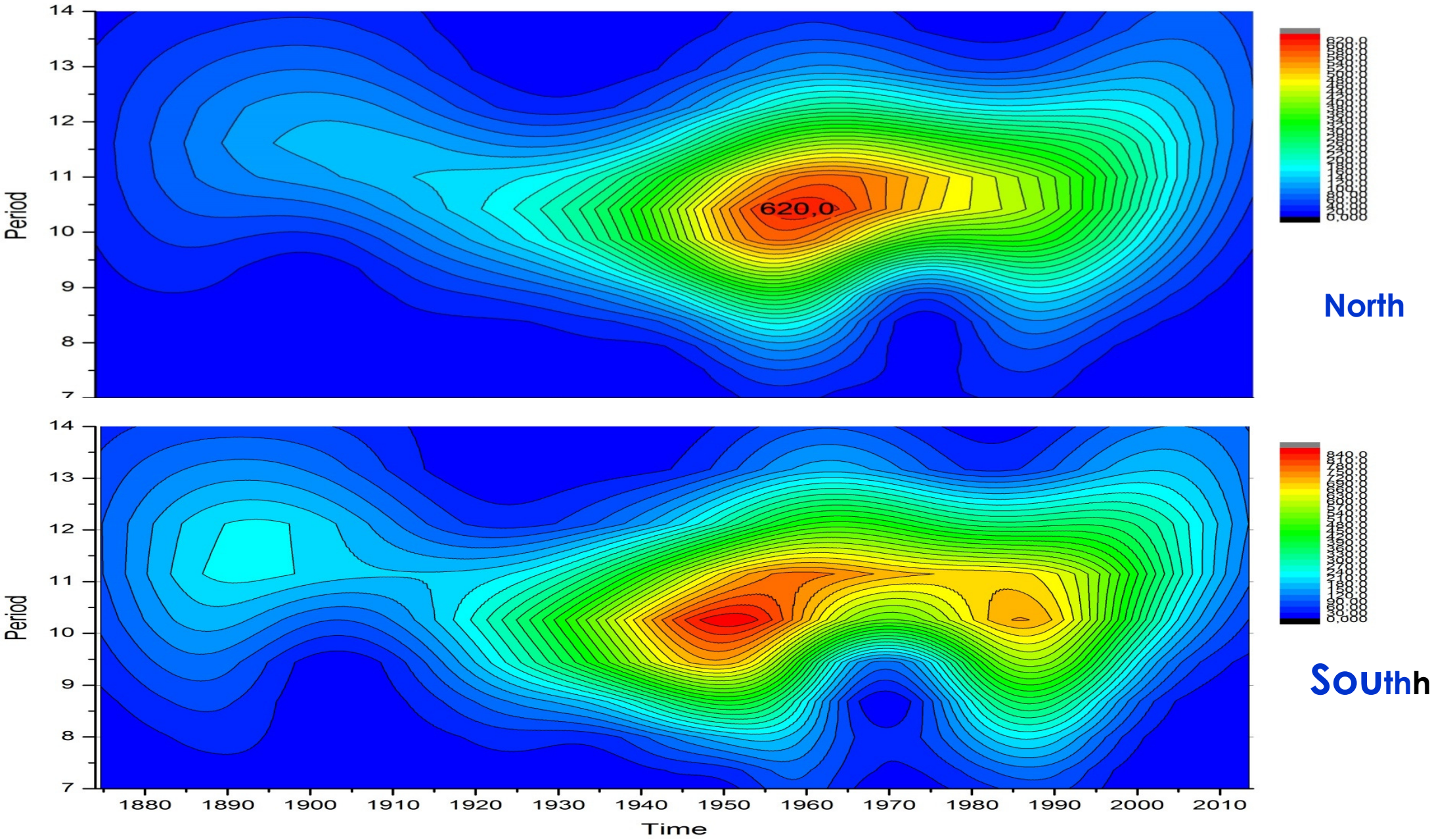

SUN spot area, Sou. O-C!
Continuous Wavelet Time-Frequency Spectrum
Integrated Power, Freq=0.25,44
44
28.597
18.587
12.08
7.8514
5.103
3.3166
2.1556
1.401
0.91058
0.59182
0.38465
0.25
Frequency
1996
1999.9
2003.8
2007.6
2011.5
Time


SUN SP North. FFT smooth. Amplitude level -30 dB.
Continuous Wavelet Time-Frequency Spectrum
2.5
852
359
657
614
792
452
308
656
829
418
637
022
0.4
0.59341
0.88033
1.306
1.9375
2.8743
4.264
6.3257
9.3844
13.922
20.653
30.64
45.455
Period
1873
1901.4
1929.8
1958.2
1986.6
2015
Time


SUN SP North. 11 years period wavelet reconstruction.
1.6
1.28
0.96
0.64
0.32
0
-0.32
-0.64
-0.96
-1.28
-1.6
SP-N
1873
1901.4
1929.8
1958.2
1986.6
Time

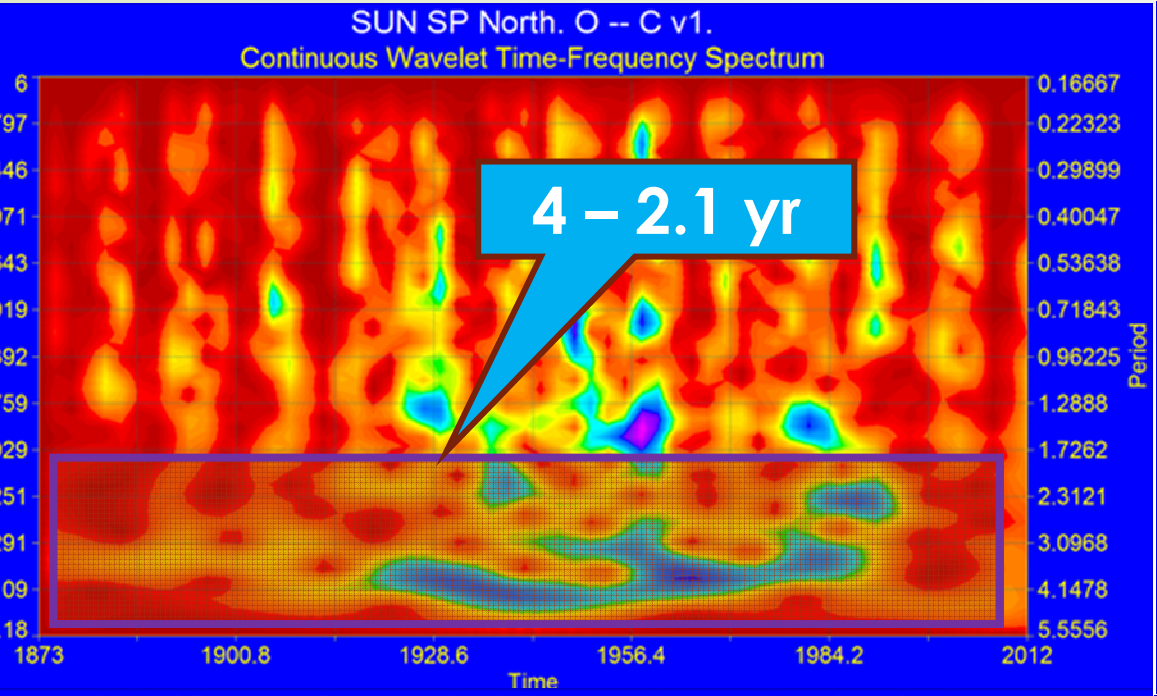

SUN --- Sp South. B-Spline Local Regression.
Gauss Deriv. Continuous Wavelet Time-Frequency Spectrum
4.5
127
758
989
683
293
833
772
483
523
955
598
016
0.22222
0.35553
0.56881
0.91004
1.456
2.3294
3.7268
5.9625
9.5393
15.262
24.417
39.065
62.5
Period
1873
1901.4
1929.8
1958.2
1986.6
2015
Time

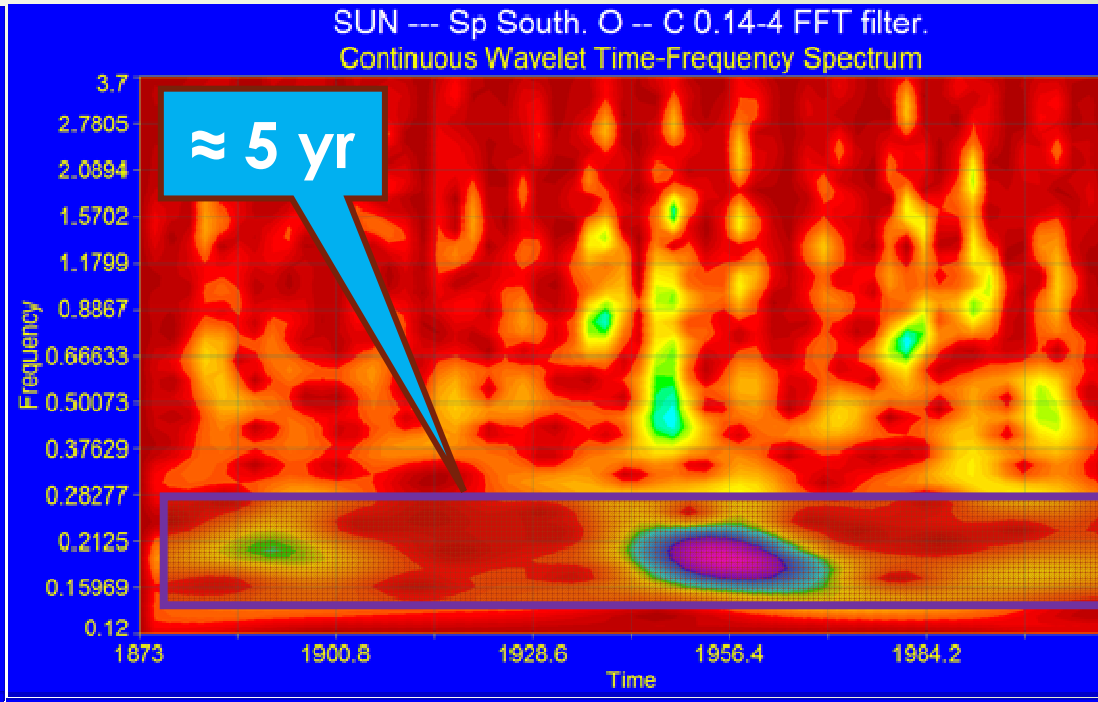

SUN --- Sp South. 11-years period.
Wavelet reconstruction
1.8
1.44
1.08
0.72
0.36
0
-0.36
-0.72
-1.08
-1.44
-1.8
SP-S
1873
1901.4
1929.8
1958.2
1986.6
Time

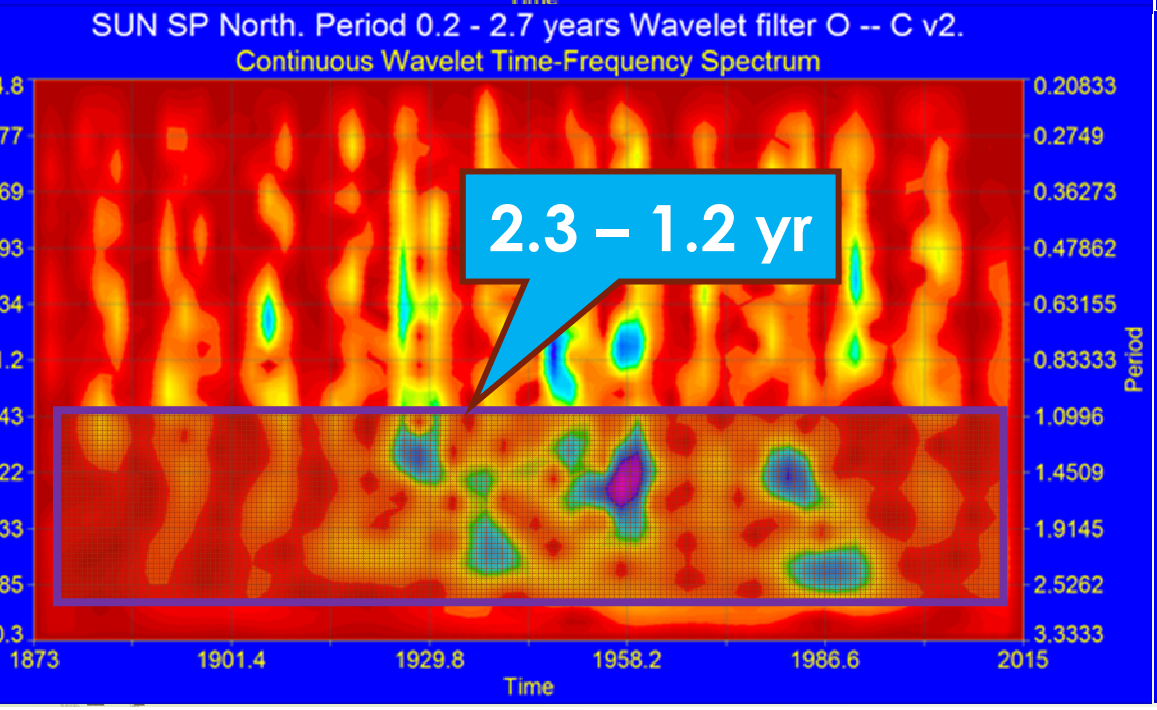

Period
14
13
12
11
10
9
8
7
620,0
620,0
6,000
North
Period
14
13
12
11
10
9
8
7
840,0
0,000
SOUthh
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Time

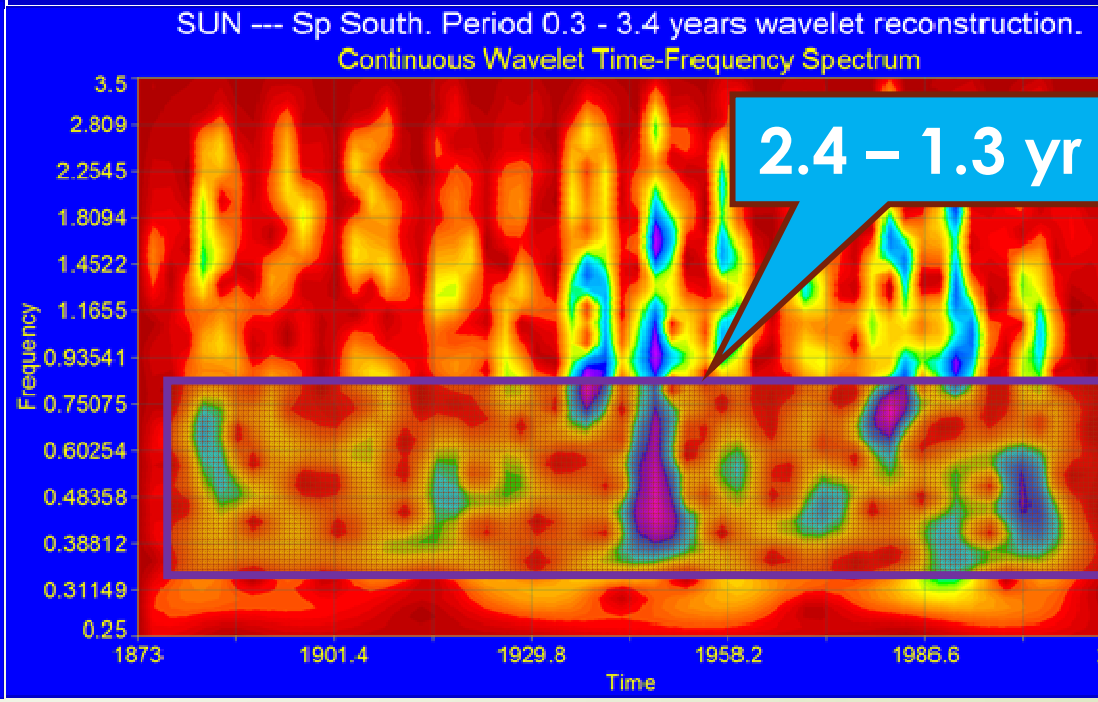
N and S cycles activity

N cycle	Sp-T min	Long T min	Sp-N min	Long N-min	Sp-S min	Long S-min
12	1878,54	10,46	1878,17	10,66	1878,84	10,21
13	1889,00	11,50	1888,83	11,75	1889,04	11,50
14	1900,50	12,54	1900,58	11,67	1900,54	12,54
15	1913,04	10,00	1912,25	10,67	1913,09	10,12
16	1923,04	10,17	1922,92	10,41	1923,21	9,96
17	1933,21	10,29	1933,33	10,34	1933,17	10,12
18	1943,50	9,96	1943,67	10,16	1943,29	9,96
19	1953,46	10,29	1953,83	10,00	1953,25	10,25
20	1963,75	11,92	1963,83	11,09	1963,50	12,67
21	1975,67	10,29	1974,92	10,75	1976,17	9,92
22	1985,96	10,00	1985,67	10,25	1986,08	10,04
23	1995,96	11,75	1995,92	10,91	1996,13	11,79
24	2007,71		2006,83		2007,92	

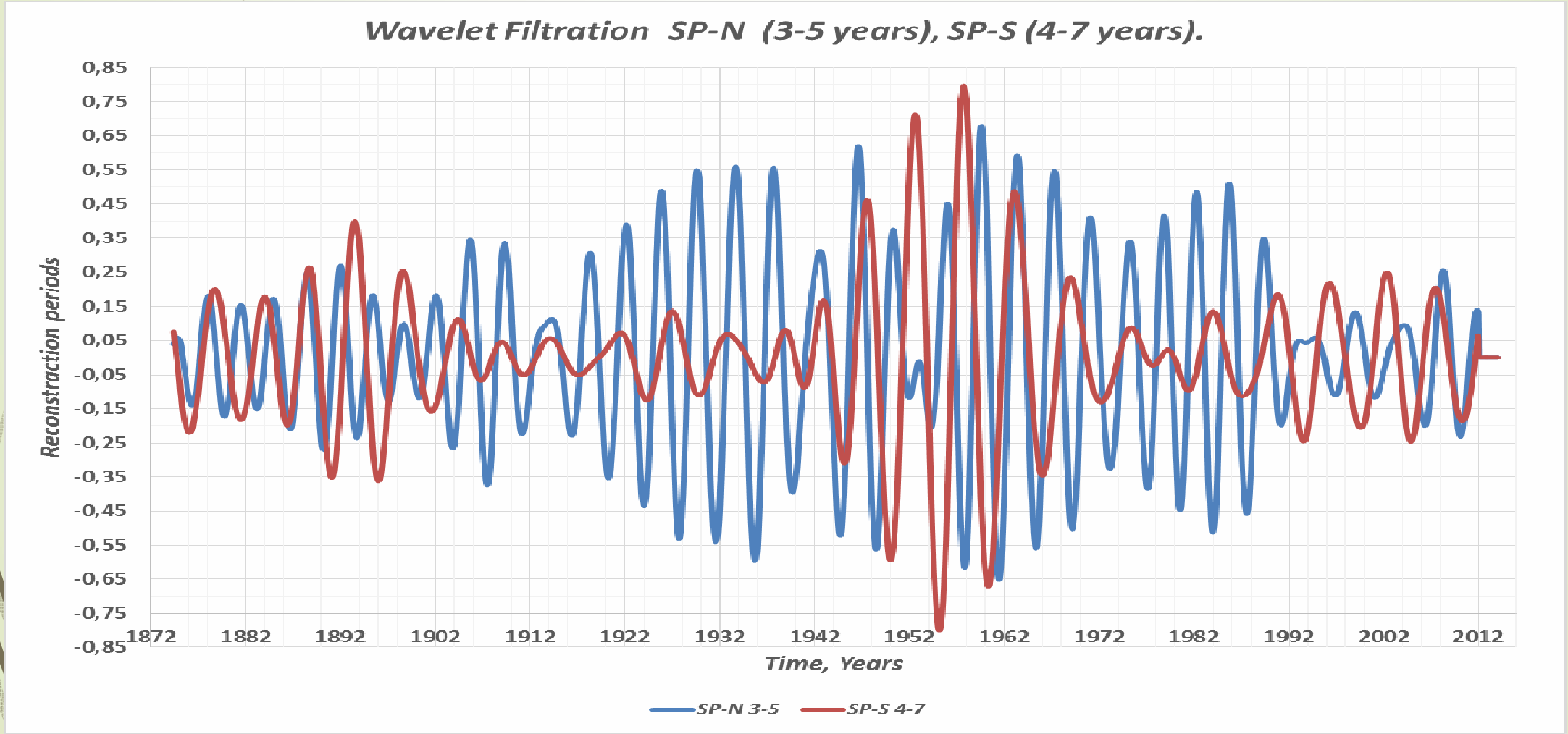

SUN SP North. O -- C v1.
Continuous Wavelet Time-Frequency Spectrum
4 – 2.1 yr
0.16667
0.22323
0.29899
0.40047
0.53638
0.71843
0.96225
1.2888
1.7262
2.3121
3.0968
4.1478
5.5556
Period
1873
1900.8
1928.6
1956.4
1984.2
2012
Time


SUN --- Sp South. O -- C 0.14-4 FFT filter.
Continuous Wavelet Time-Frequency Spectrum
≈ 5 yr
3.7
2.7805
2.0894
1.5702
1.1799
0.8867
0.66633
0.50073
0.37629
0.28277
0.2125
0.15969
0.12
Frequency
1873
1900.8
1928.6
1956.4
1984.2
Time


SUN SP North. Period 0.2 - 2.7 years Wavelet filter O -- C v2.
Continuous Wavelet Time-Frequency Spectrum
2.3 – 1.2 yr
0.20833
0.2749
0.36273
0.47862
0.63155
0.83333
1.0996
1.4509
1.9145
2.5262
3.3333
Period
1873
1901.4
1929.8
1958.2
1986.6
2015
Time


SUN --- Sp South. Period 0.3 - 3.4 years wavelet reconstruction.
Continuous Wavelet Time-Frequency Spectrum
2.4 – 1.3 yr
3.5
2.809
2.2545
1.8094
1.4522
1.1655
0.93541
0.75075
0.60254
0.48358
0.38812
0.31149
0.25
Frequency
1873
1901.4
1929.8
1958.2
1986.6
Time

N and S cycles (period 3-7 years)



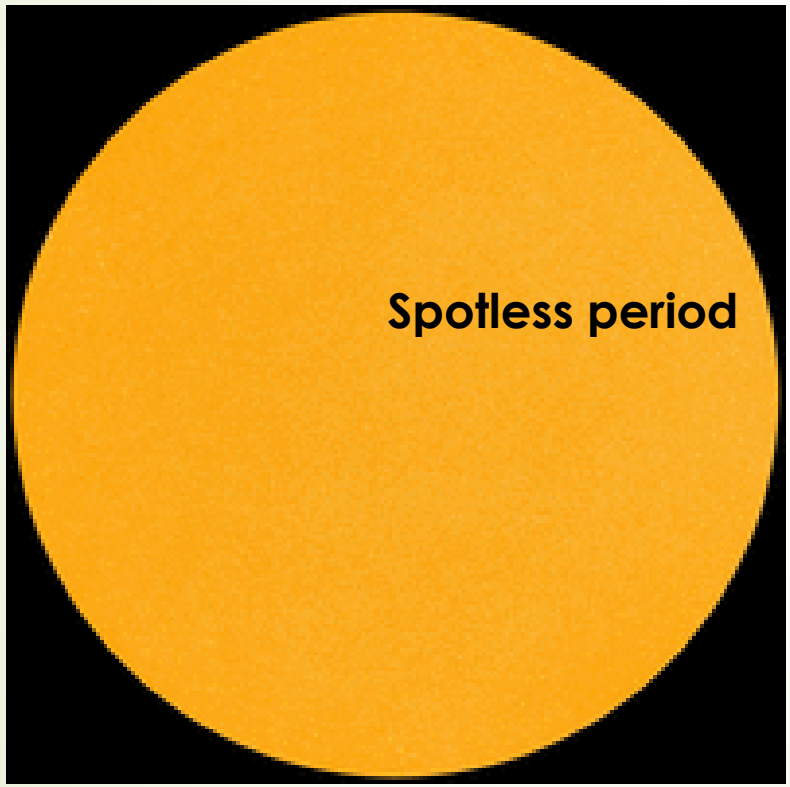
Major intervals periods manifestations of solar activity

- Long-period (about 11 years).
- During periods of moderate duration (2-7 years)
- Fluctuations of (O-C) (less than 2 years)

Statistical and physical activity indices

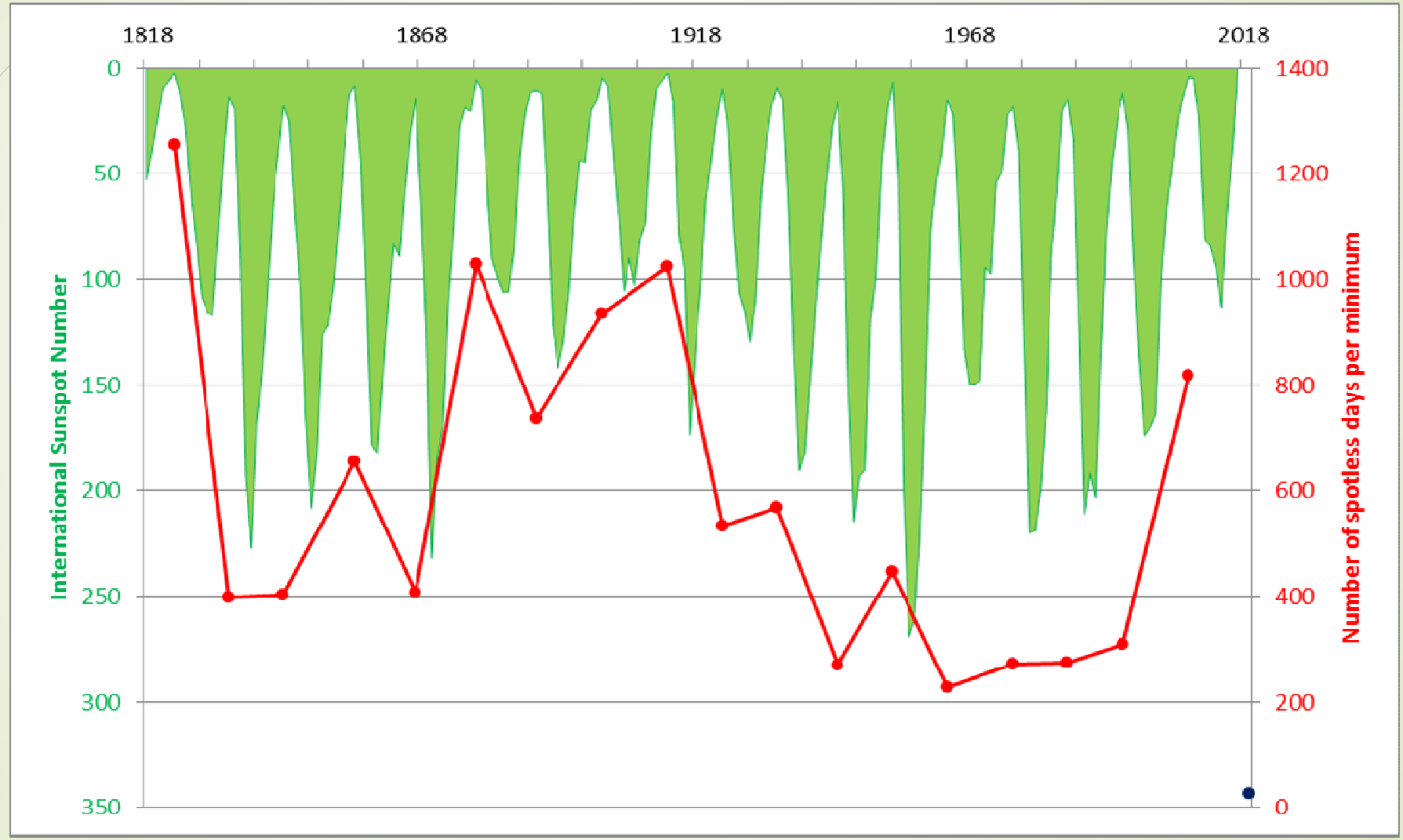
- $W = WN + WS$
- $Sp = SpN + SpS$
- $Fl = Fi + Fi\ S$
- spotless days = sdN +sdS

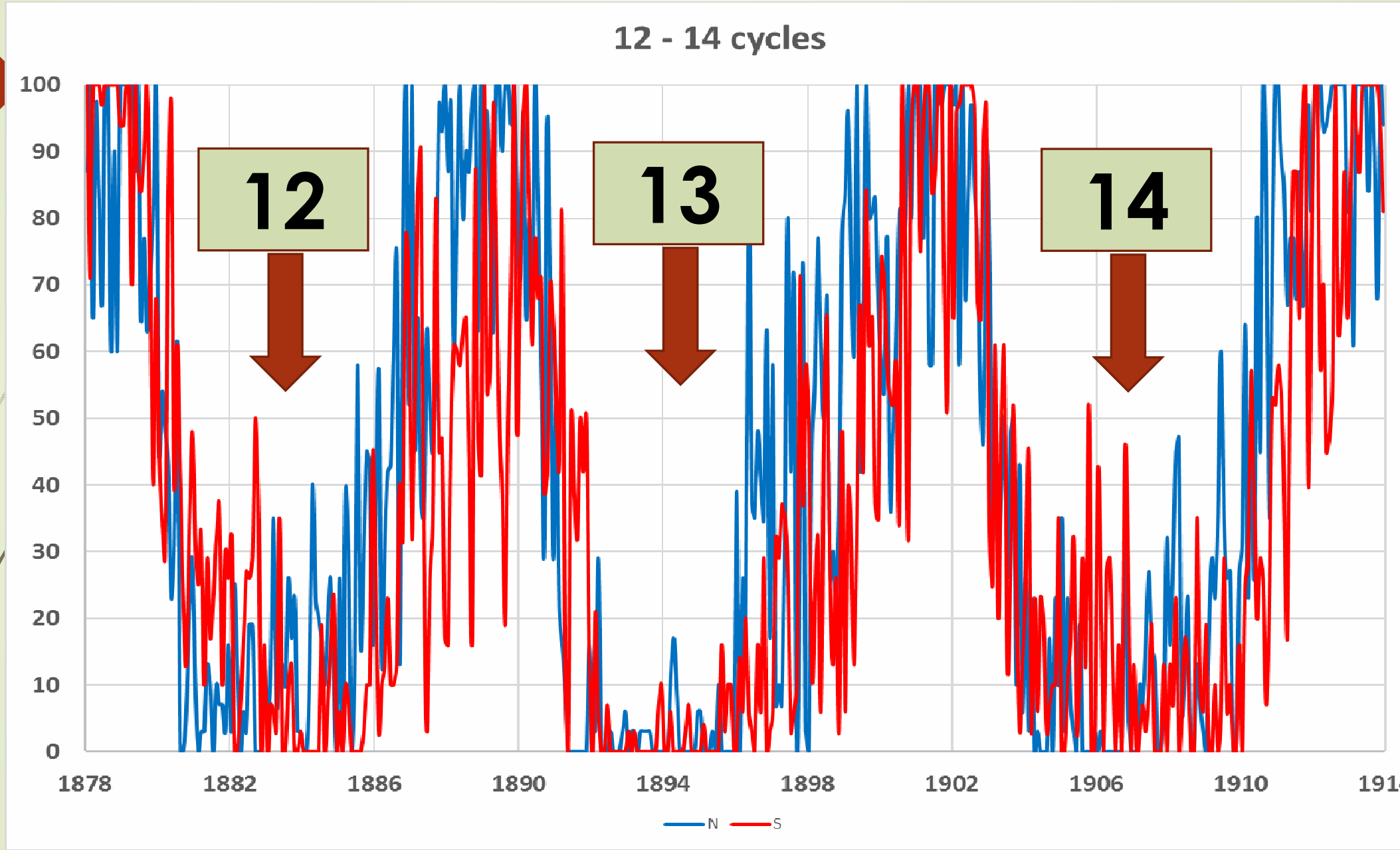
Anti-cycles of solar activity

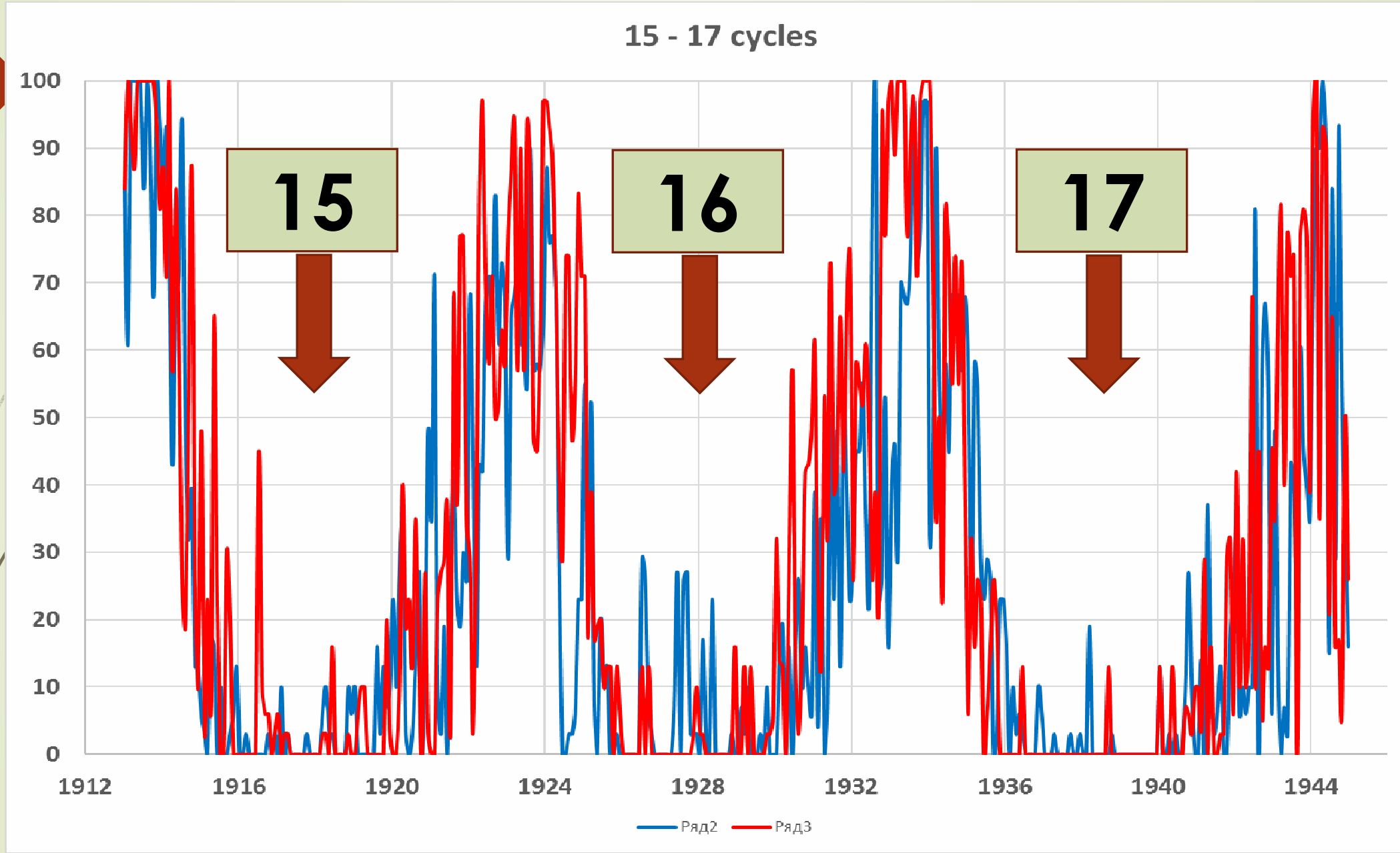


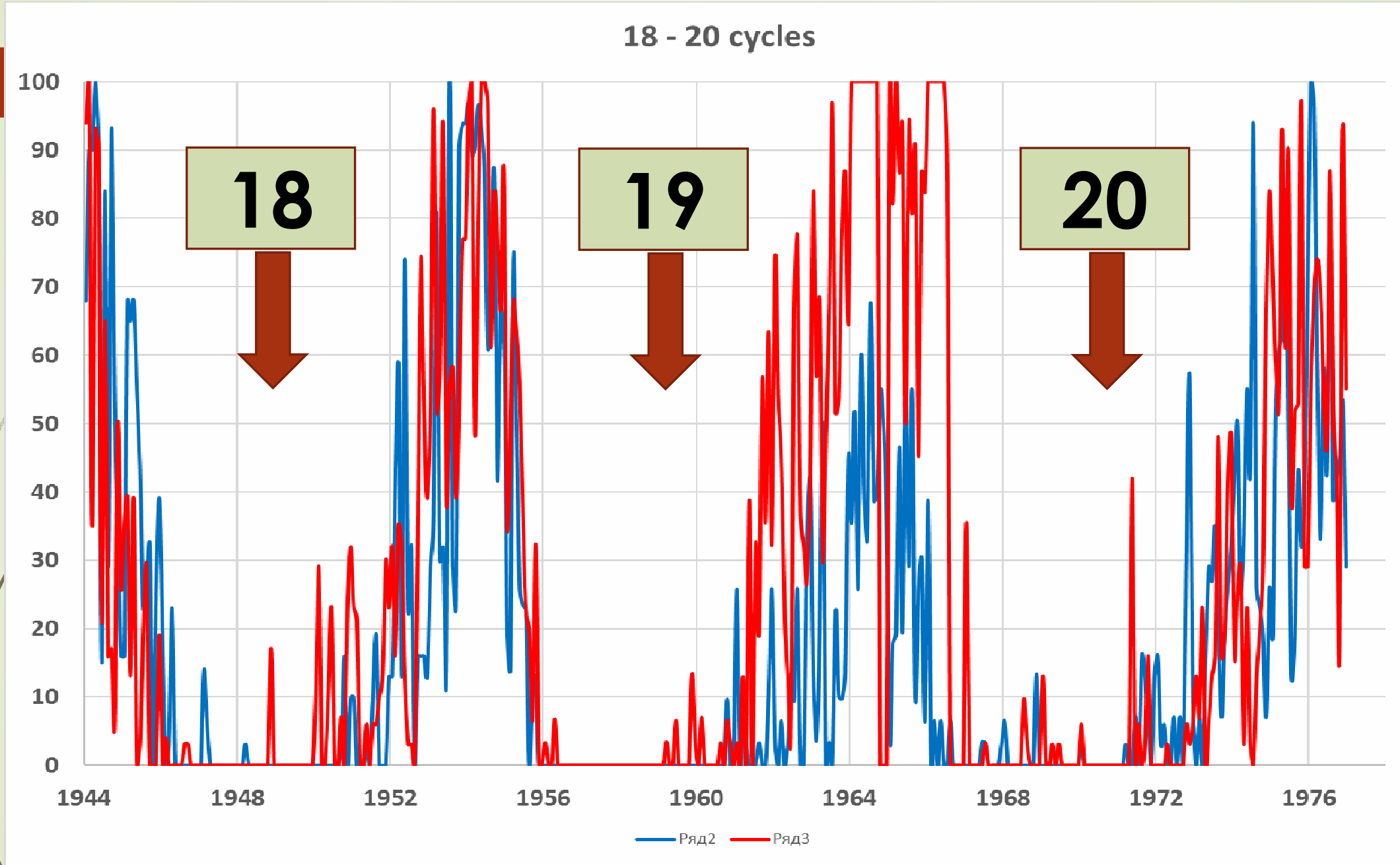
- The spotless days "contains important information about the periods ending generate magnetic fields, groups of spots.
- They describe the properties of anti-cycles activity, which can be identified on the basis of daily data.
- We evaluated anti-index cycle of solar activity in the form of monthly values of the number «spotless days « as a percentage of the total number of days in month.

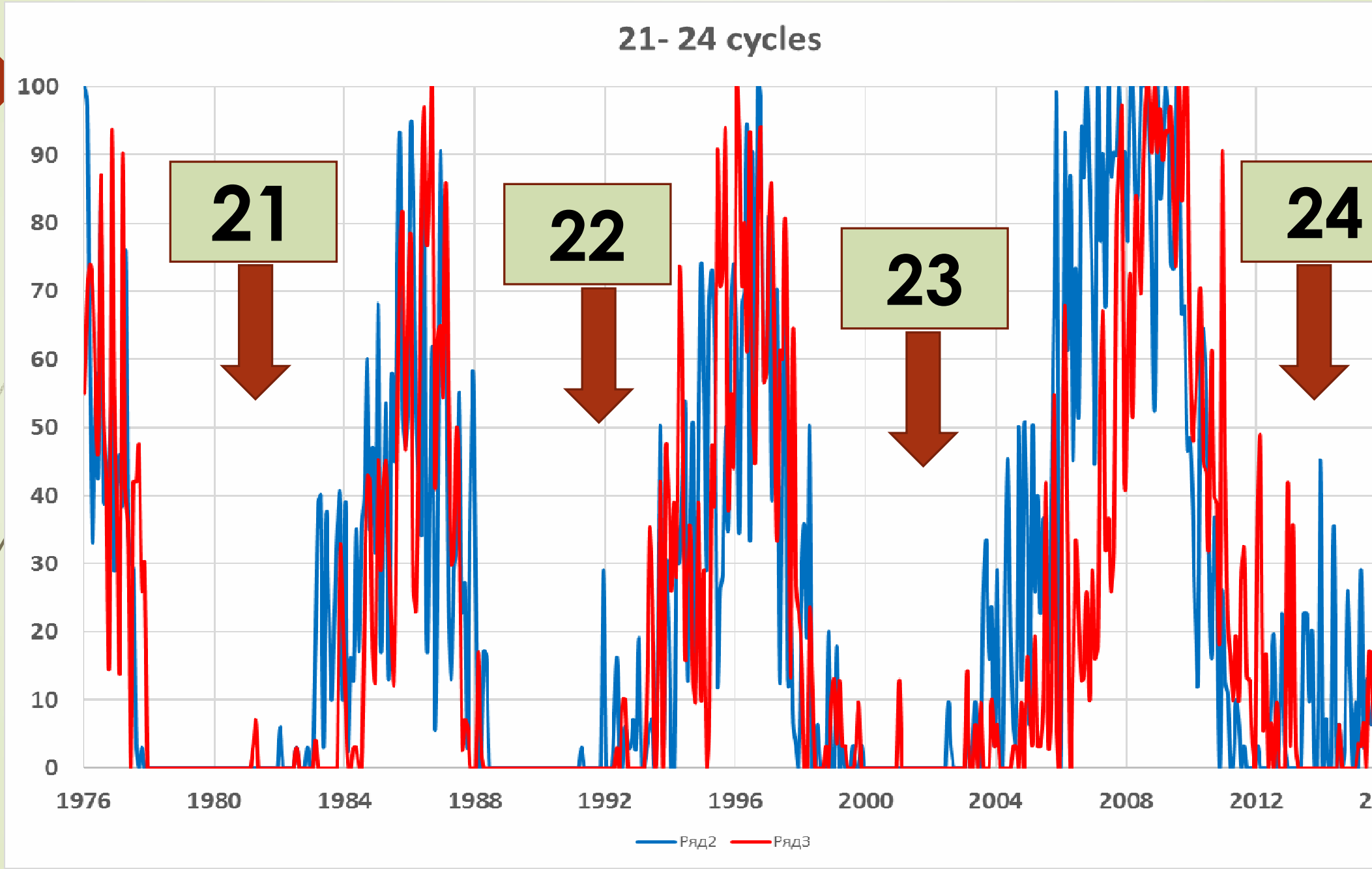
Spotless data on SIDS



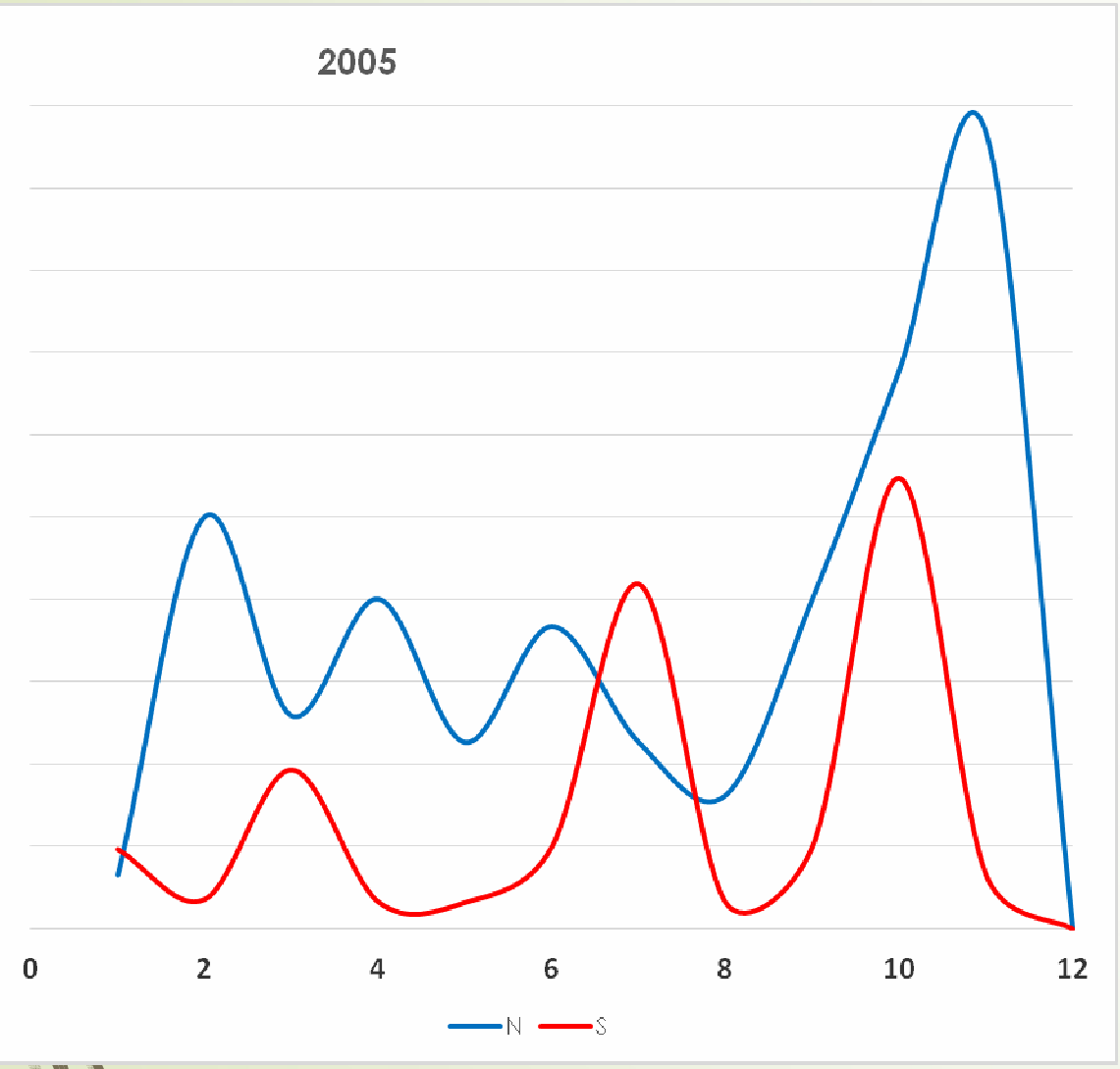

12 - 14 cycles
12
13
14
100
90
80
70
60
50
40
30
20
10
0
1878
1882
1886
1890
1894
1898
1902
1906
1910
N
S

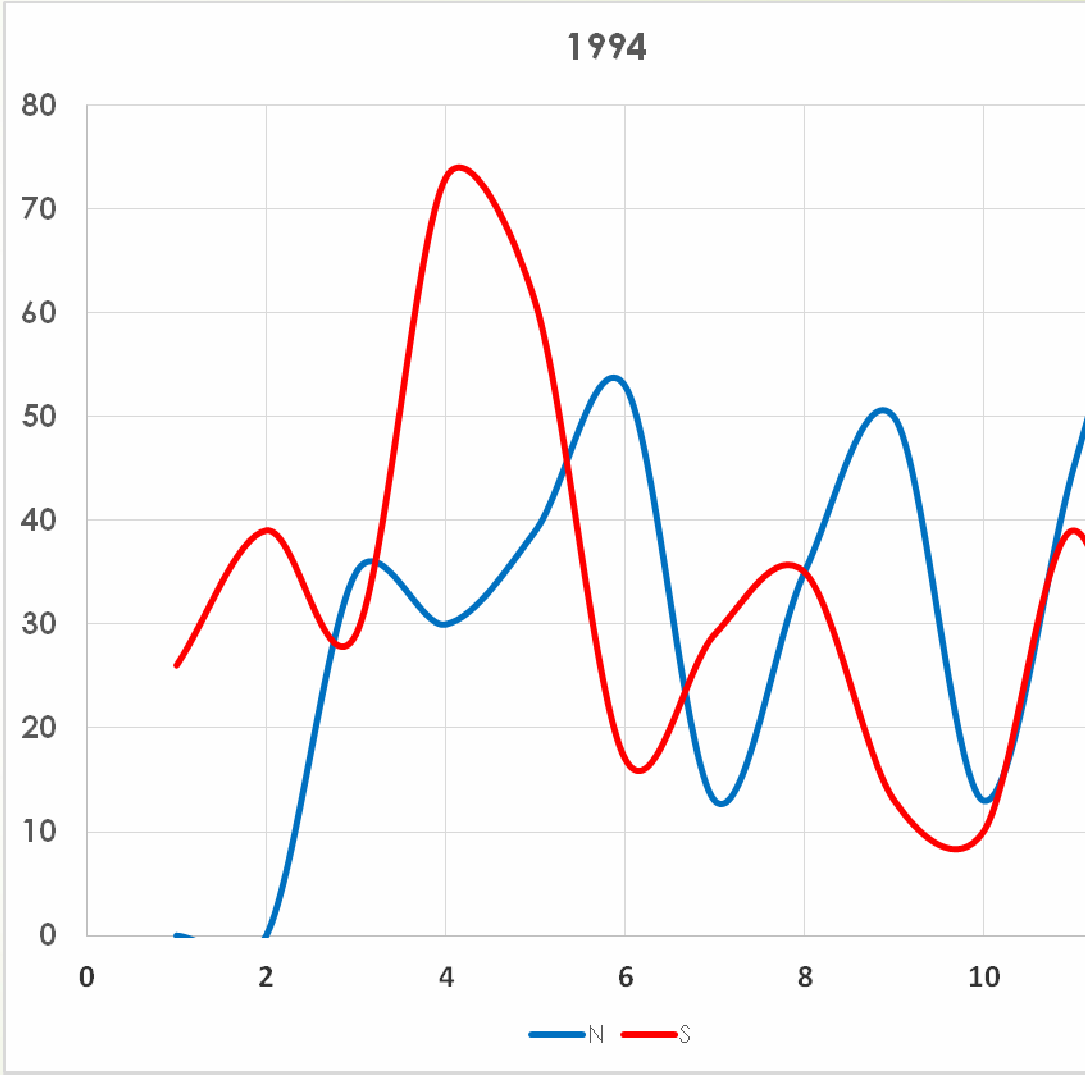

15 - 17 cycles
15
16
17
100
90
80
70
60
50
40
30
20
10
0
1912
1916
1920
1924
1928
1932
1936
1940
1944
Ряд2
Ряд3


18 - 20 cycles
18
19
20
100
90
80
70
60
50
40
30
20
10
0
1944
1948
1952
1956
1960
1964
1968
1972
1976
Ряд2
Ряд3

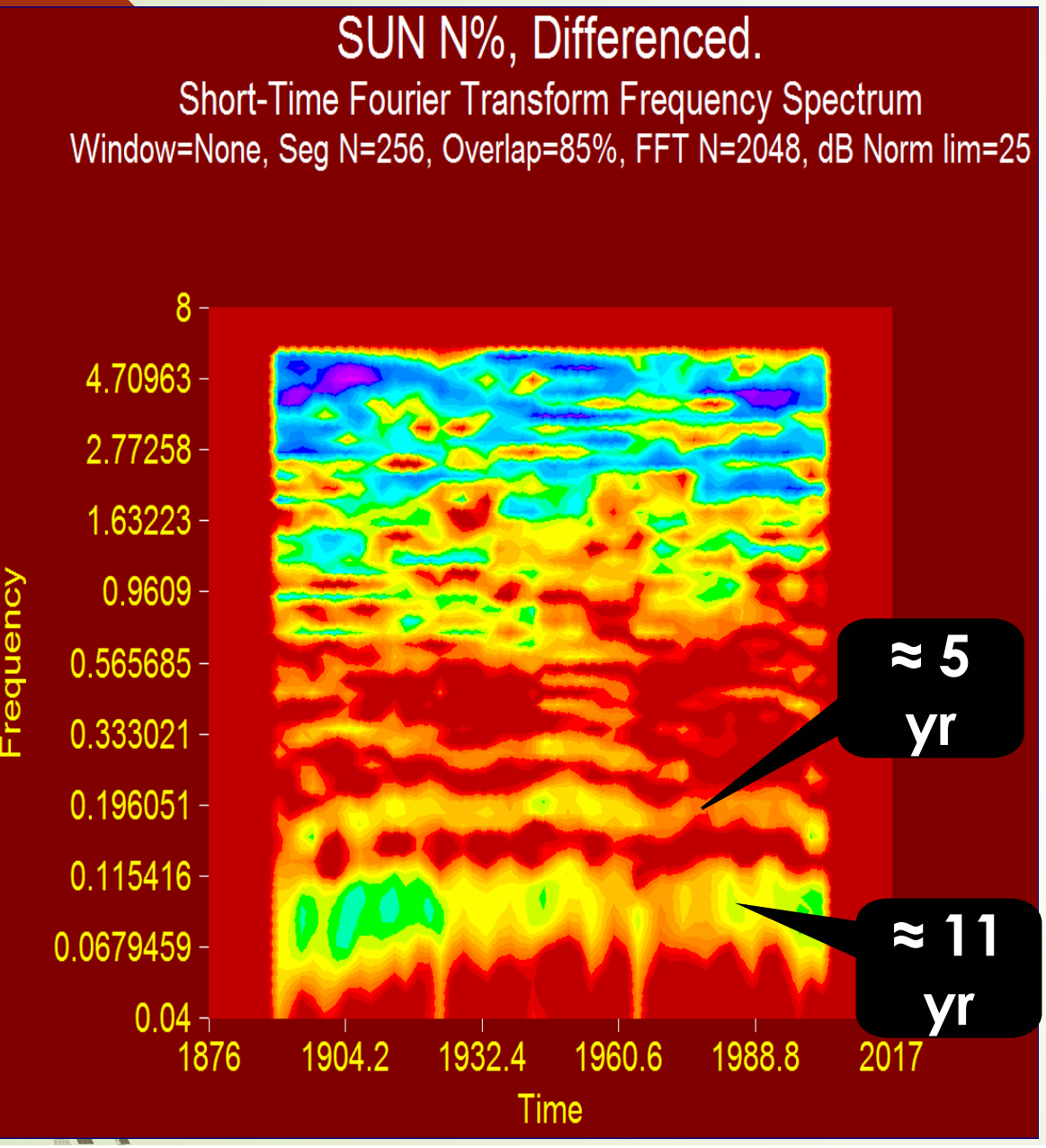

21- 24 cycles
21
22
23
24
100
90
80
70
60
50
40
30
20
10
0
1976
1980
1984
1988
1992
1996
2000
2004
2008
2012
Ряд2
Ряд3

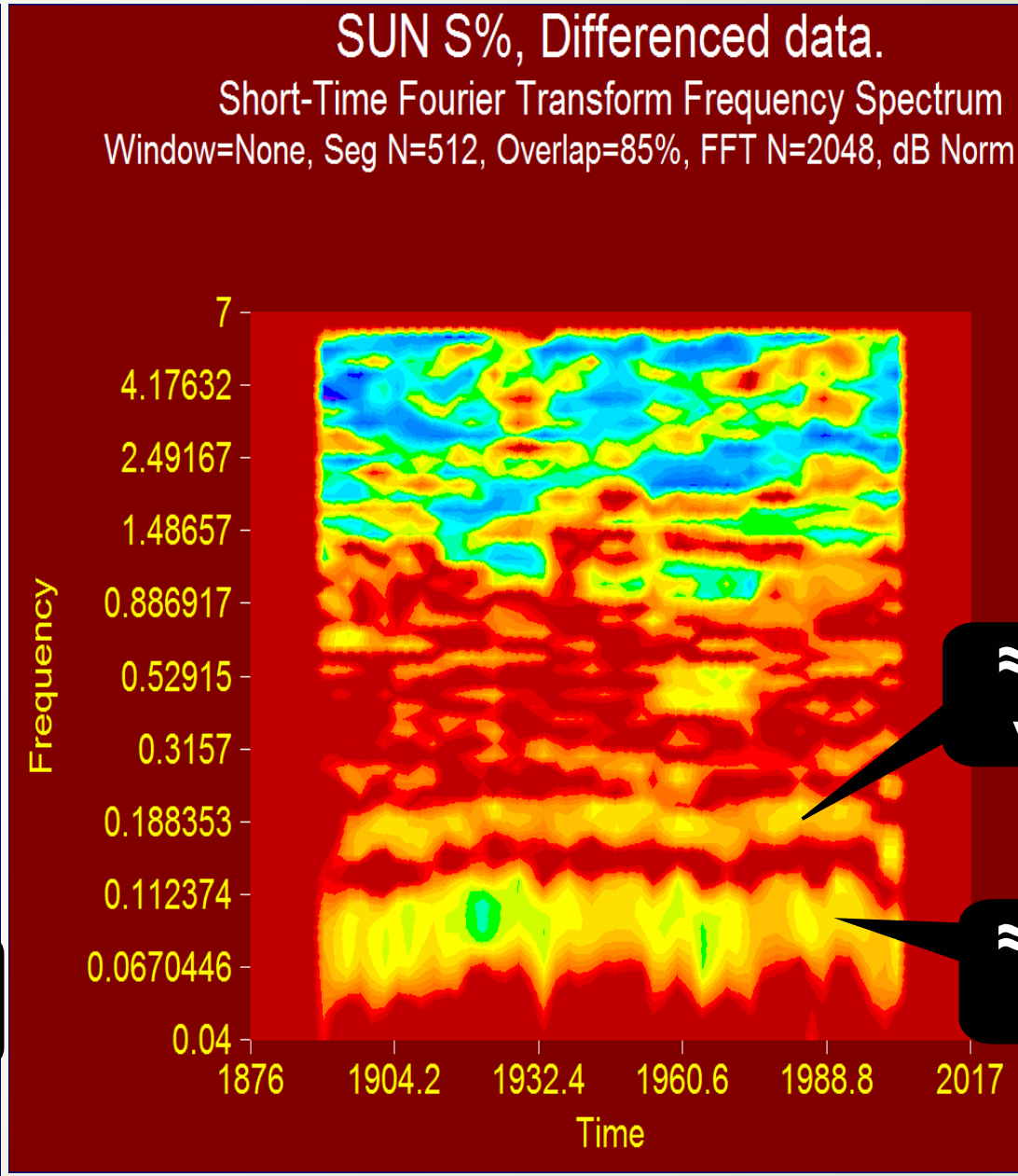
Variations of anti- cycles N and S activity hemispheres within one year.



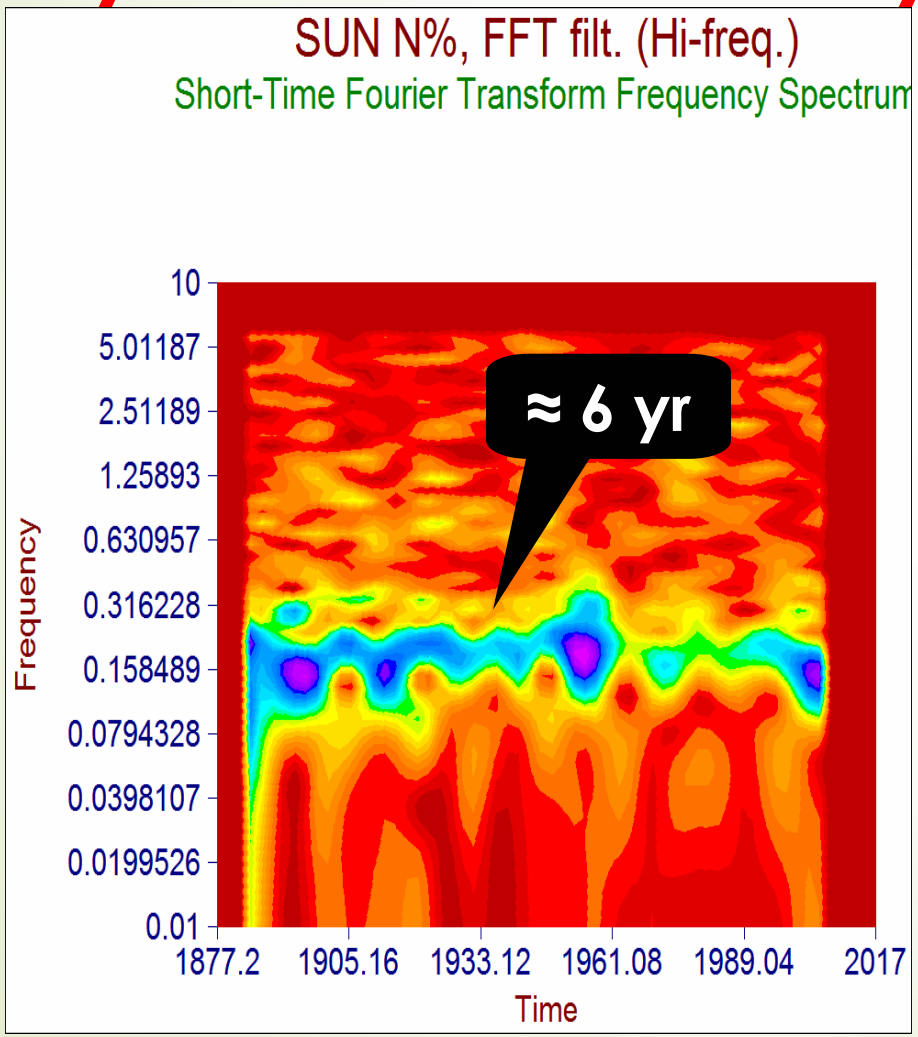


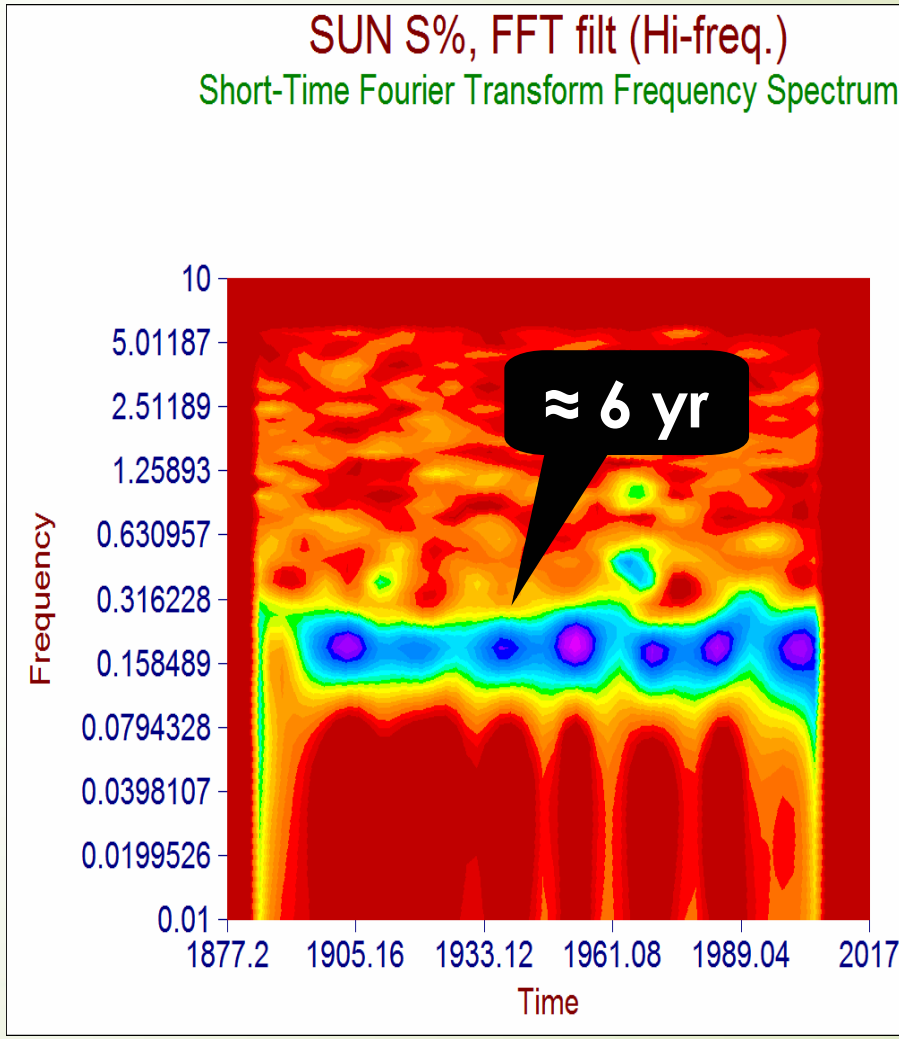
N and S anti-cycles solar activity





Dynamic 6 year period in N and S anti - cycles solar activity

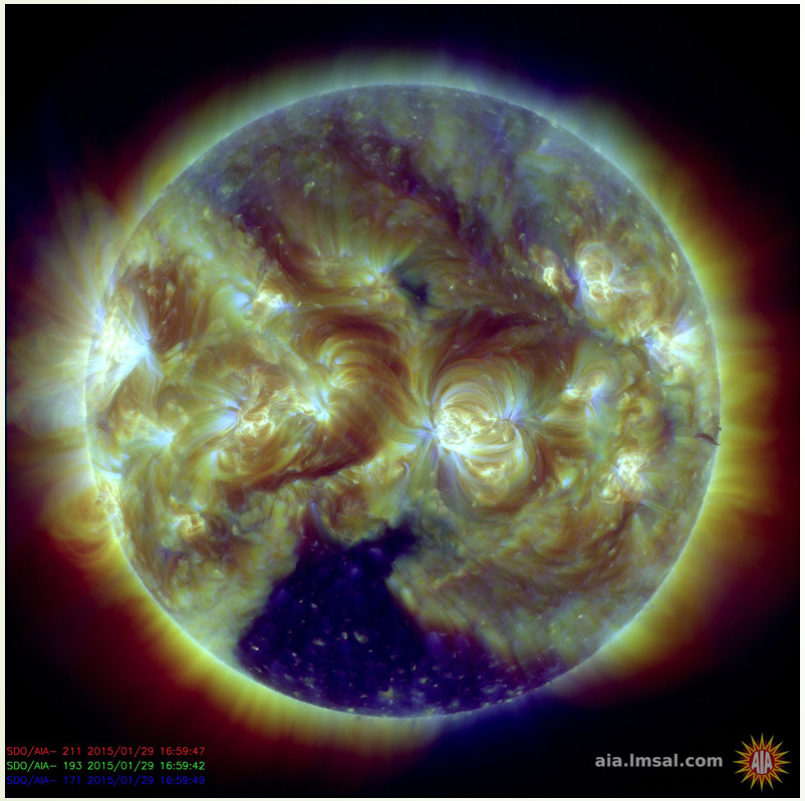


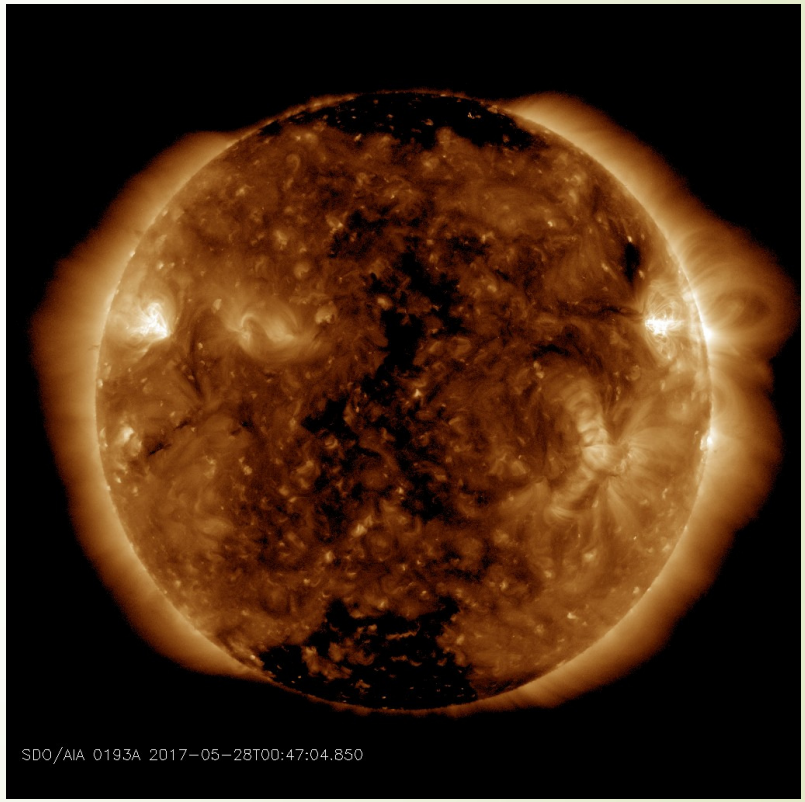


Coronal Holes cycles

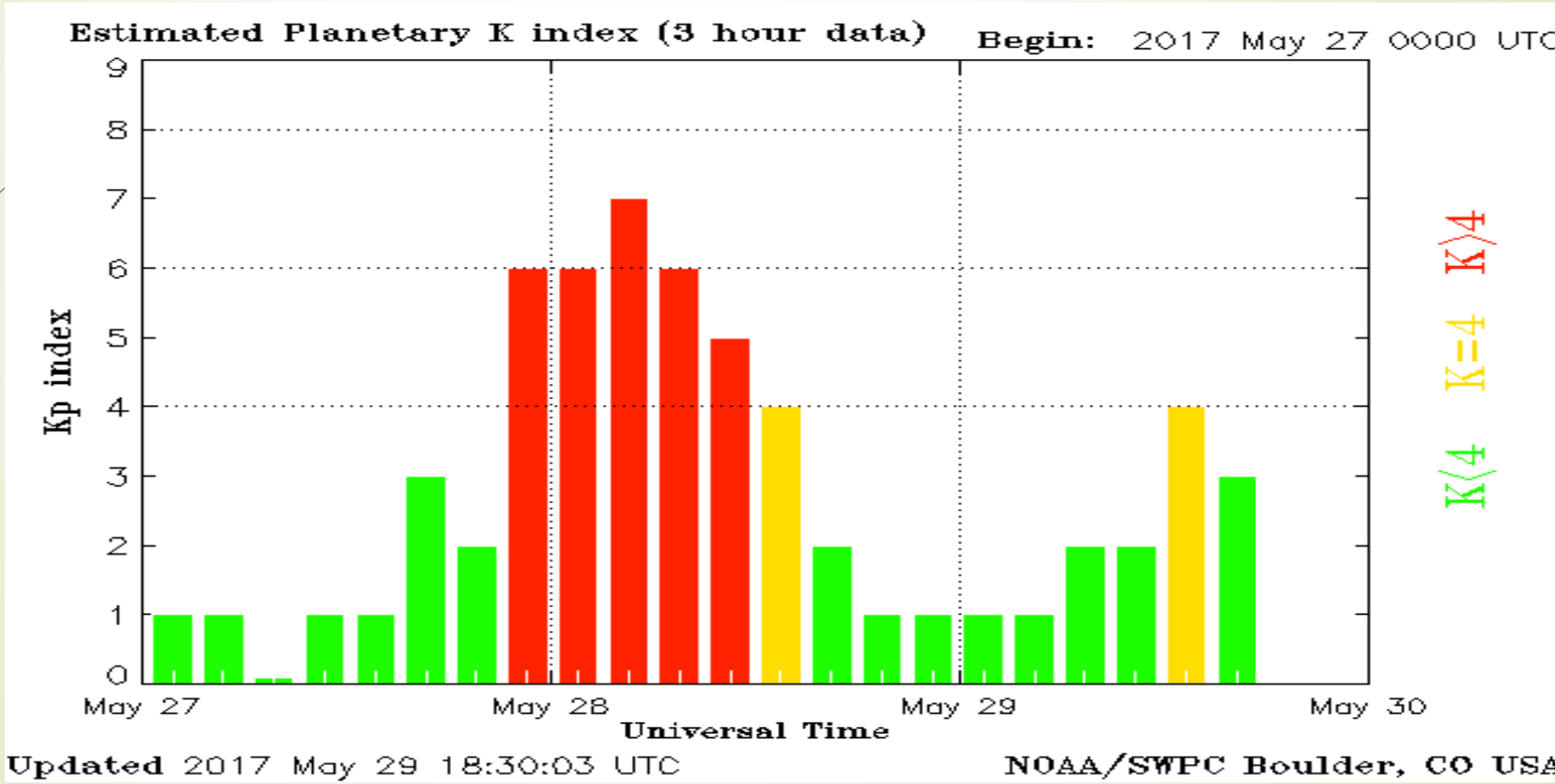
- Coronal holes are long-lived on the Sun.
- Their life times can reach 27 rotations of the Sun.
- Coronal hole is dynamic structure, they can change their shape, texture and brightness during one rotation of the Sun.(V.N. Obridko «Relationship between the Parameters of Coronal Holes» Solar Phys (2011) 270: 297–310)
- Their evolution differs from the evolution of groups of sunspots.

Coronal holes cycles

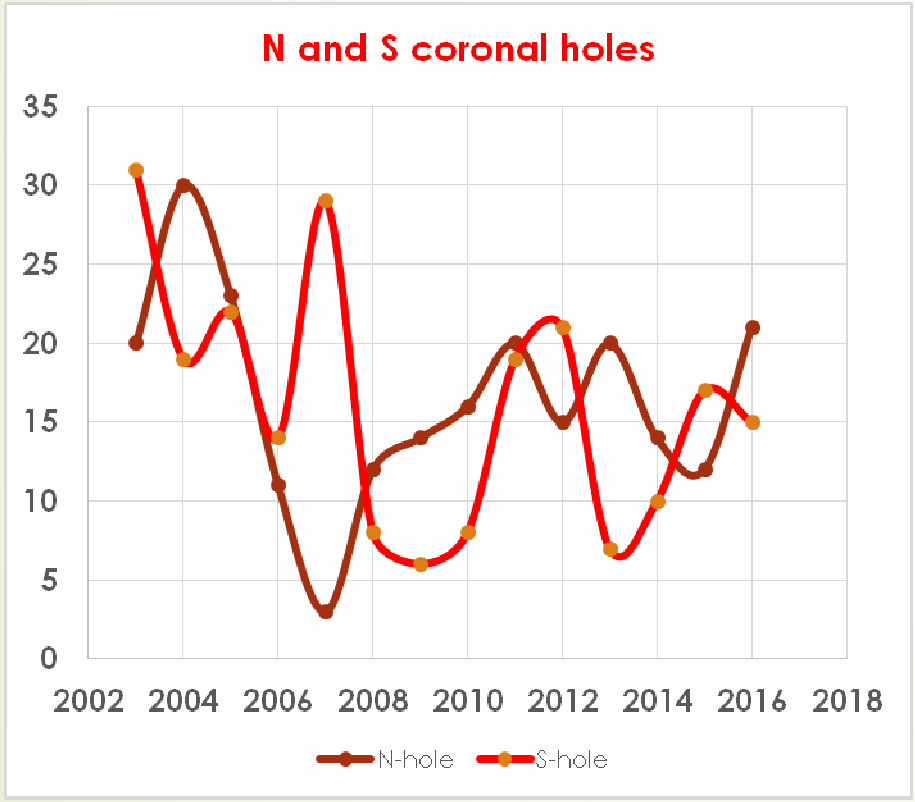


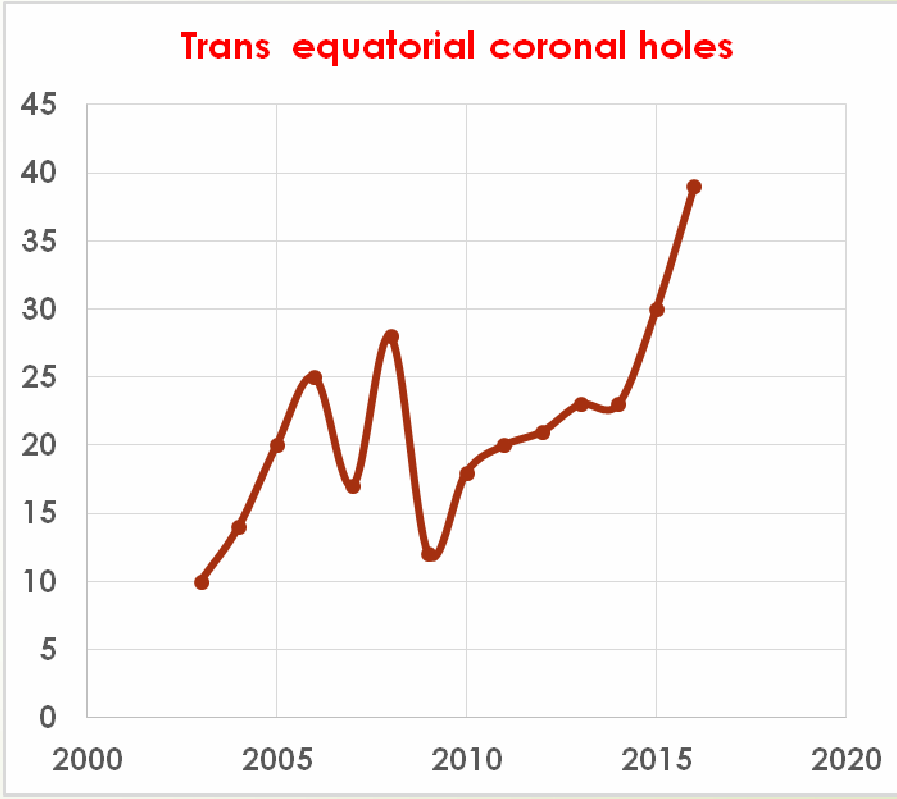


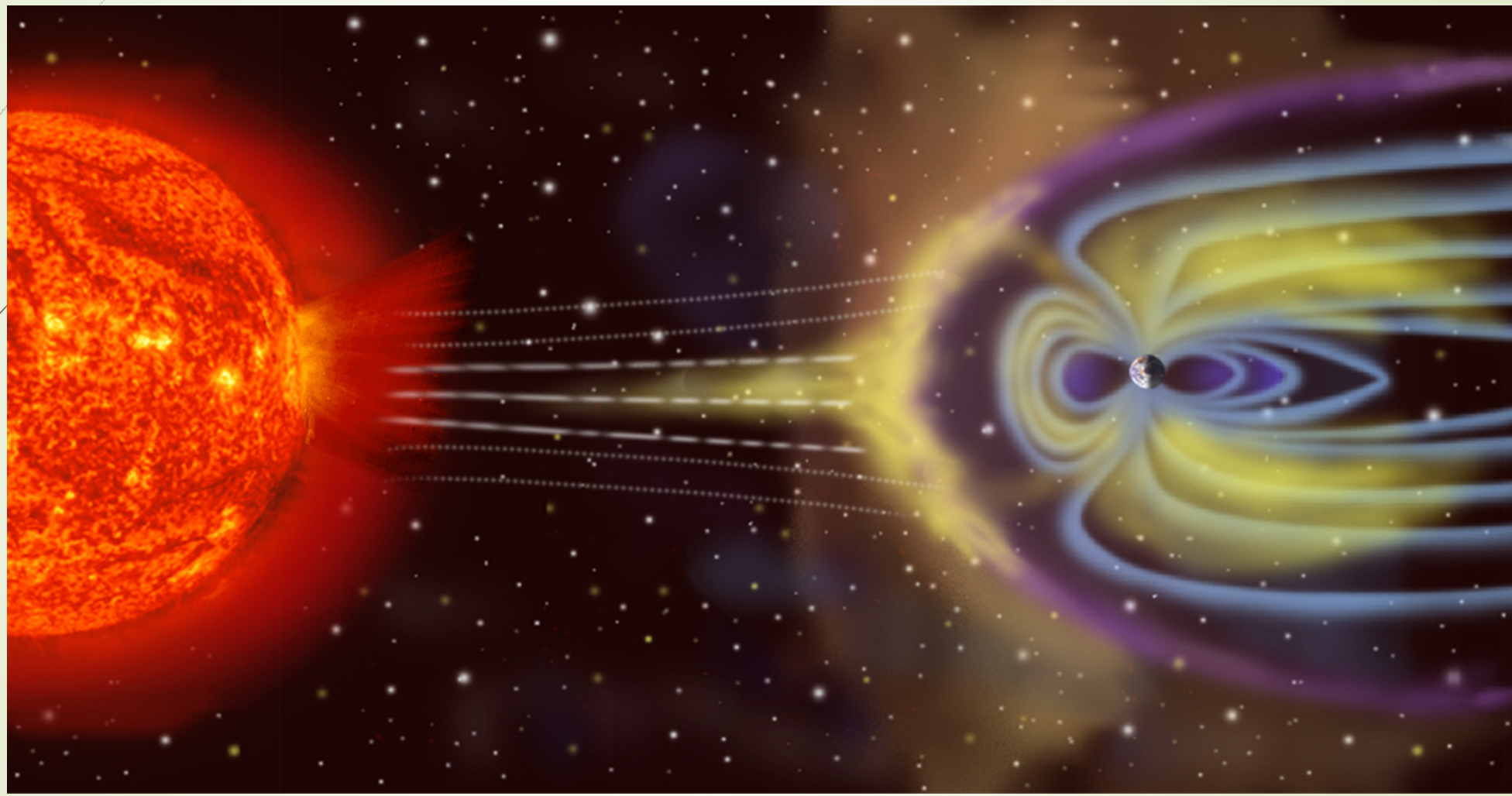
Coronal holes is main sources magnetic storms in nearest future



Cycles of North and South coronal holes (2002-2016 years)



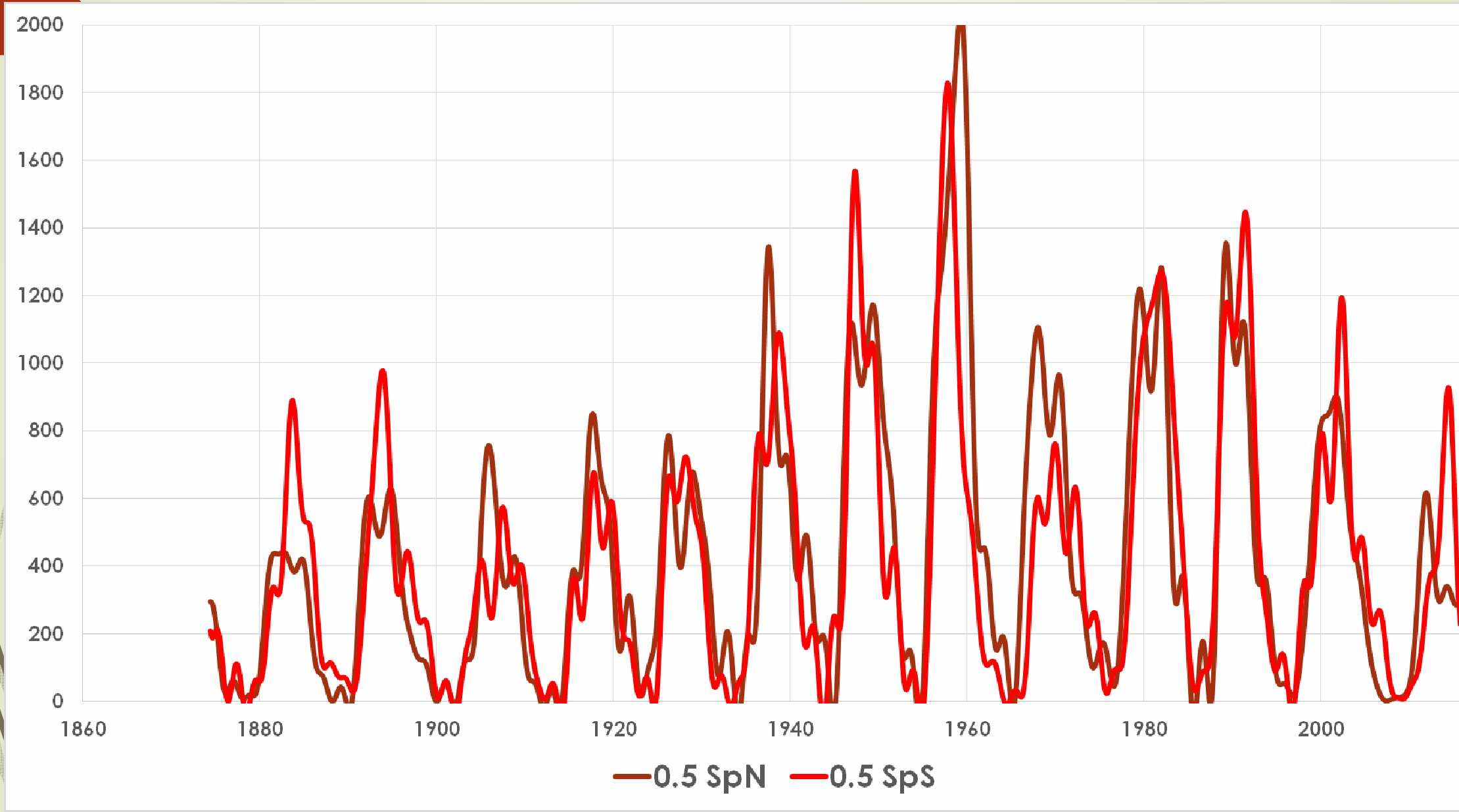




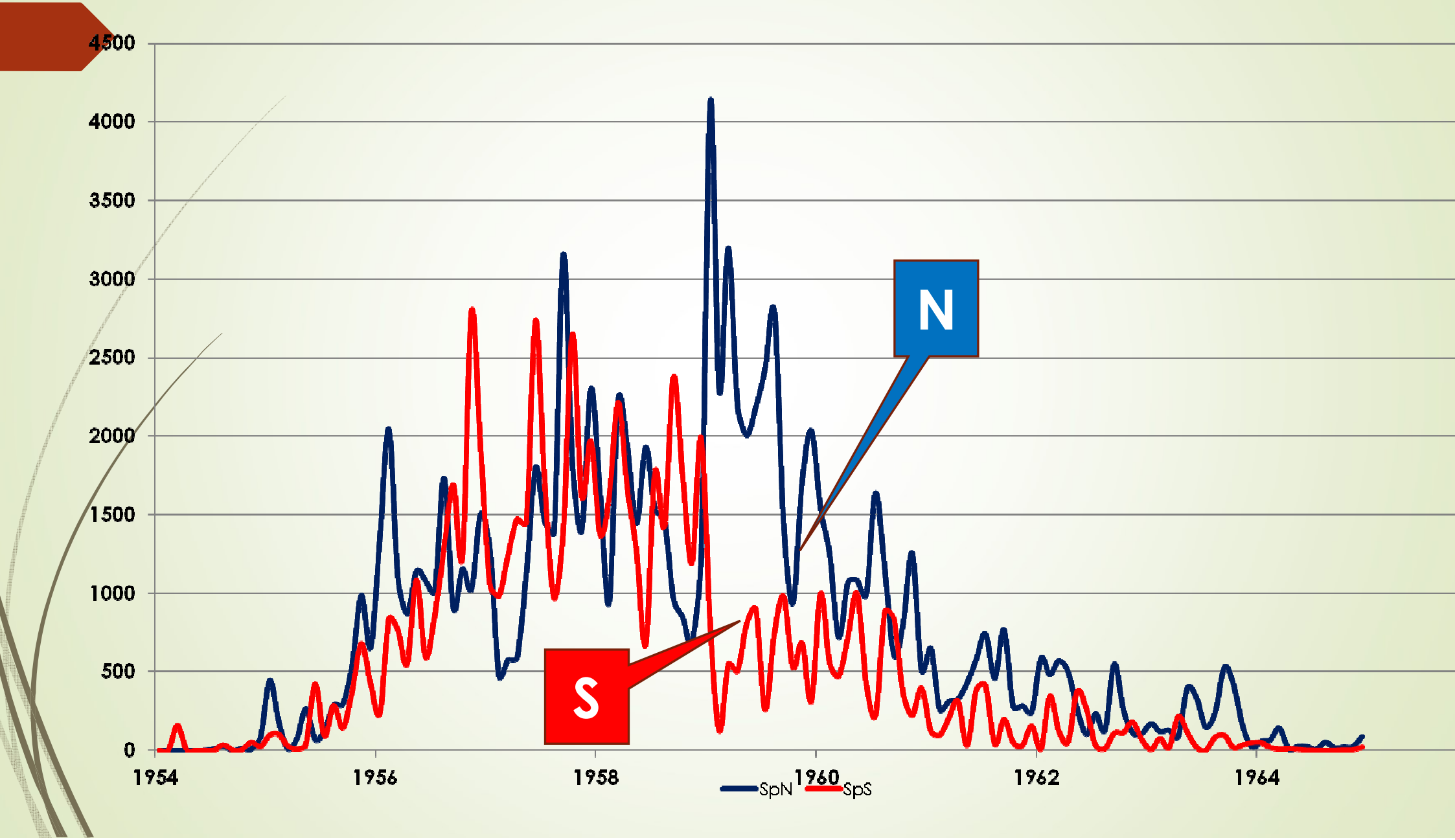
Predictions of cycles solar activity – base data

- The existence of cycles and anti-activity cycles of Northern and southern hemispheres, manifestation of their discrete nature of basic property of the solar cycle.
- The cycle of solar activity is a periodic process constantly implemented the Sun discrete way.
- The Sun is always active and this should be taken into account in the projections on the solar-terrestrial relationship. ..

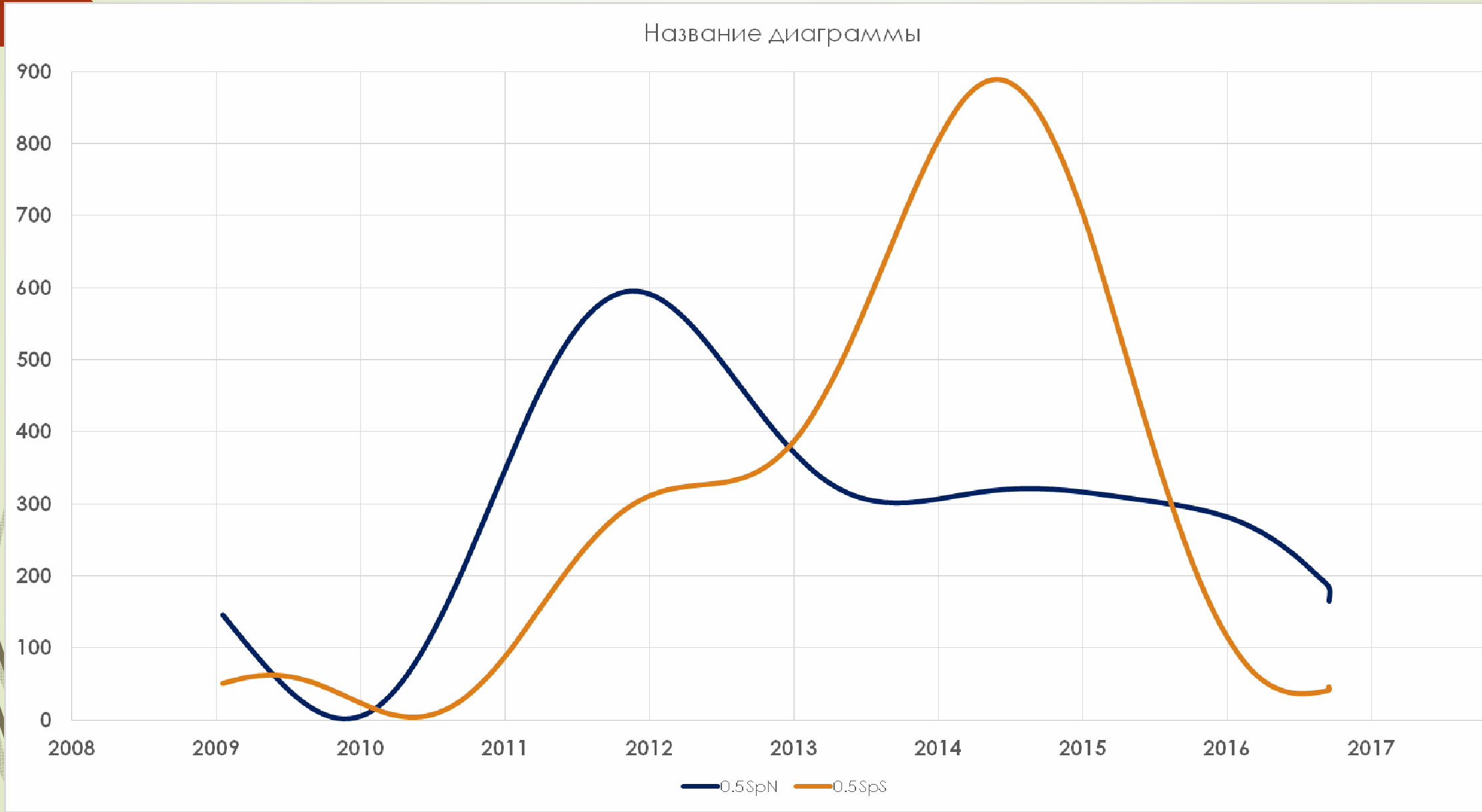
N and S cycles (Sp, more 2 years periods)



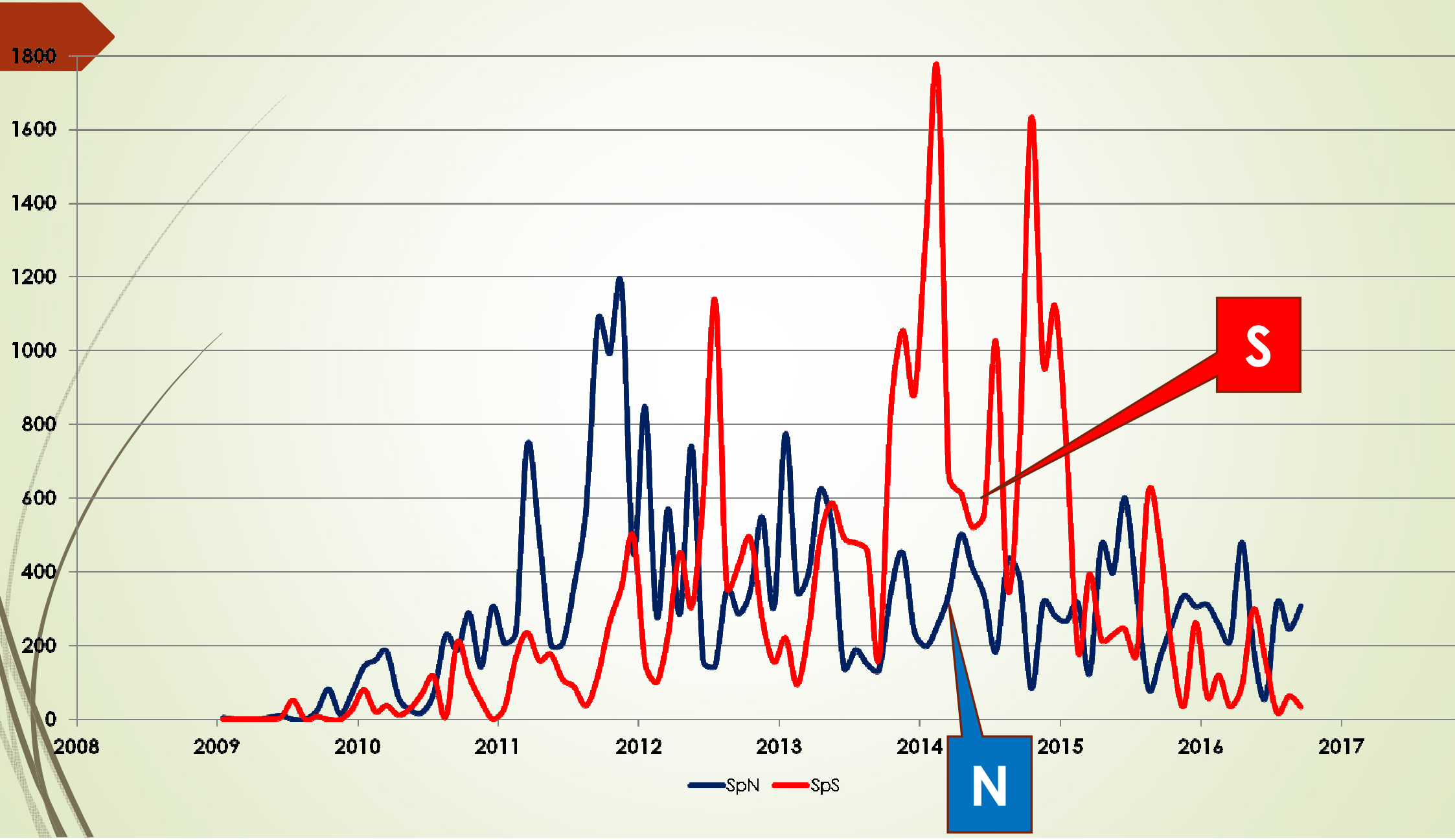
19 cycle (SpN-S)



24 cycle (SpN-S) Filtr (more 2 years)



24 cycle activity (SpN-S)



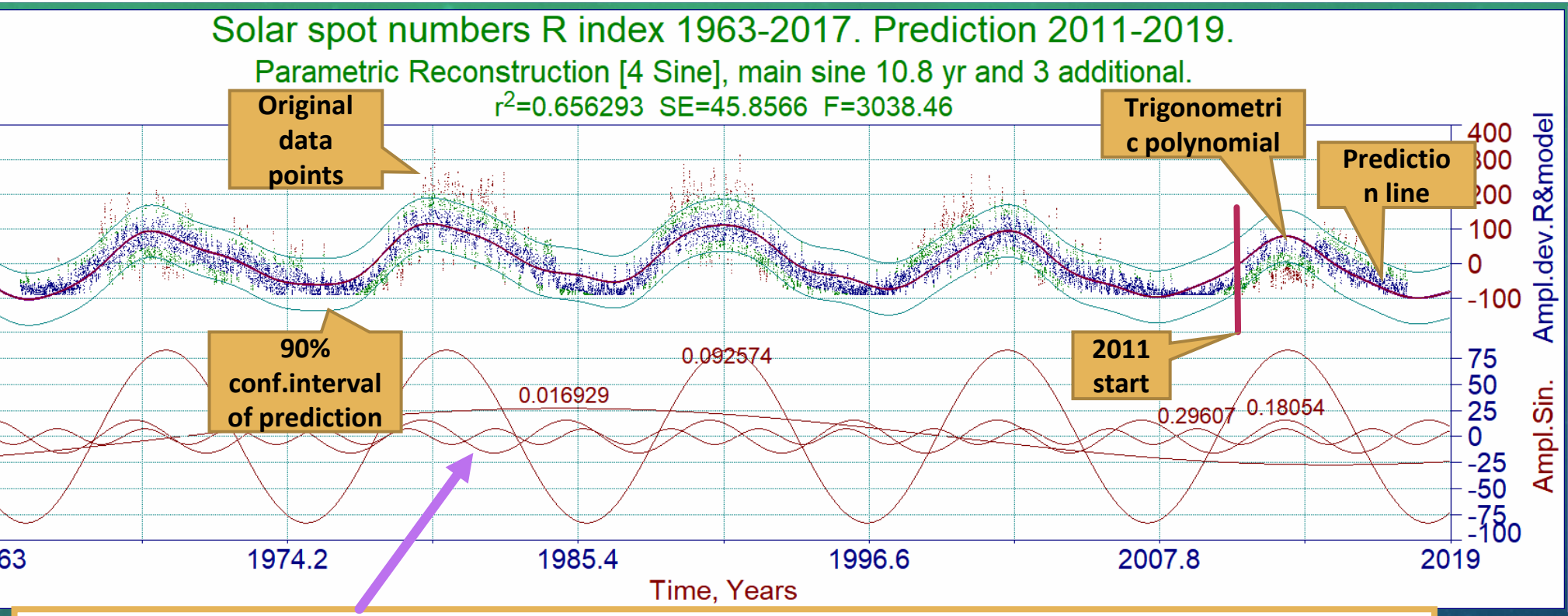
Conclusions

- The formation of each cycle is the result of the joint effect of long-period (11 years) periods of moderate duration (2-7) and short periods (less than 2 years).
- 2-7 years periods and shorter when transitioning between cycles suggest merging, splitting and limiting its lifetime.

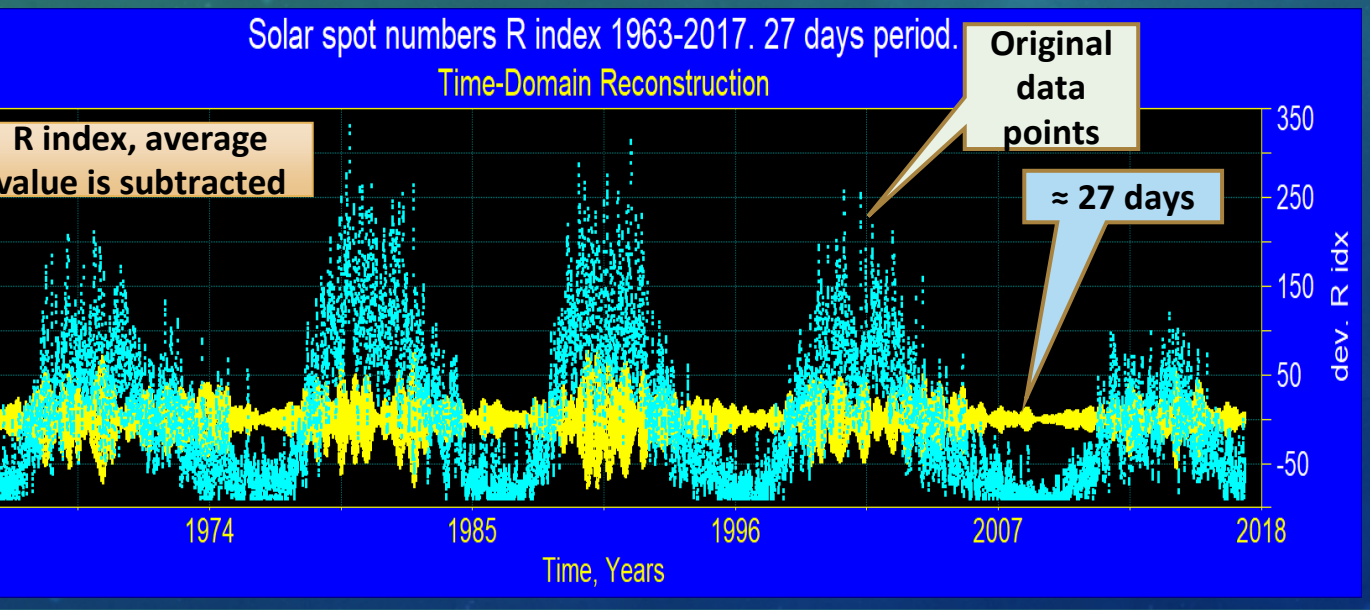
Conclusions

- Difference of properties of cycles and anti-cycles of activity for Northern and southern hemispheres is their fundamental and must be at the heart of modern models of solar cycles and their prediction

- The characteristic property of manifestations of cycles is their discrete nature, which requires an adequate view.

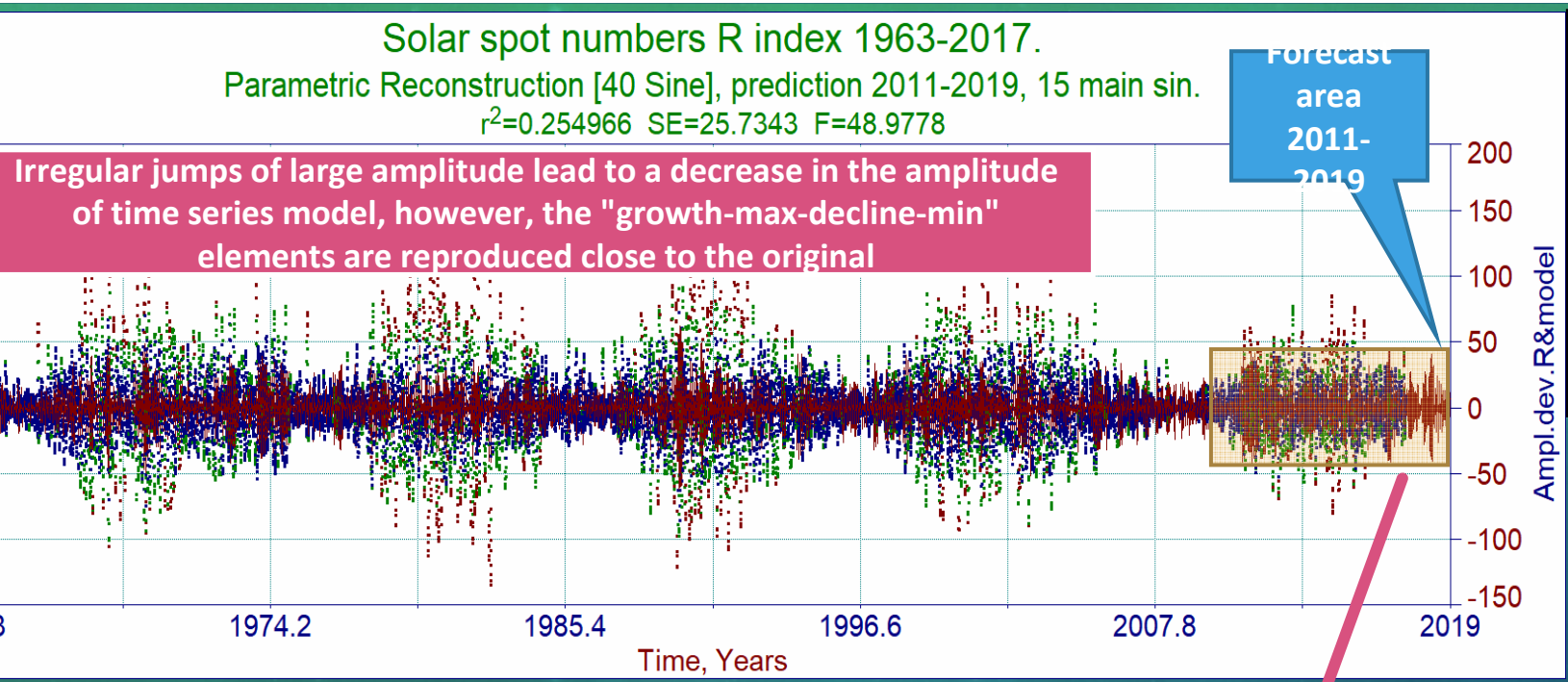


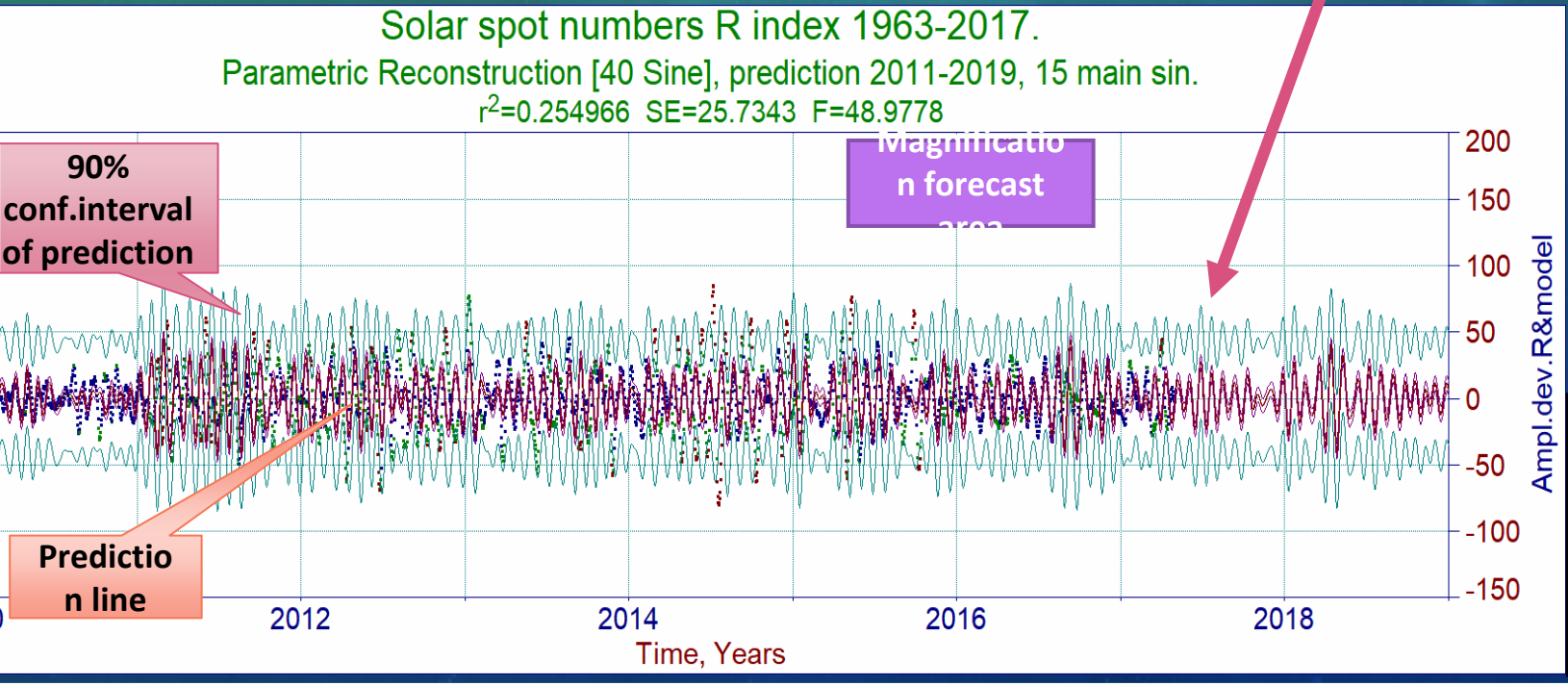
Separate sinusoids, after optimizing the least squares, sum of which gives a trigonometric polynomial-model



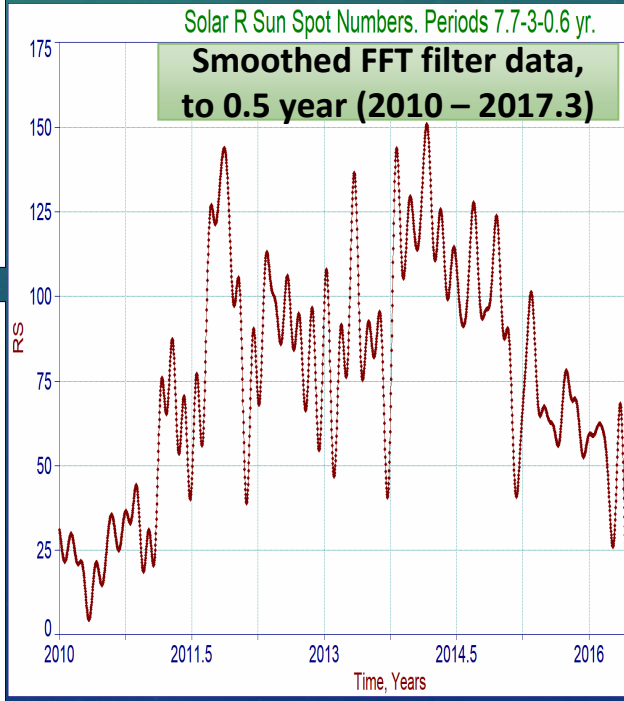
To estima
forecast f
year cy
(from 20
2019),
sinusoids
main 11.8
and 3 aux
were use
compensa
observed
sinusoidal
cycle

A difficult task is forecast the short-periodi
of solar data. The figure on the left shows
27-day period, which makes a significa
contribution to rapid variability. In addit
there are shorter variations in number of s
This requires the task and optimization of
parameters of model that significantly sl
calculations and can lead to false model ju
which worsens the quality of the foreca

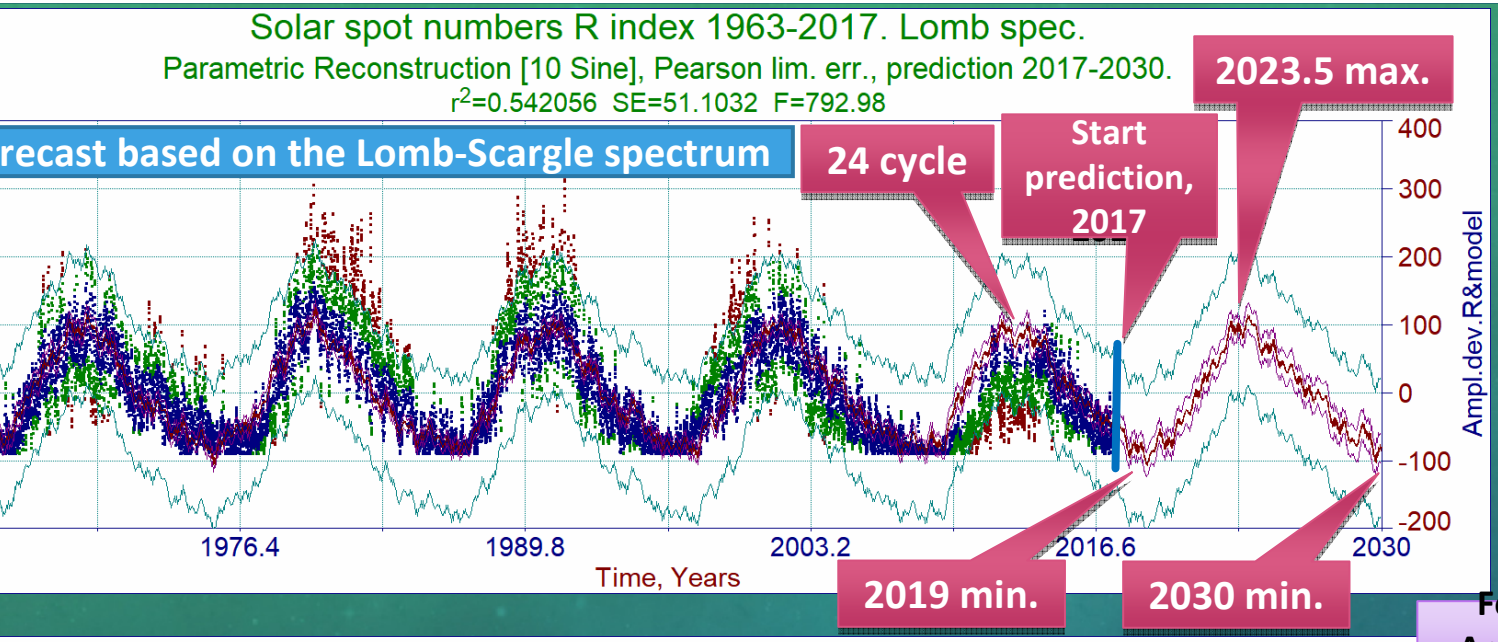




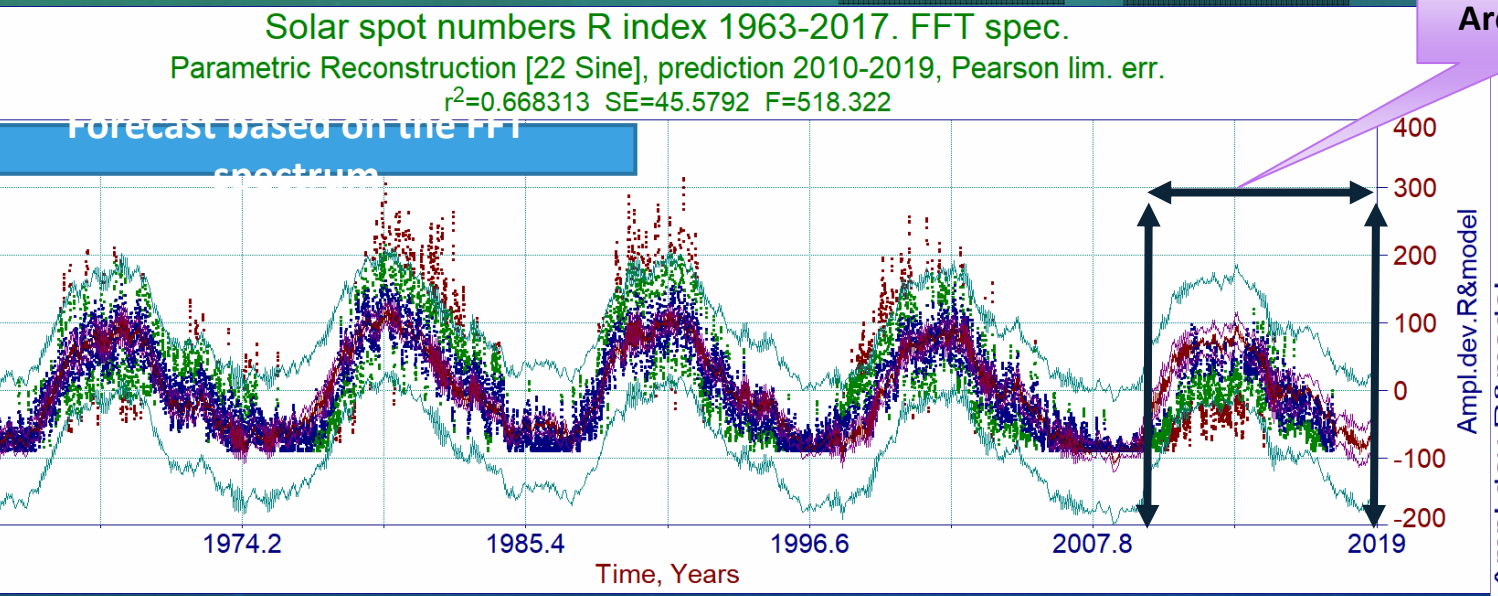
It is convenient to divide a series o into long-term (years) and fast (te days) variability ranges, for a sepa analysis. This greatly speeds up calc and allows to more accurately dete periods of oscillations that can be against on other's hi-amplitud background fluctuations.



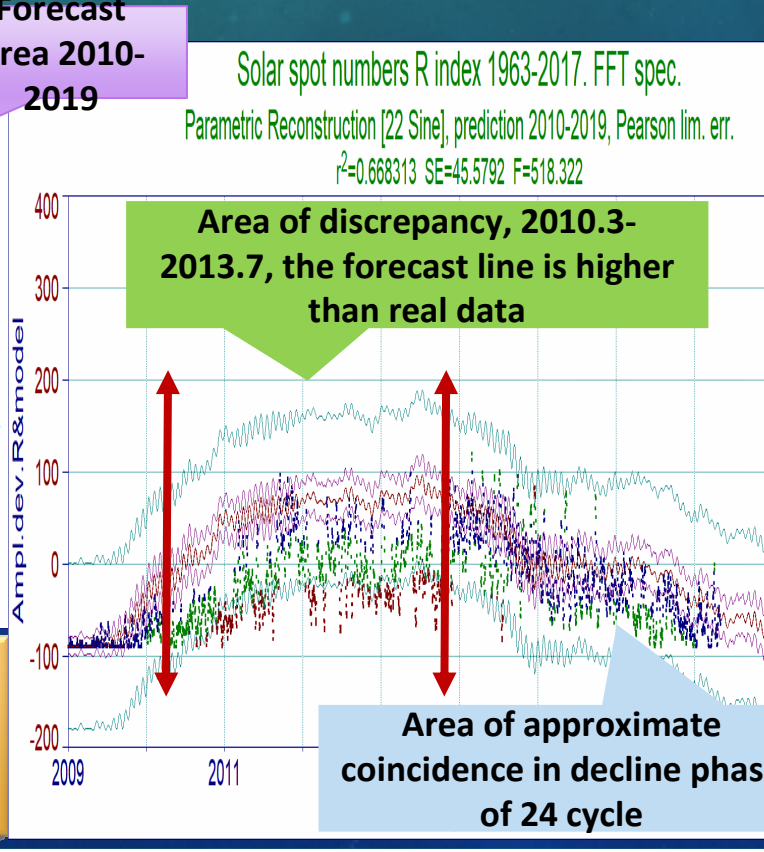
Adding individual forecasts different frequency ranges + 11 cycle can help improve quality forecast in comparison with d calculation for entire series



Test forecast 25 cycles. We used undamped sinusoids based on the L Scargle spectrum. A minimum of 24 is possibly in 2019, a maximum of cycles in 2023.5, the next minimu 2030. A robust fit uses the Pears distribution to minimize deviation o model from original data points

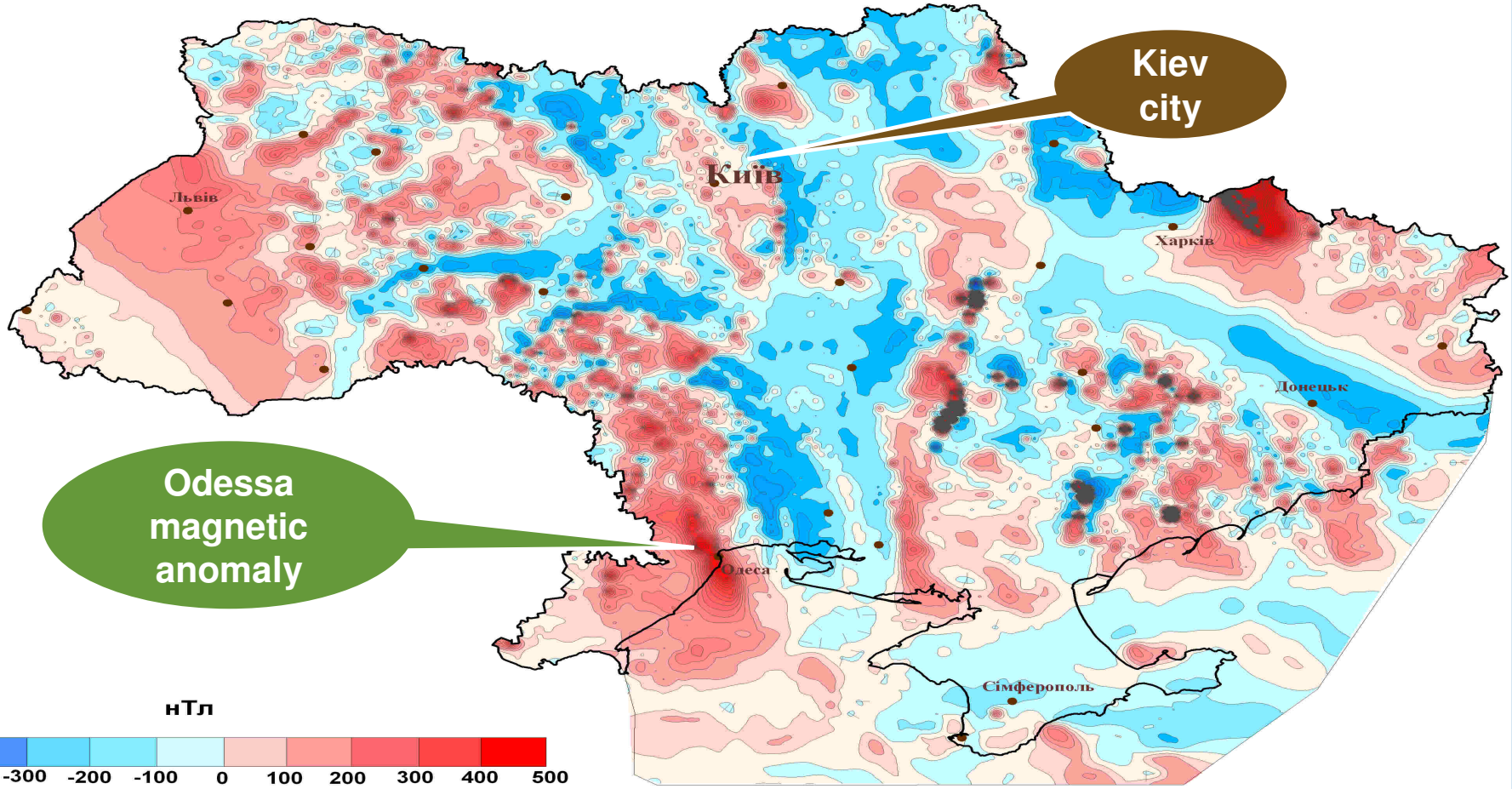


Forecast Area 2010-2019



es of forecasts, where the spectra Lomb Scargle (least squares method) and FFT are used ermine the initial parameters of the sinusoids. Both methods have an wrong deviation in th phase of the 24 cycle and a good match with the original data in the phase of the 24 cycle decline. Best coincidence when applying Lomb Scargle spectrum for forecast.

ORIGINAL OBSERVATIONAL DATA AND MAP OF ANOMALOUS GEOMAGNETIC FIELD ON TERRITORY OF UKRAINE.



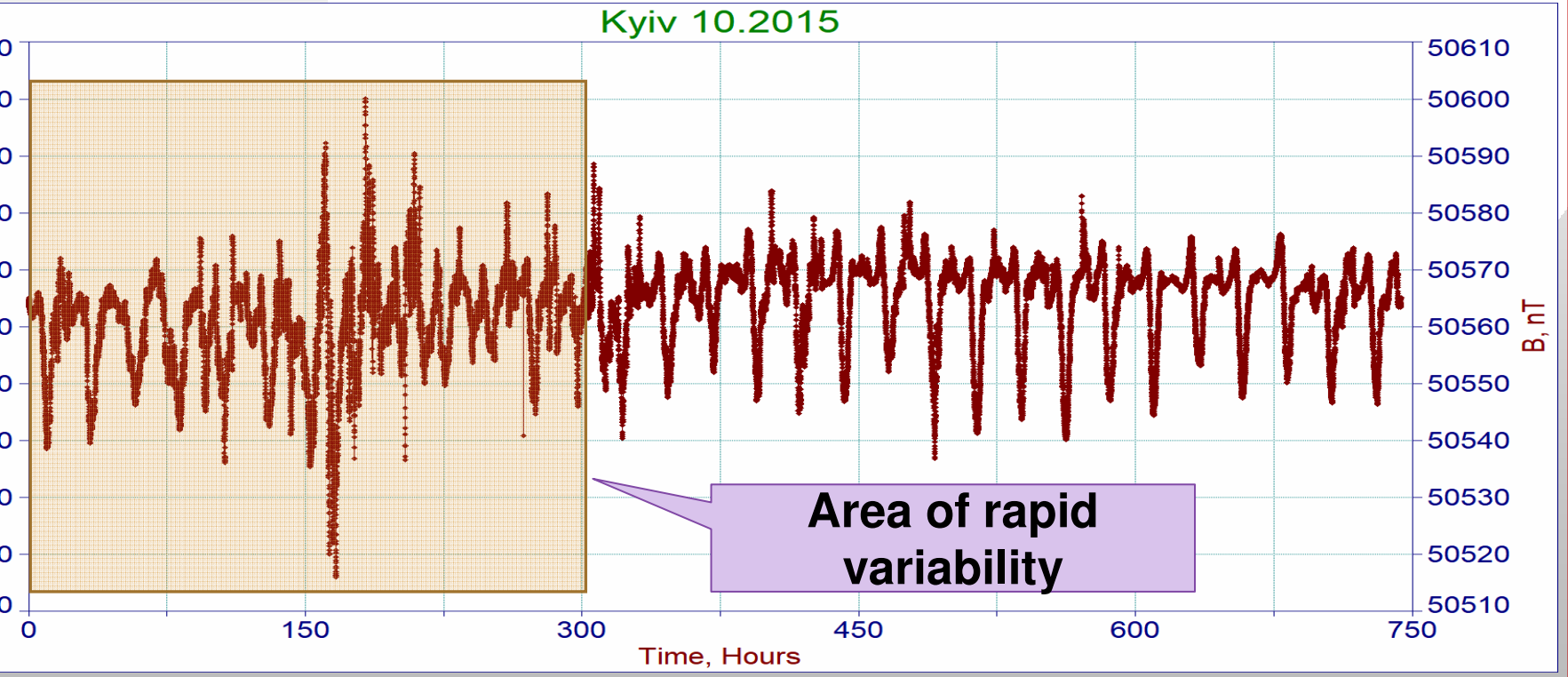
Magnetic anoma
are regions on
Earth's surface
which value ar
direction of the Ea
magnetic field ve
differs significa
from normal valu
geomagnetic fie
Local magneti
anomalies reach a
of hundreds km2
associated wit
structure of upp
parts of crust (
particular, occurr
of iron-bearing ro
or features o
magnetization
surface rocks

e original data sets are every minute counts of the
induction vector of geomagnetic field, obtained at
gnetic observatories near Odessa and Kiev cities.
of largest magnetic anomalies in Ukraine is located
in territory of Odessa and the Odessa region.

The original data was very noisy and for remov
noise and drop-out points and fill small data gaps
Fourier-smoothing and approximation method v
used.

VARIATIONS OF GEOMAGNETIC FIELD. KIEV 2015.

the FFT spectra (Fast Fourier transform) of complete vector of geomagnetic field inducti
ained at observatories "Odessa" and "Kiev" regular variations of magnetic field with peri
24 and 12 hours are allocating, as well as harmonics of 8 and 6 hours, sometimes less. Th
re created, mainly, changes in electric currents in ionosphere of the Earth during the day



example of digital recording of magnetic field induction in the observatory "Kiev", October 2015.

However, thes
periods are
unevenly distribu
in time, their
amplitude is
different for diffe
months, and valu
of these period
also change,
especially durin
magnetic storm

Integrated studies of solar activity (multiwavelen
lio) CrAO

ed on RT-22 and three
all radio telescopes there is
mplex of multiwave study
ar activity.
s included in the world
work of 14 ground stations
l orbital observatories.

Thank you !