THE MAIN PROPERTIES OF THE ACTIVITY OF THE NORTHERN AND SOUTHERN HEMISPHERES AS THE BASIS OF THE SOLAR CYCLE FORMATION.

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Introduction

- This work is a continuation of the research of activity cycles of the northern and southern hemispheres of the Sun. We showed the basic properties of the cycles based on the application of wavelet analysis of daily and monthly average values of indexes of the North (N) and South (S) hemispheres: WN, WS (the Wolf number), SpN, SpS (summary of sunspots groups) and FIN, FIS (Flare index) for all time of their observation.

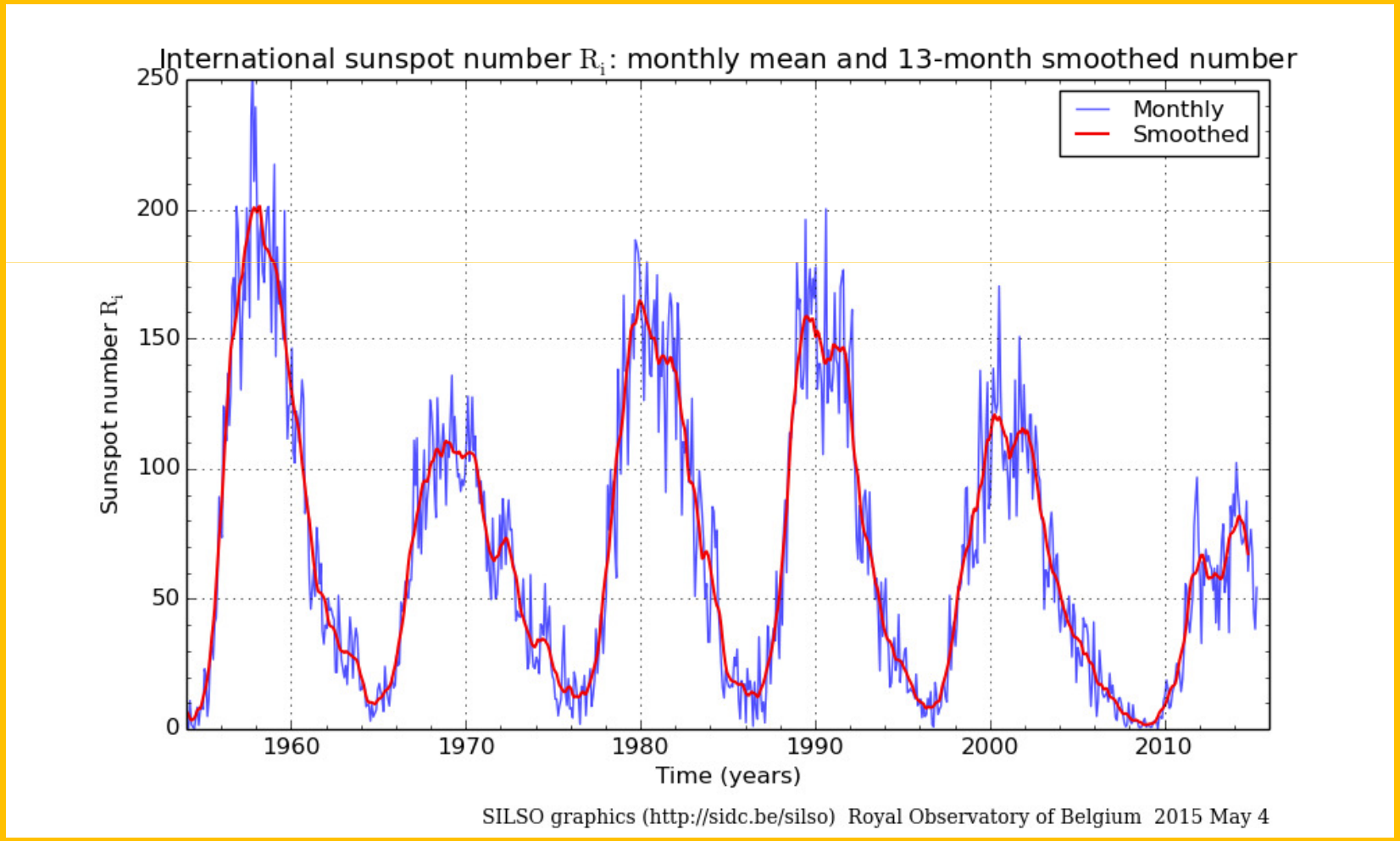
Introduction (continue)

- We received the main data cycles: the start and end time, increase phase, maximum and decrease phase, global Wavelet spectra, prevailing processes of cycle formation, time of their existence, spotless periods. We showed the difference of these indicators for the studied indexes. On the basis of the daily index values we identified features of alternating predominance of activity of the northern and southern hemispheres.

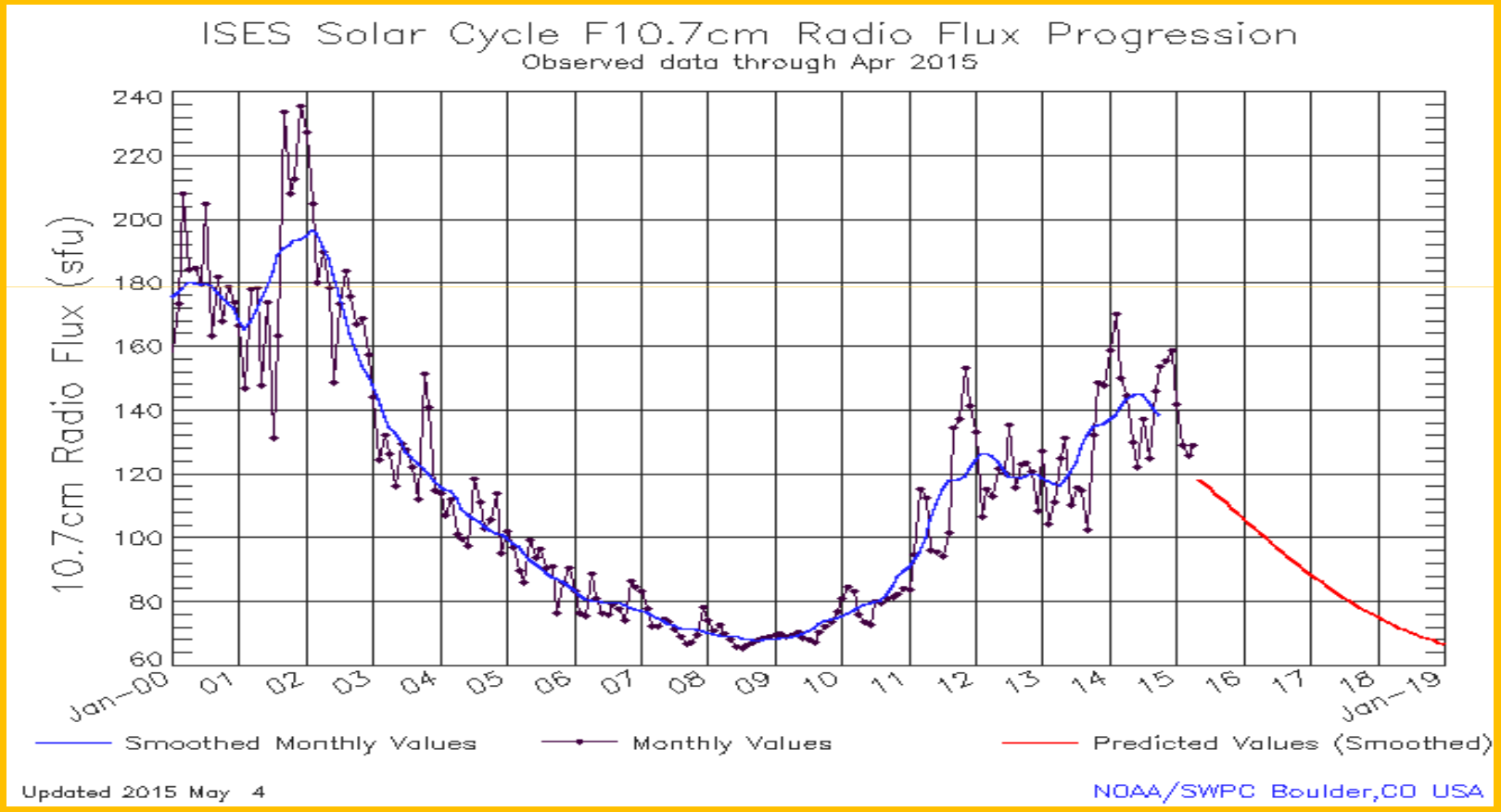
Introduction (continue)

- Start and end times of the activity in each of the hemispheres of the Sun in each cycle are synchronized in a certain way. Application of the method of bandpass filtering results of wavelet analysis allows differentiating between the two cycles: "11-year-old" part, interim periods from 2 to 7 years in the transition from cycle to cycle, spectra periods forming phase of heightened activity.

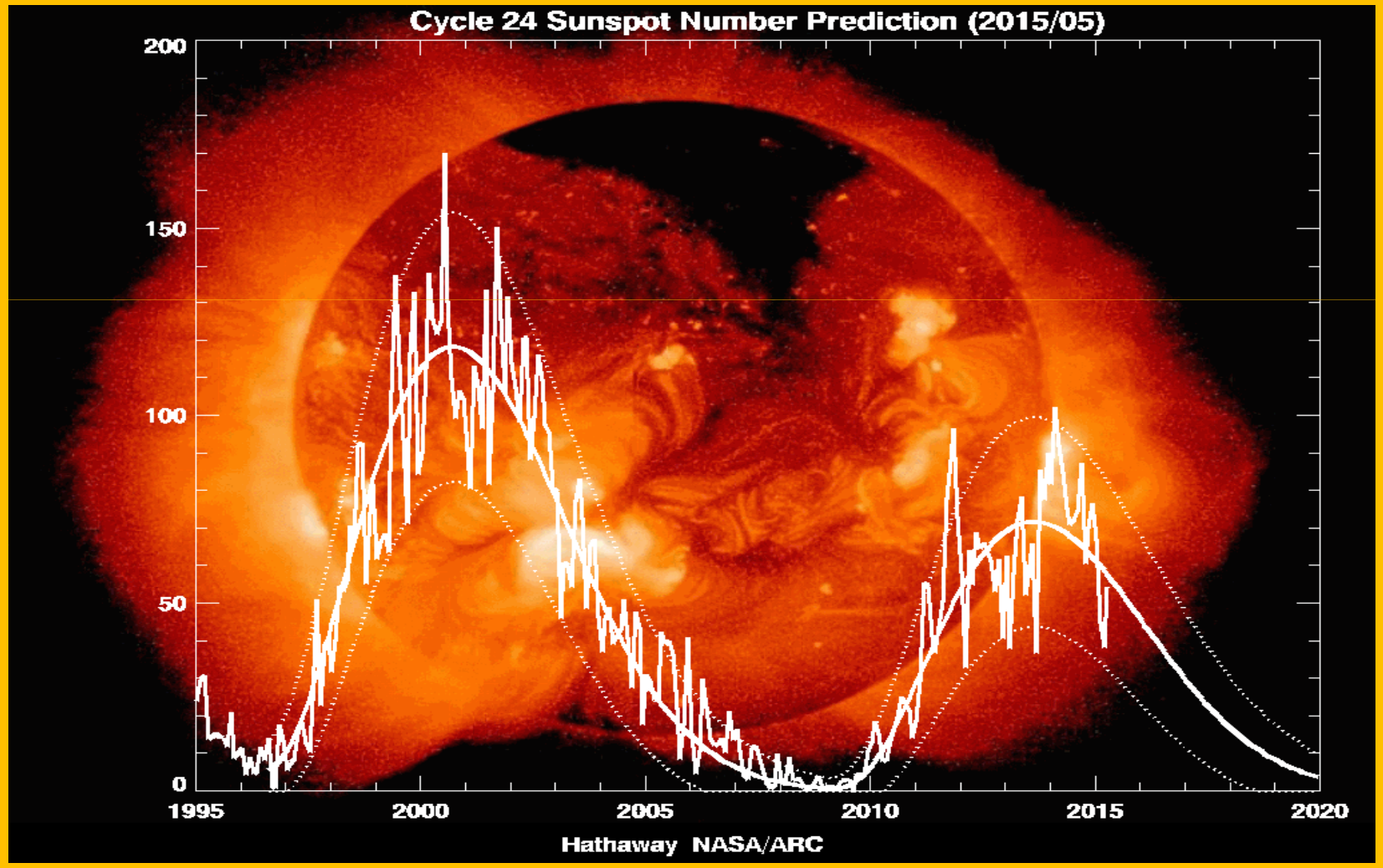
Traditional data solar cycles



23-24 solar cycles



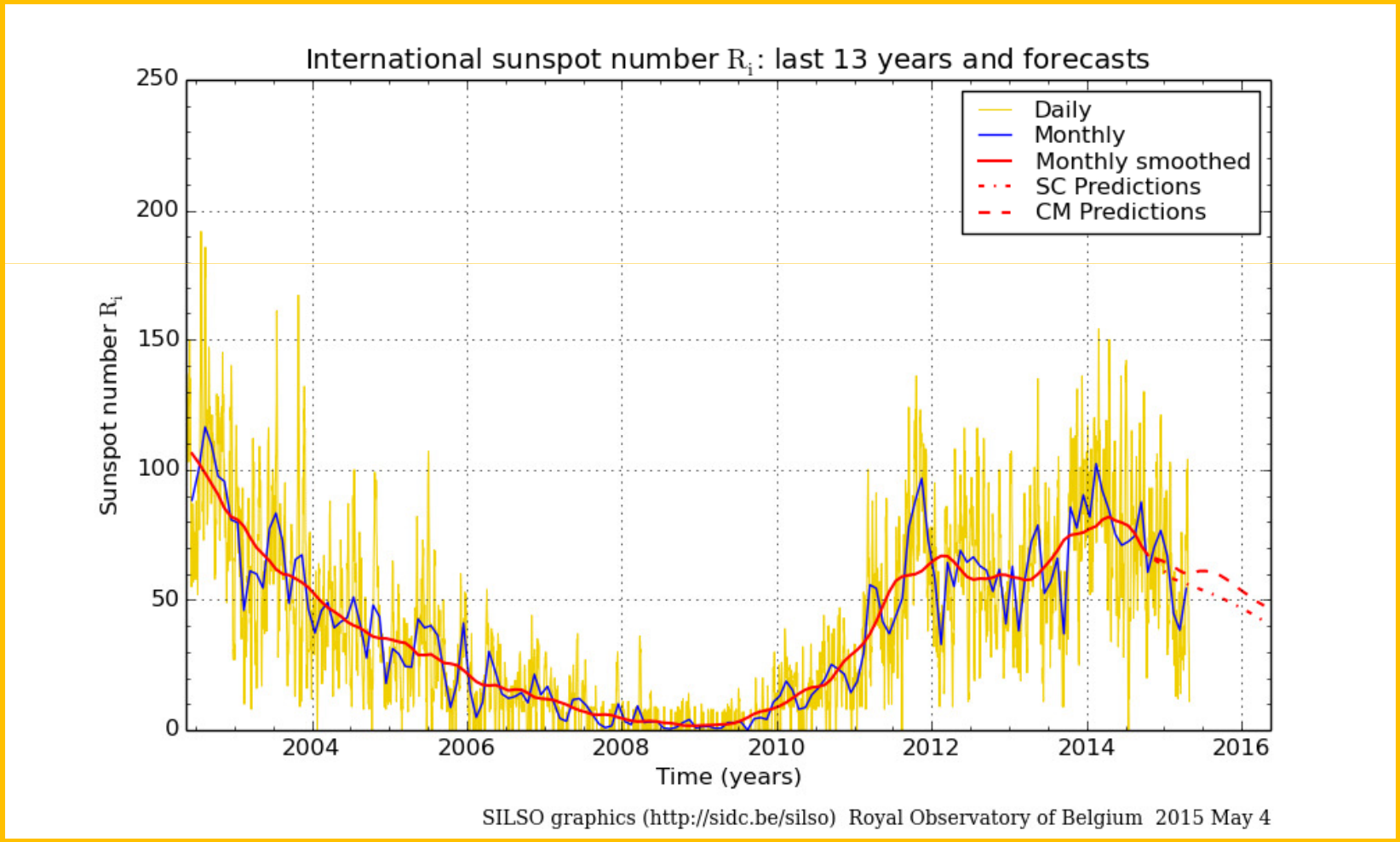
23-24 cycle


Cycle 24 Sunspot Number Prediction (2015/05)
200
150
100
50
0
1995
2000
2005
2010
2015
2020
Hathaway NASA/ARC

Phase 23 cycle activity

- Start cycle May 1996
- Phase increase Sept. 1997 - Sept 1999 .
- Phase max Oct. 1999 – June 2002 .
- Phase decrease June 2002 – Jule 2006 .
- Phase min - Jul 2006 – December 2008.
- 1-th Max - April 2000 (W = 120,7)
- 2- th Max - Nov 2001 (W = 115,8)
-

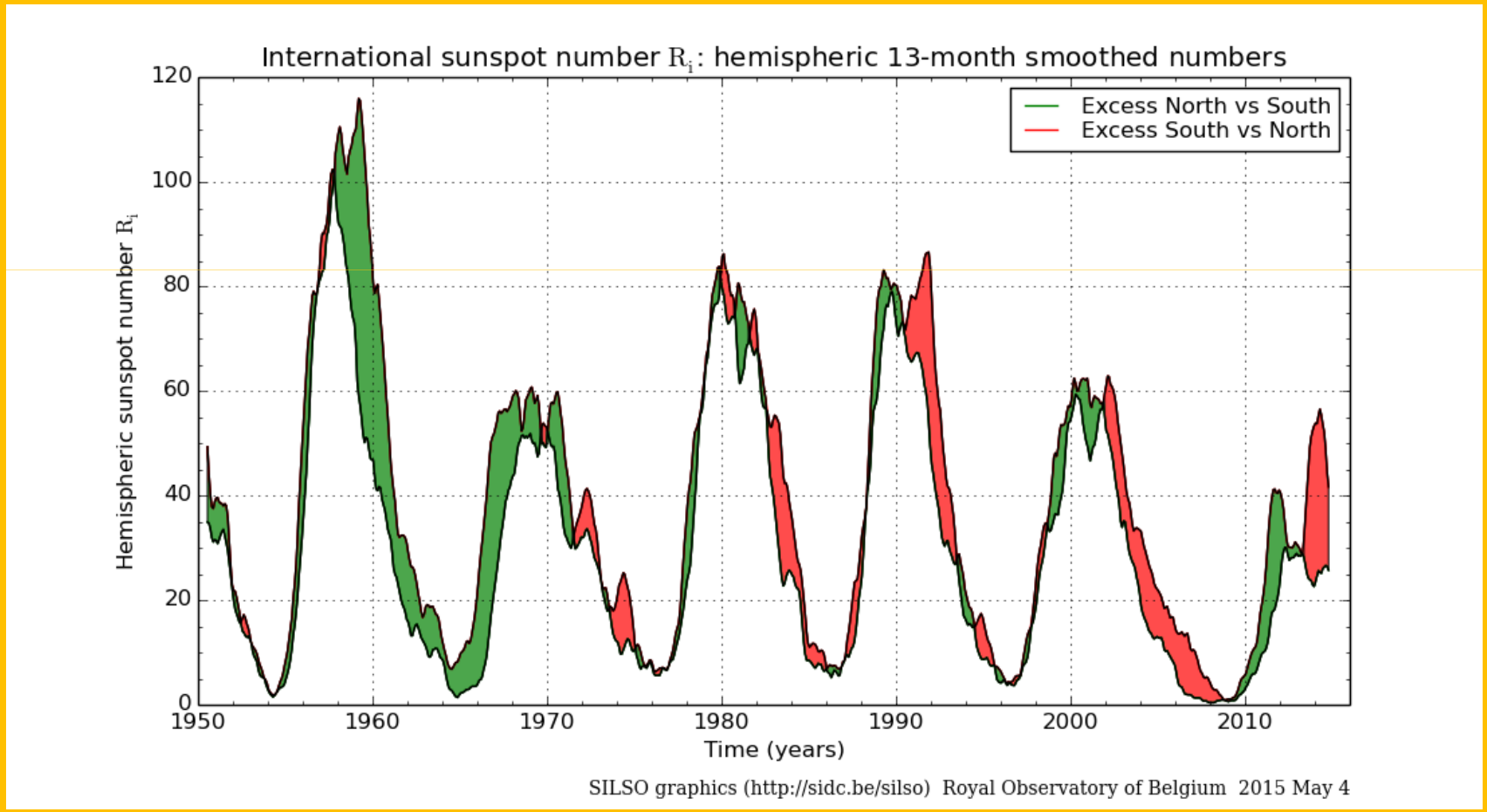
24 cycle activity



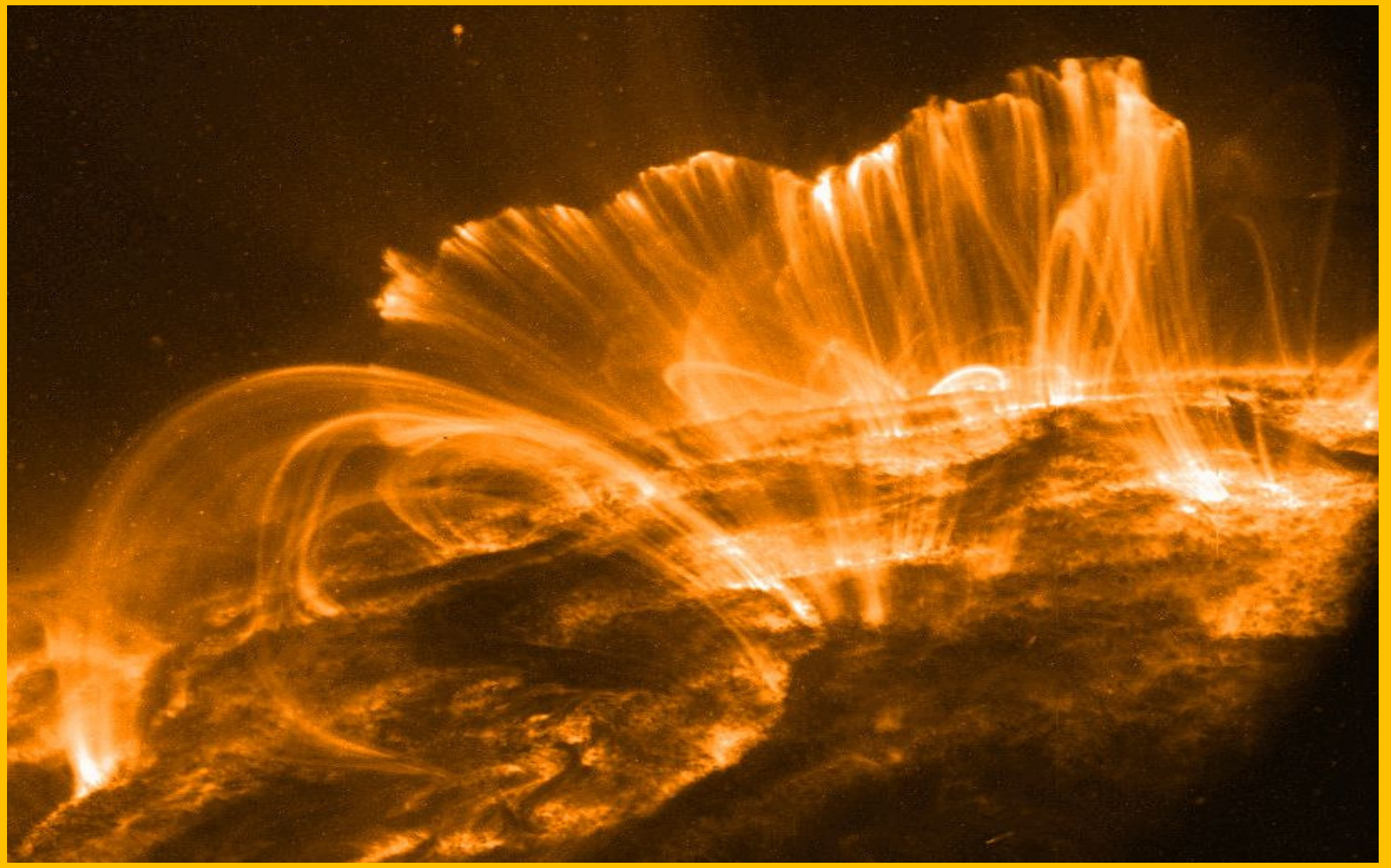
Contemporary state of the problem of nature of the cycle of solar activity

- All basic manifestations of the cycle of activity are determined according to the data from all solar disk.
- Such basic indices is the number of groups of spots - W and the summary area of the sunspots groups - Sp

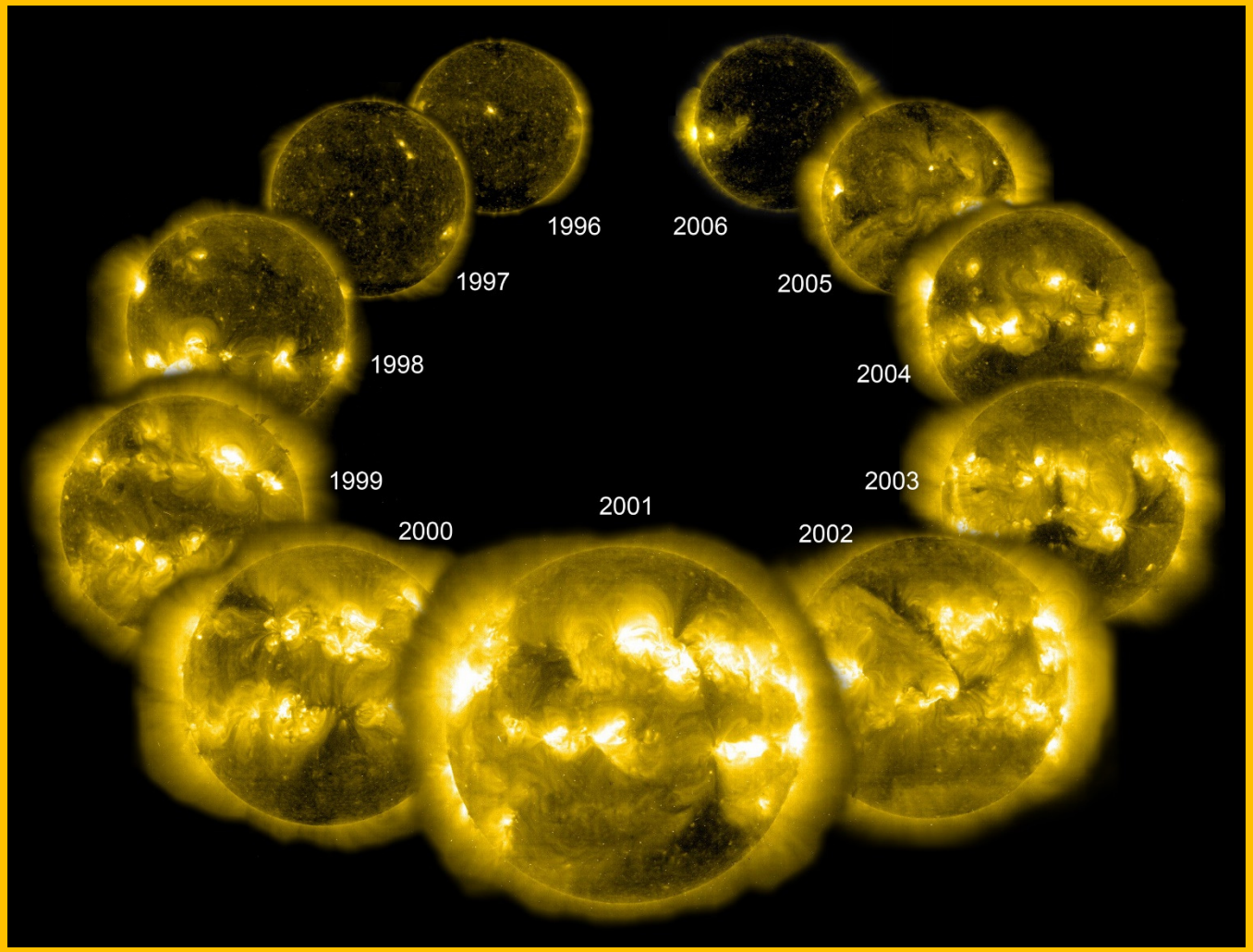
Noth-South asymmetry



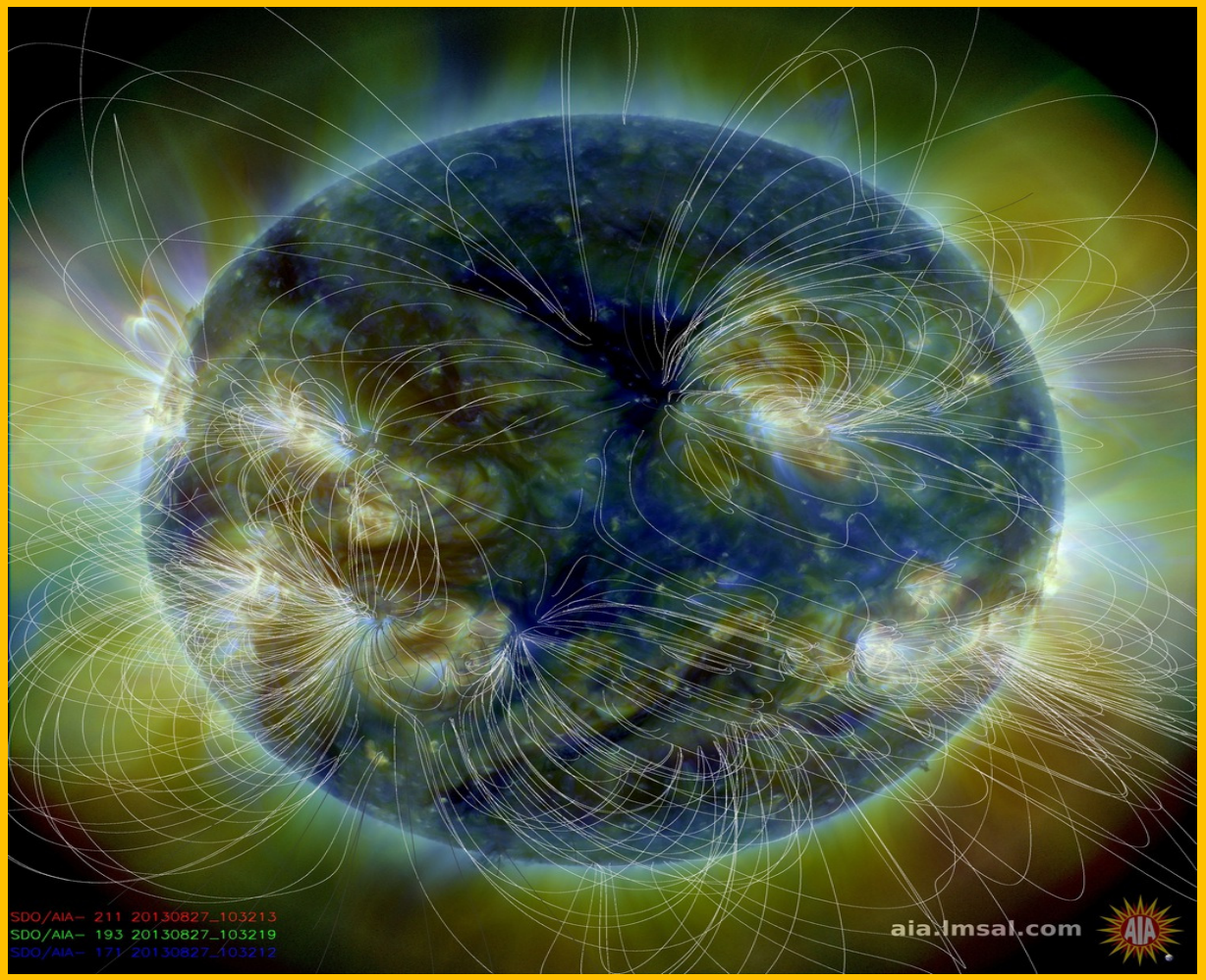
UV image complex activity regions



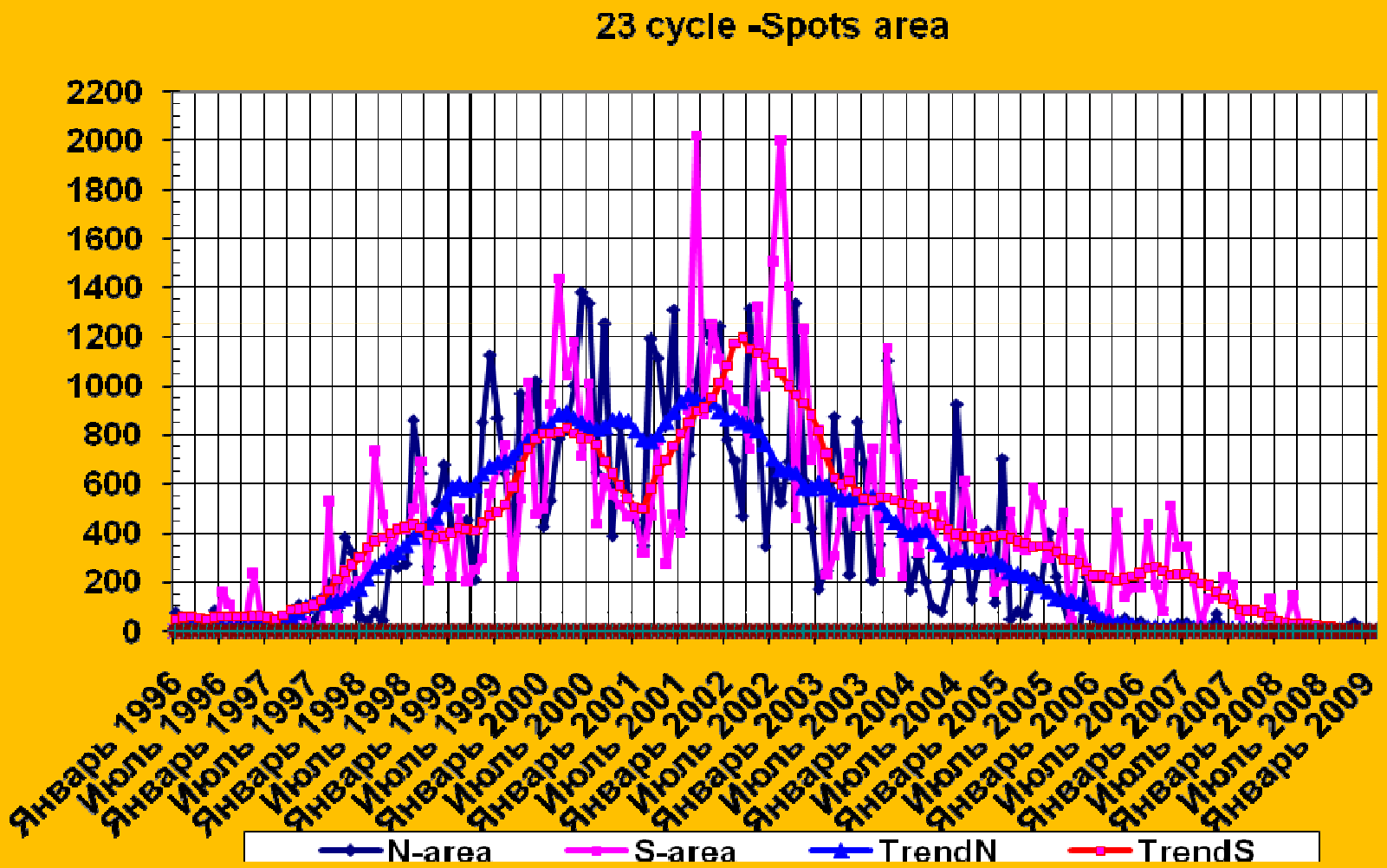
23 cycle –dynamic activity



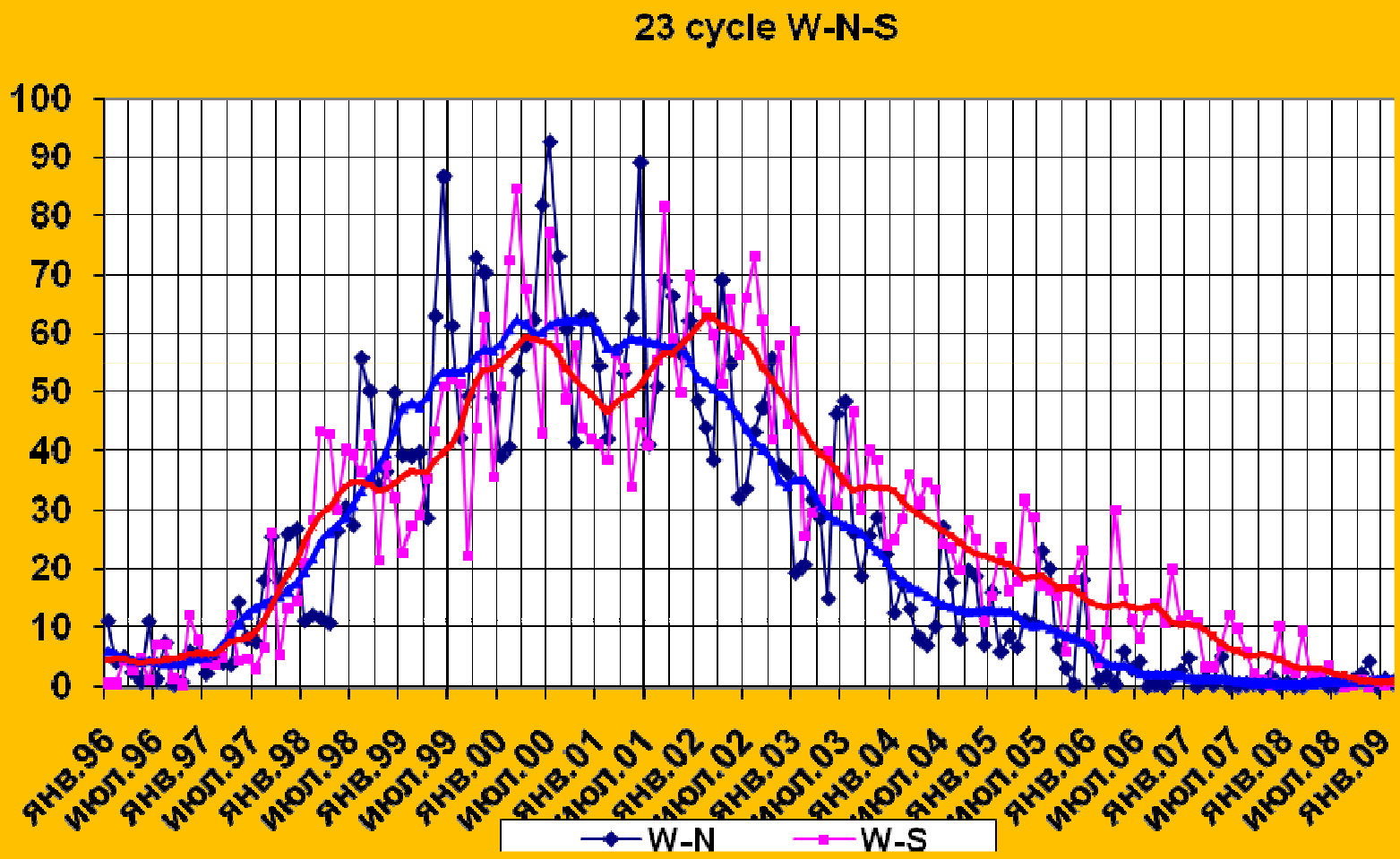
Global complex activity



23-th cycle (Sp index)



23 –th N and S cycle (W index)



Phase N и S solar cycle

- **Increase Mar. 1997**
- **Start Max- Mar. 1999**
- **1-th max. Nov. 2000**
- **2-th max May 2001**
- **Fin max. - Jan. 2003**
- **Phase min – Jan 2007**

- **Increase Apr. 1997**
- **Start Max . Aug. 1998**
- **1-th max. Apr. 2000**
- **2-th max. Feb. 2002**
- **Fin max. Jul. 2003**
- **Phase min – Dec 2008**

Base data for investigations

- **The data for the study is:**
- **1. Monthly values of groups of sunspots in Northern (Sp-N) and Southern hemispheres (Sp-S) 140 years (1874-2014)**
- **2. Daily Wolf numbers in the Northern (W-N) and Southern hemispheres (W-S) – 21 years (1992-2013),**
- **3. Daily values of flare index FI-N and FI-S**
- **30 years (1976-2006).**

The questions arises

- 1. North- southern asymmetry is this property of the united cycle of solar activity?
- 2. North- southern asymmetry is a result of the combination of two independent cycles activity of the solar hemispheres?

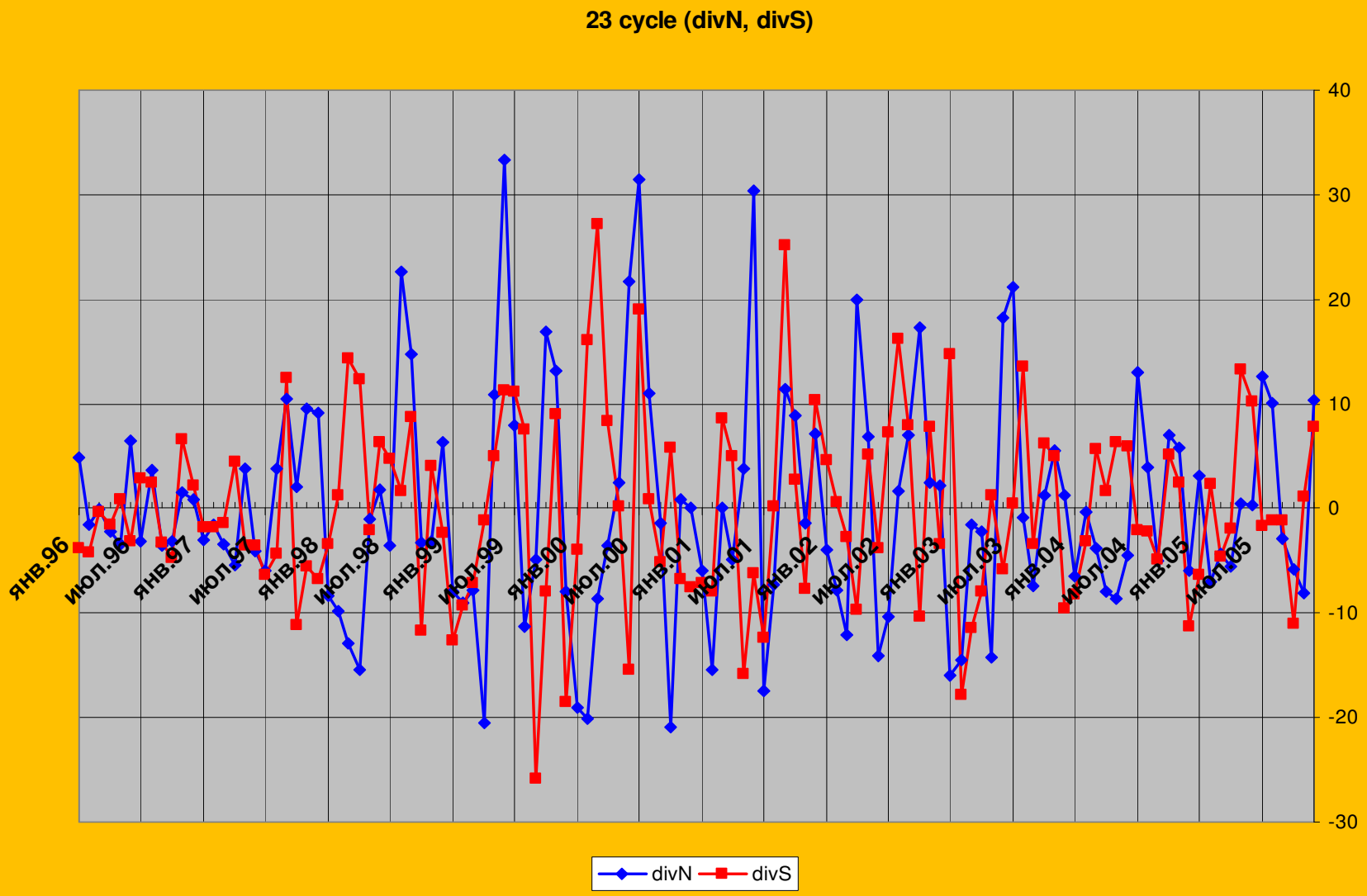
Contemporary state of the problem of nature of the cycle of solar activity

- All basic manifestations of the cycle of activity are determined according to the data from all solar disk.
- Such basic indices is the number of groups of spots - W and the summary area of the sunspots groups - Sp

Variation of solar indexes

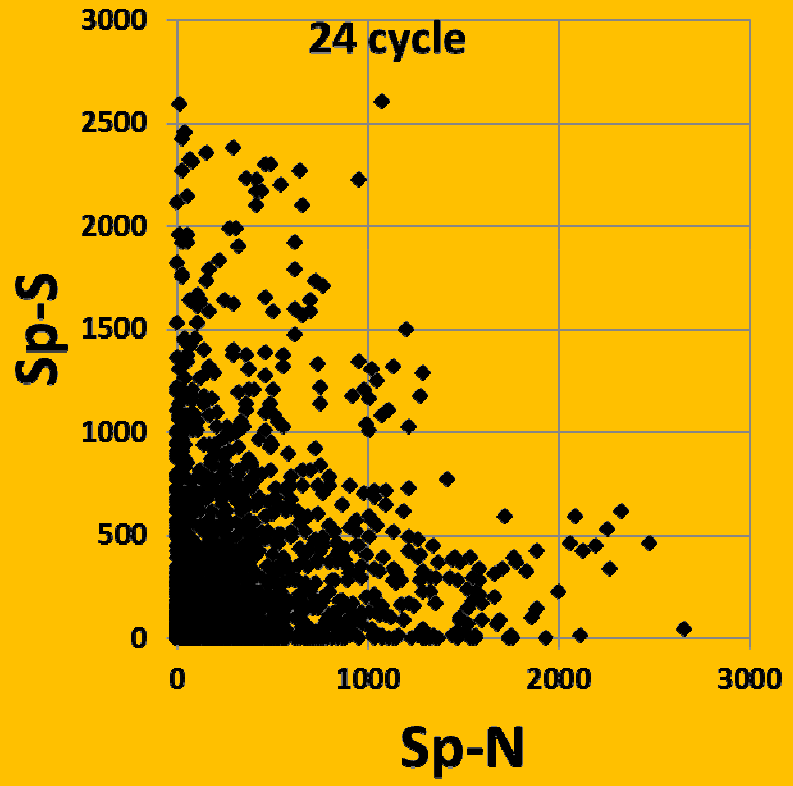
- Long variations (near 11 years and more) .
- Mean long variations (2-7 years)
- Fluctuation (O-C) data (less than 2 years)

Fluctuation W (N-S) data (1996-2006)

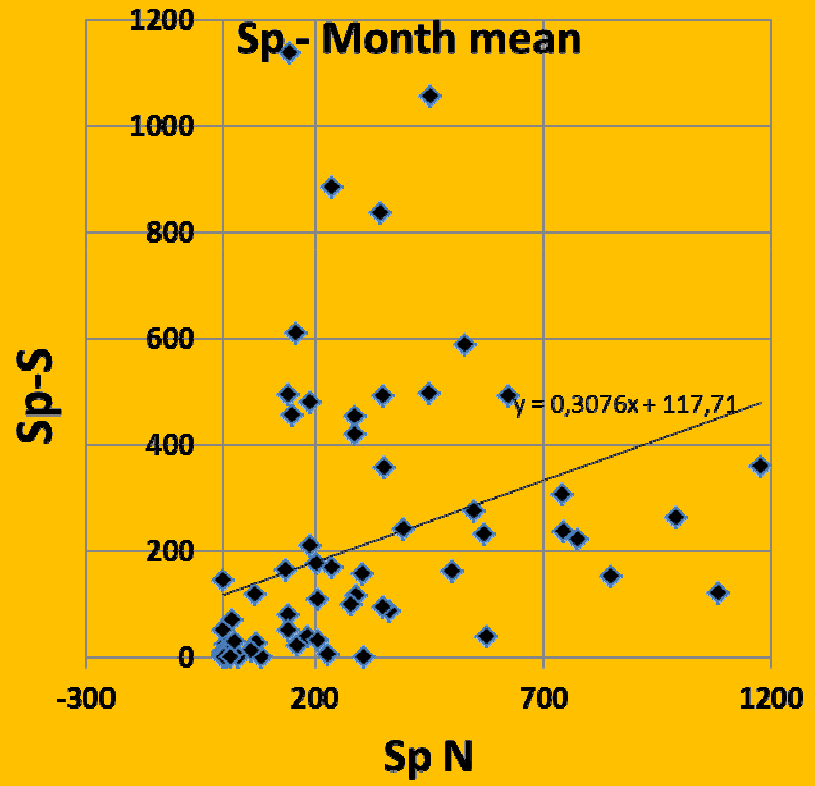


24 цикл активности

Sp ежедневные

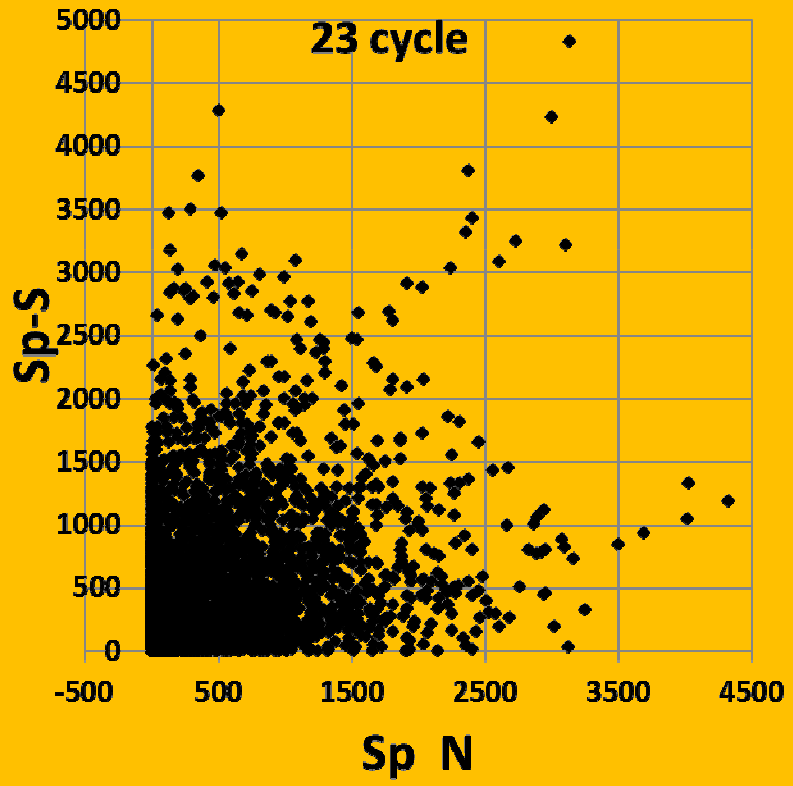


Sp среднемесячные

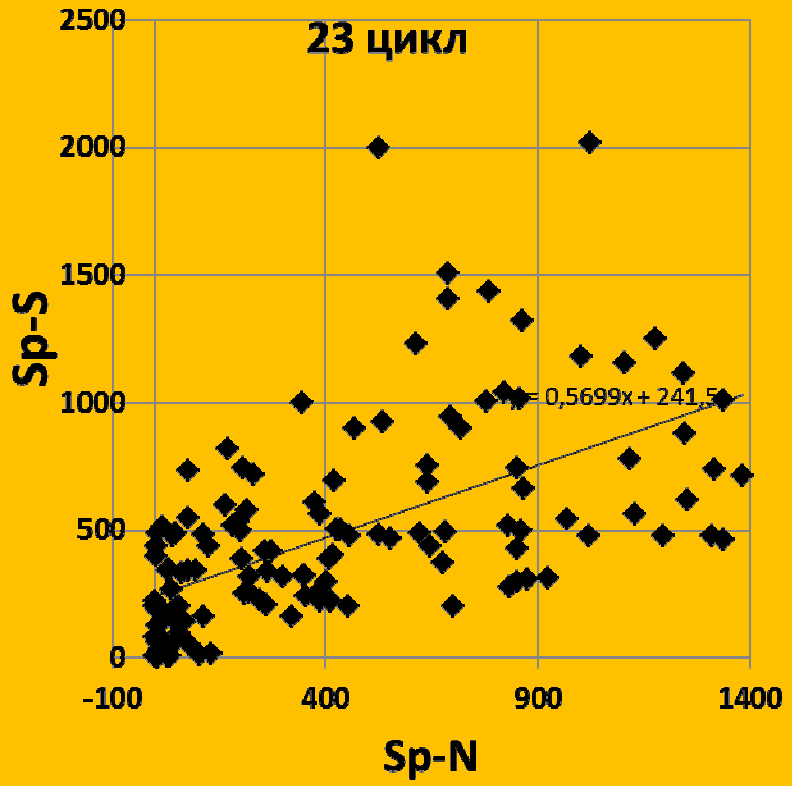


23 cycle activity

Sp- every days

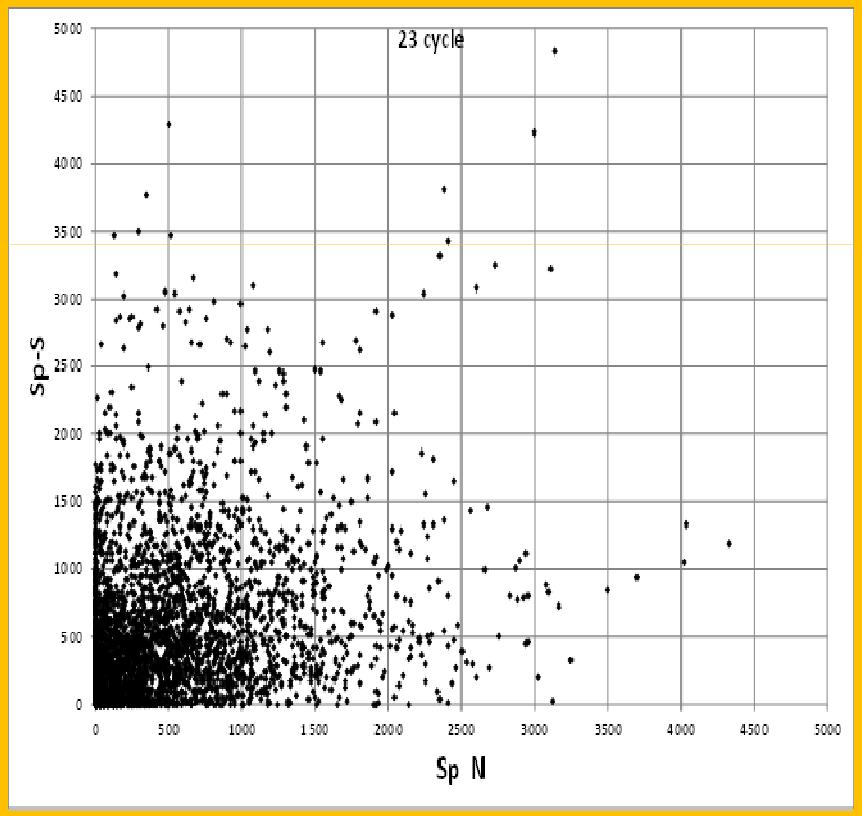


Sp – mean month

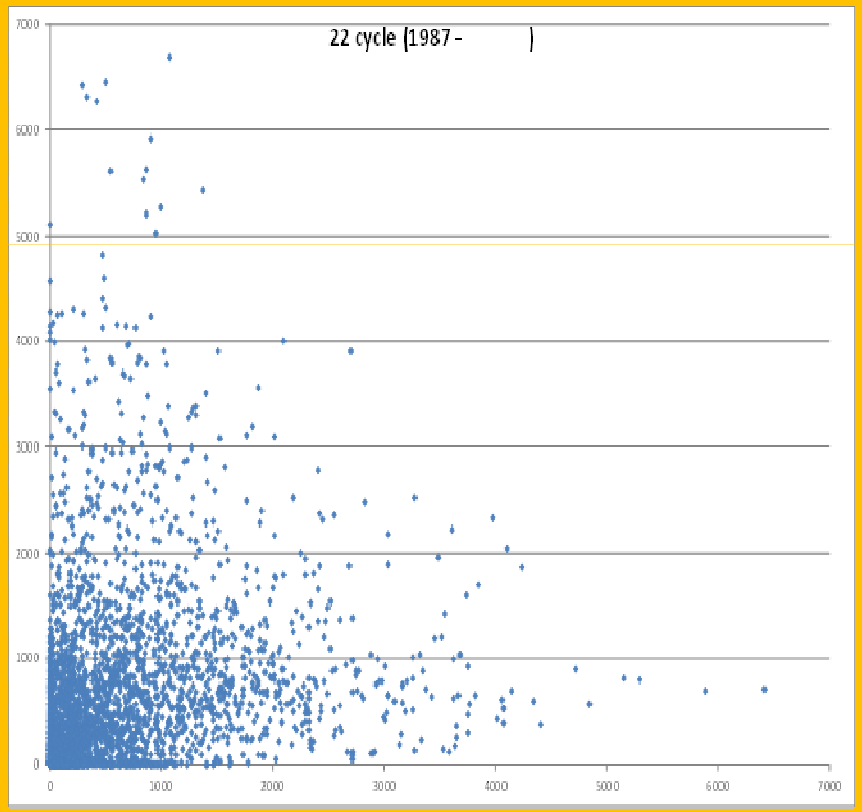


22-23 cycle

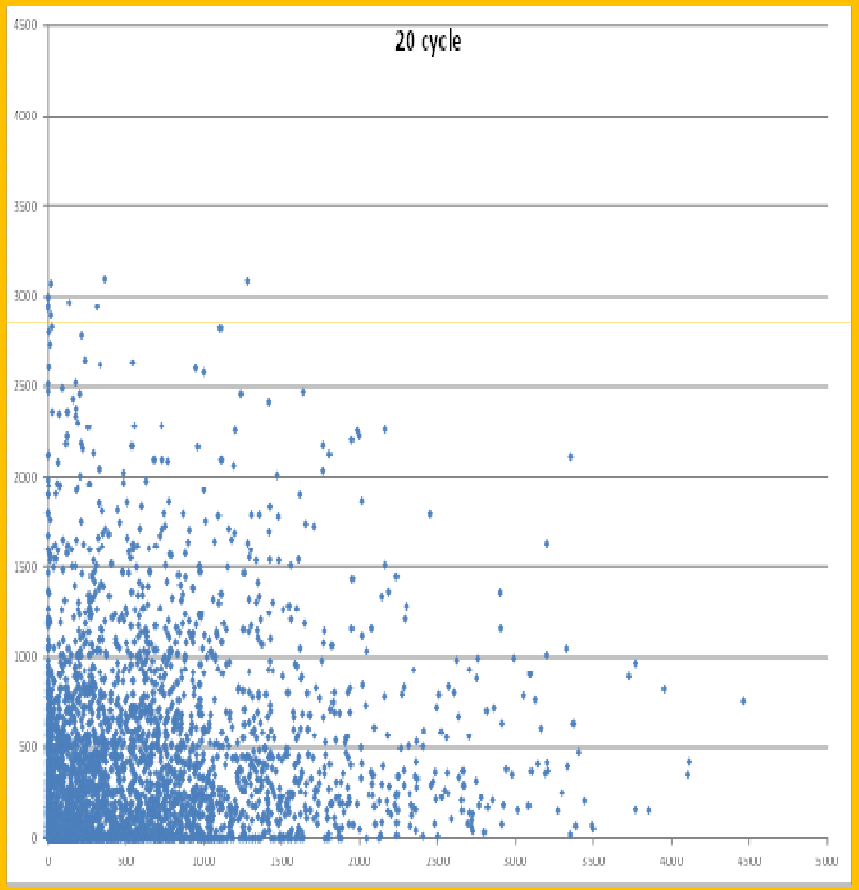
23 cycle every days data

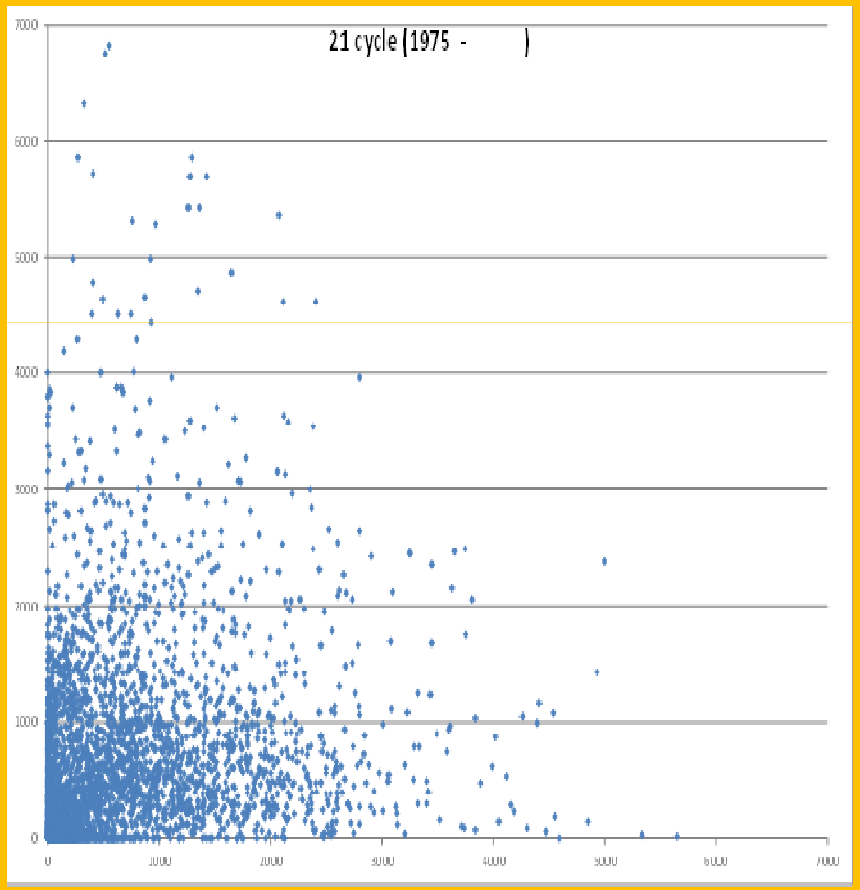


22 cycle every days

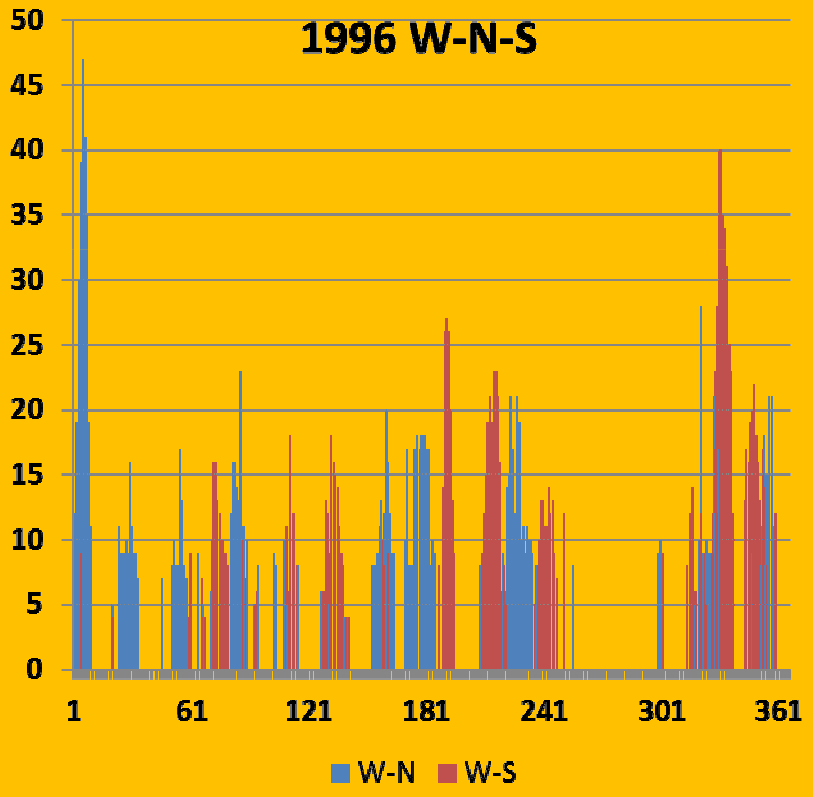


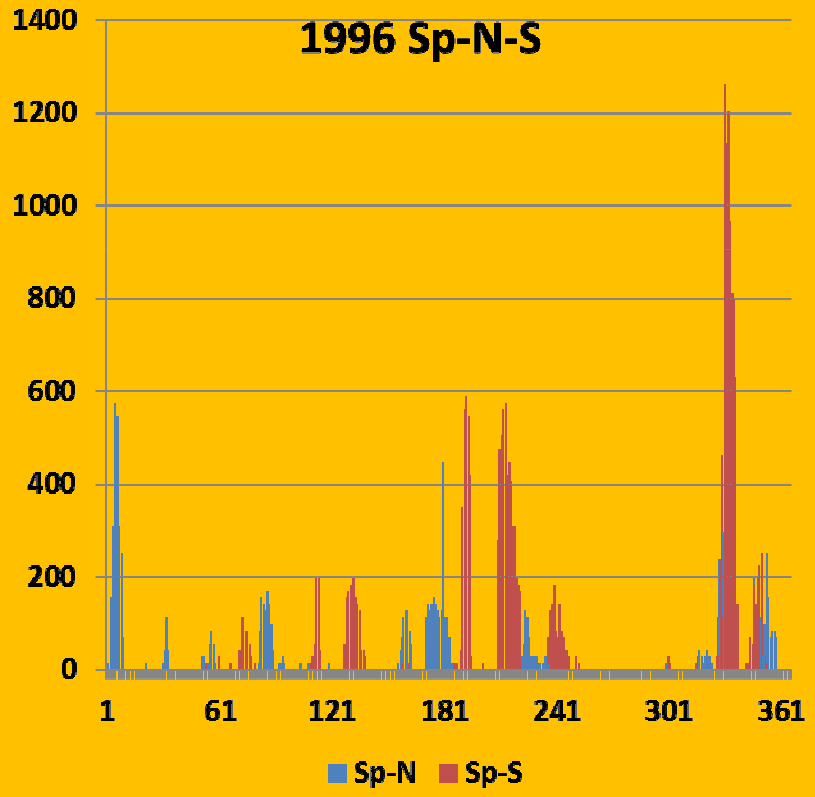
20-21 cycle



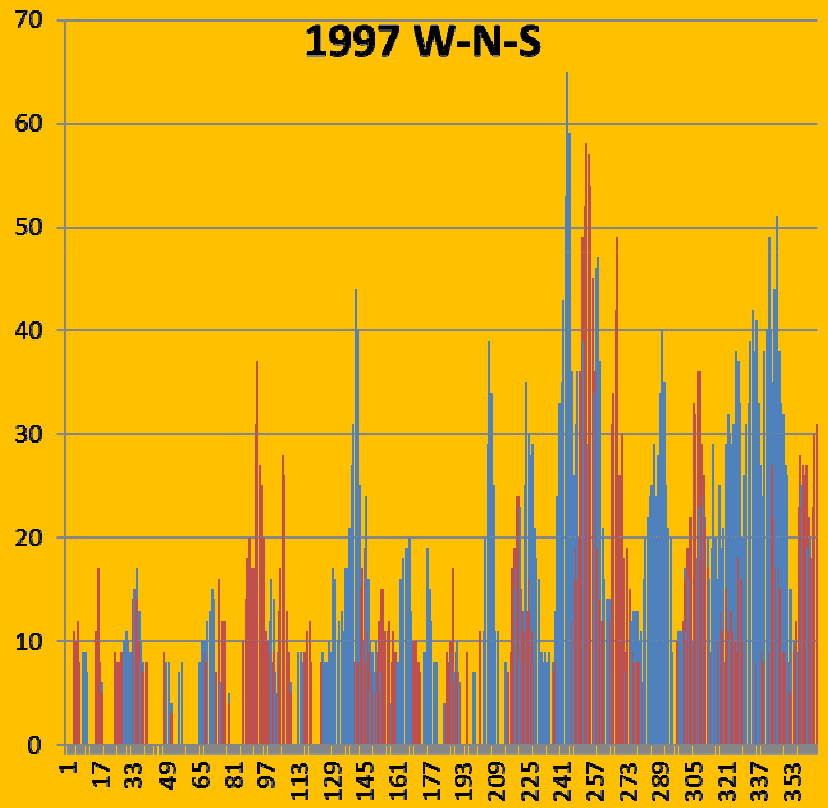


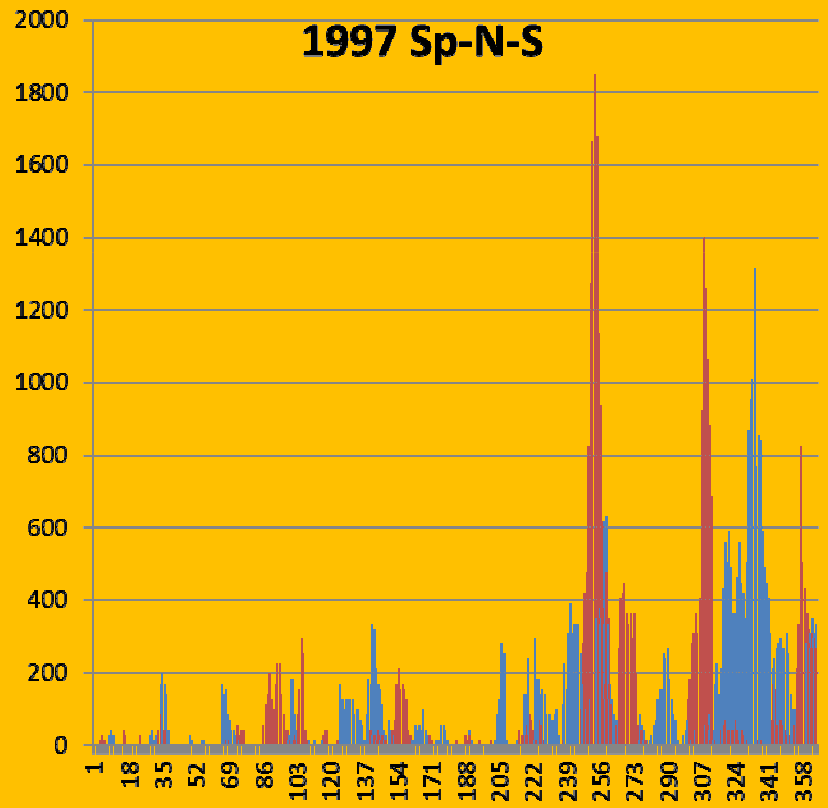
W and Sp time interval (1996 year)





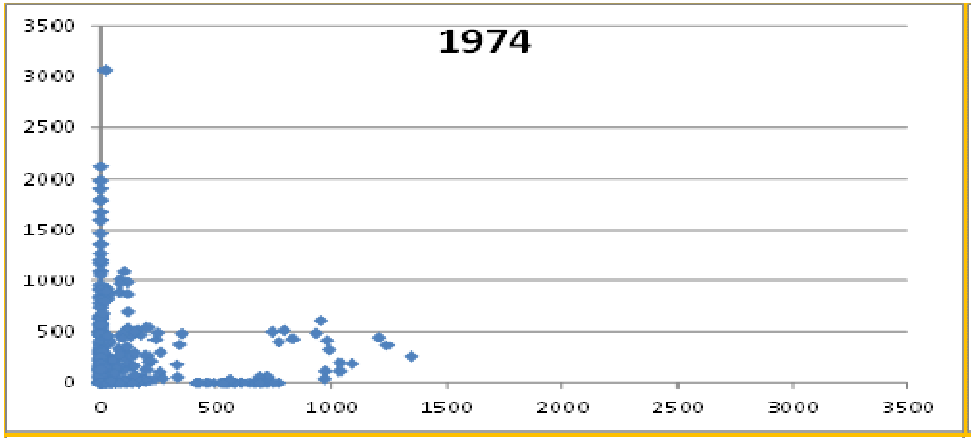
W and Sp time interval(1967 year)

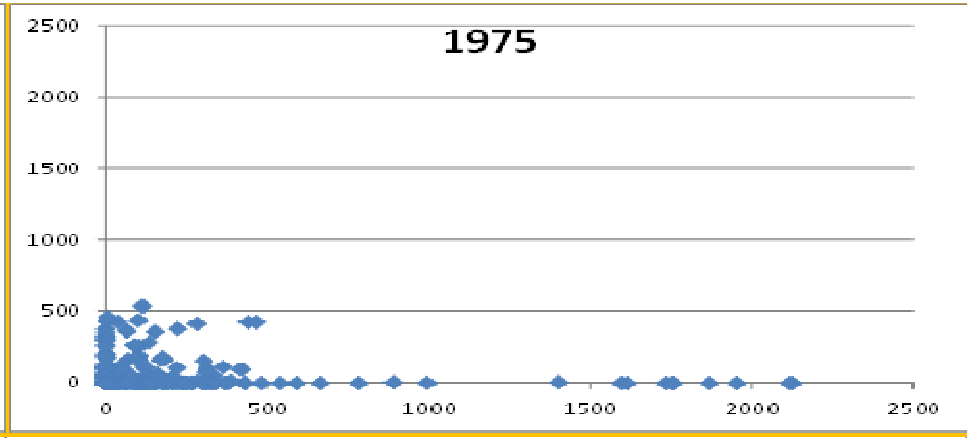


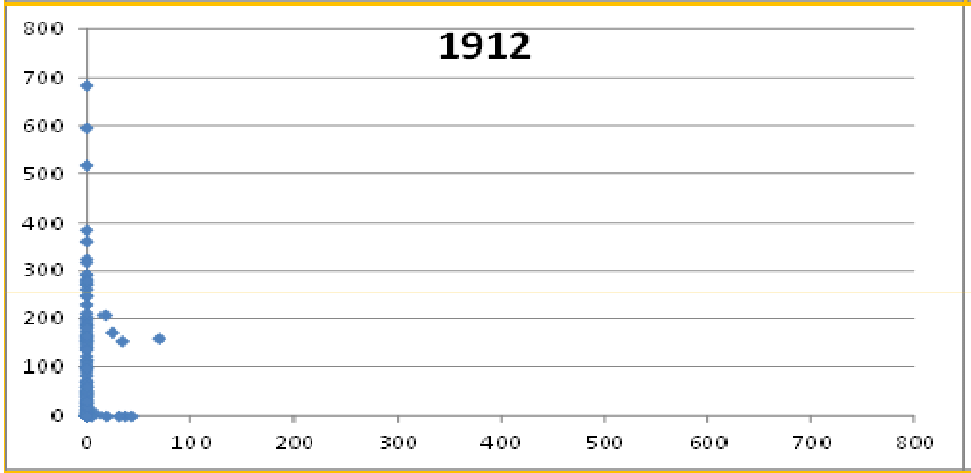


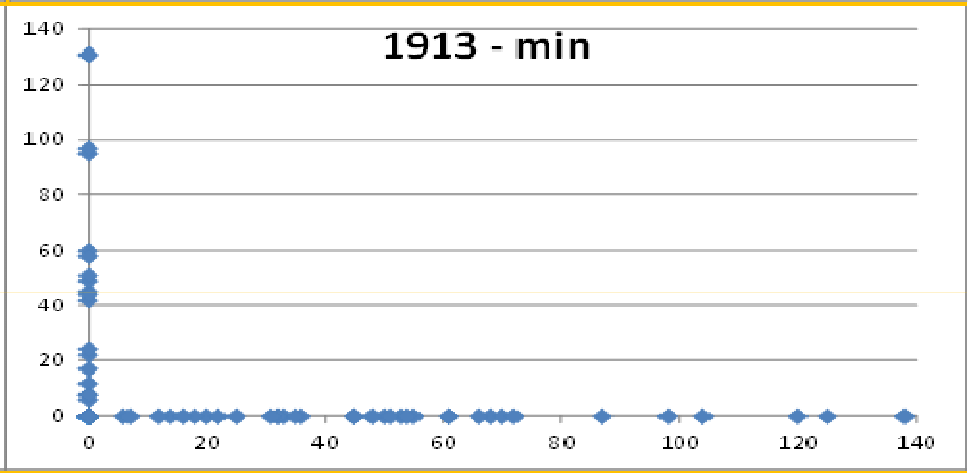
Switch effect

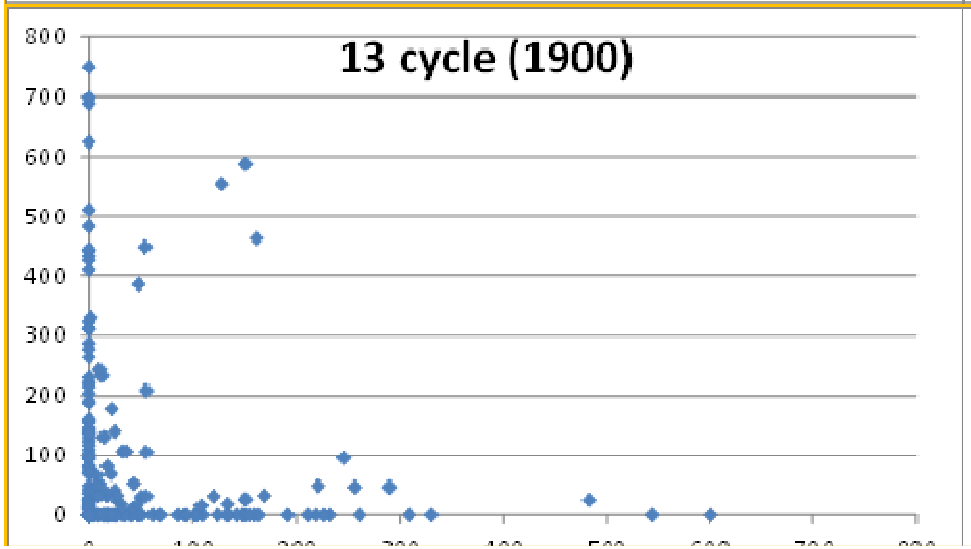
- Switch effect- quick change of activity from one hemisphere to another.
- The effect is observation at the beginning and end of the solar cycle.
- This effect might be a control centre cycles of Northern and Southern hemispheres.

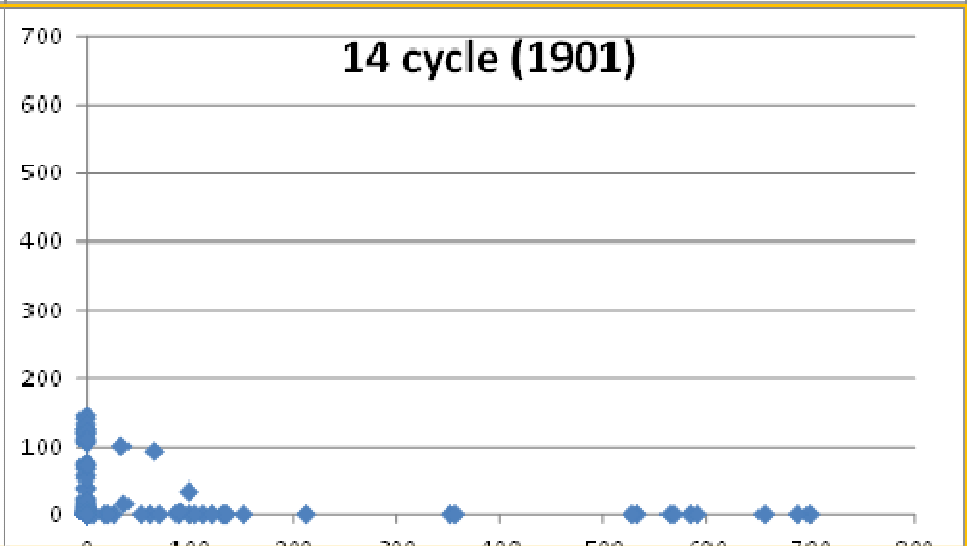

1974
3500
3000
2500
2000
1500
1000
500
0
0
500
1000
1500
2000
2500
3000
3500


1975
2500
2000
1500
1000
500
0
0
500
1000
1500
2000
2500

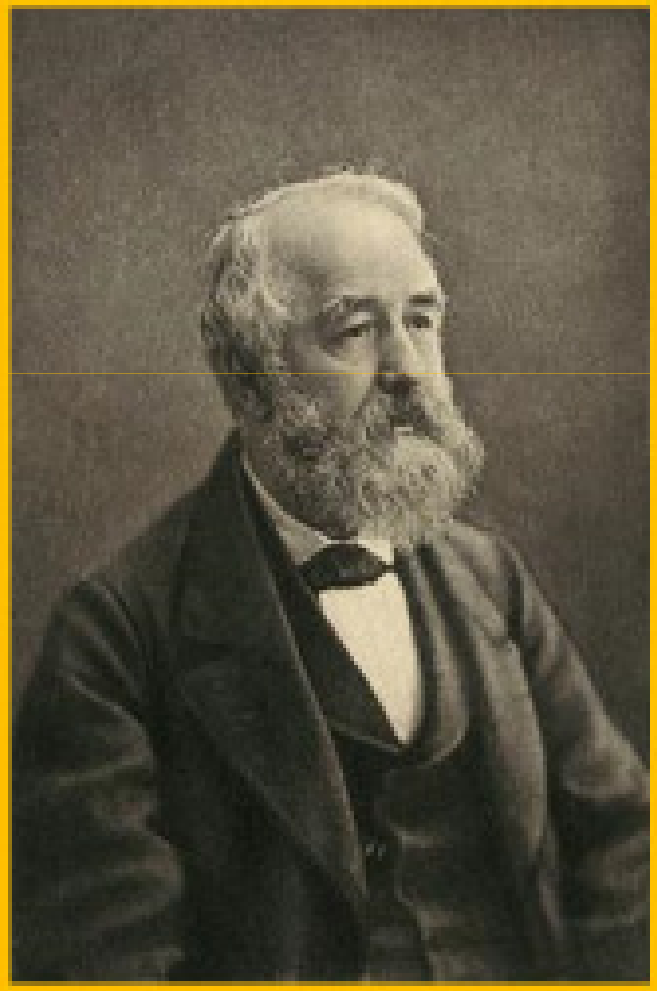

1912
800
700
600
500
400
300
200
100
0
0
100
200
300
400
500
600
700
800


1913 - min
140
120
100
80
60
40
20
0
0
20
40
60
80
100
120
140


13 cycle (1900)
800
700
600
500
400
300
200
100
0


14 cycle (1901)
700
600
500
400
300
200
100
0

View solar cycle as a superposition of periods.

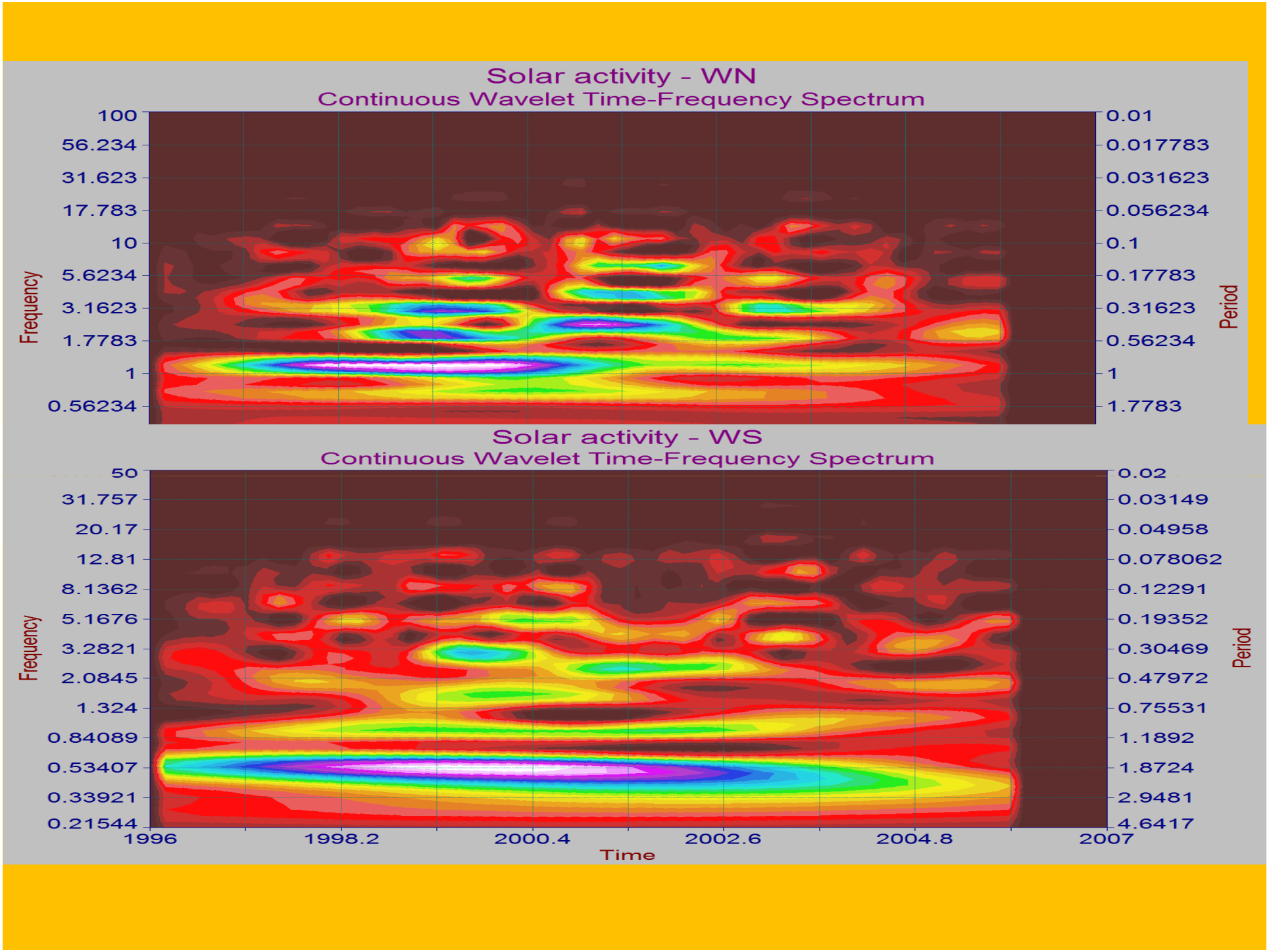


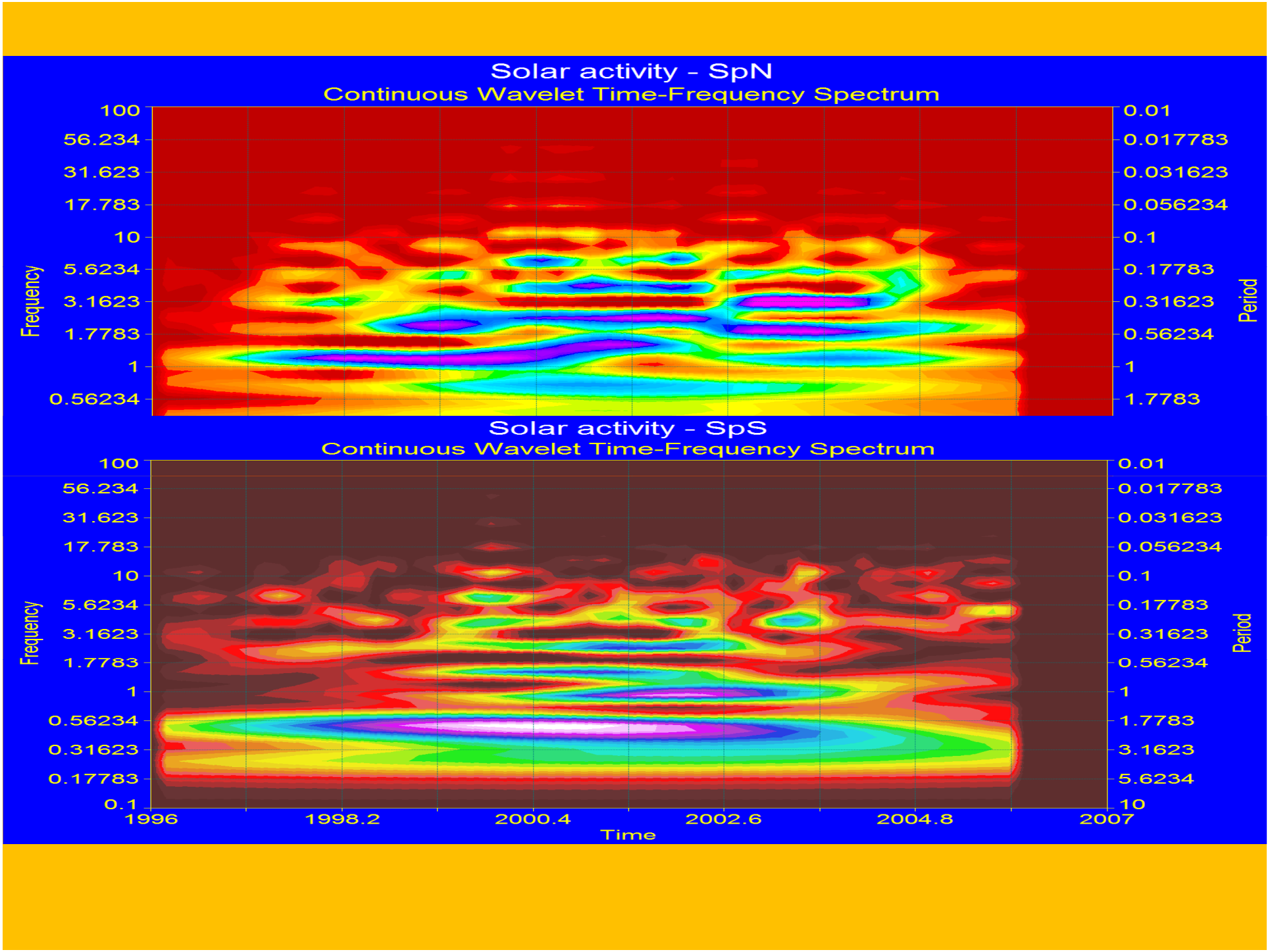
Superposition-curve hypothesis of the relative sunspot number occurs as a result of the composition many periodic components.

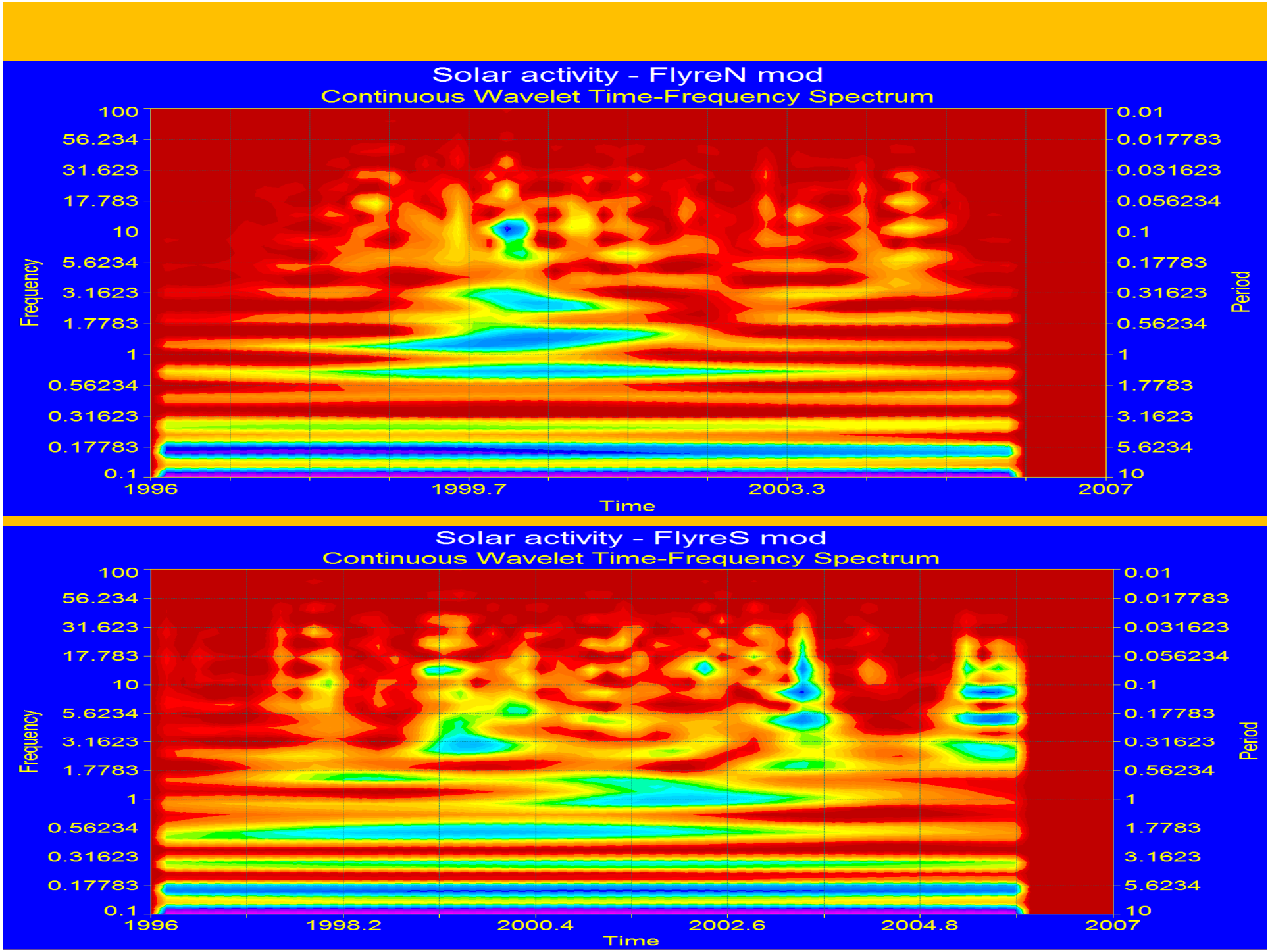
R.Wolf (1889 year.)

Application of wavelet analysis

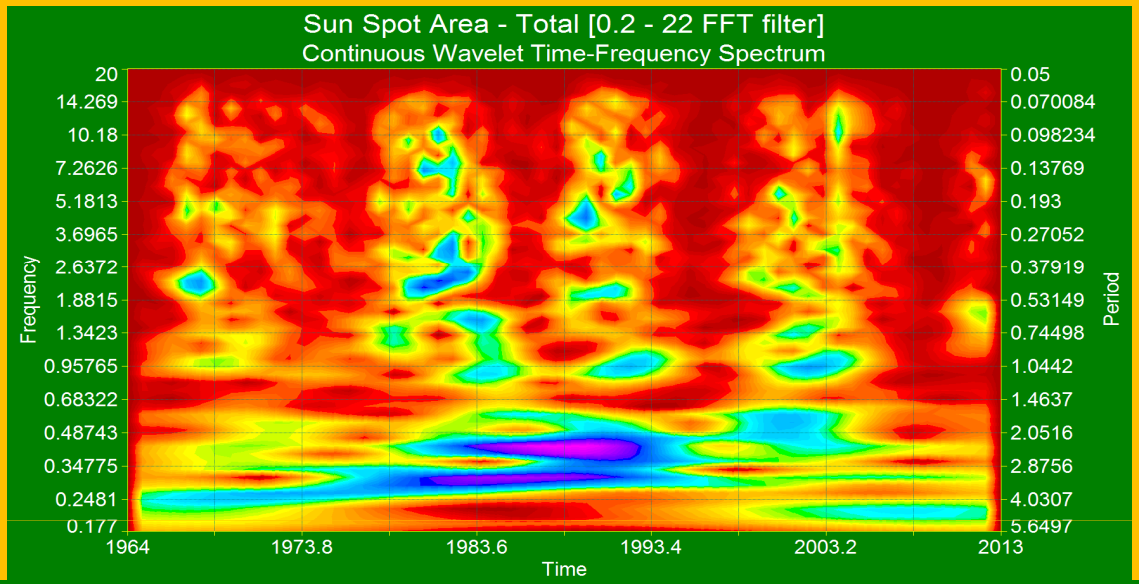
- Application of wavelet analysis enables you to see the detailed structure of the process and the evolution of harmonic component of the signal over time.
- **CONTINUOUS WAVELET TIME-FREQUENCY SPECTRUM**
- On time-frequency spectrum of harmonic components of the signal are seen as bright spots oriented along the time axis. These spots have bends, merging, and transitions from one period to another.
- **It identifies "Spectra" periods which form a cycle of activity!**
- **GLOBAL WAVELET SPECTRA**
- With the help of the global spectrum of wavelet in frequency range, you can find out the distribution of signal energy along the time axis.
- **It identifies the main characteristics of the phases of activity!**
- **BAND-PASS WAVELET FILTERING**
- **Allows you to highlight the dynamics of groups of periods!**

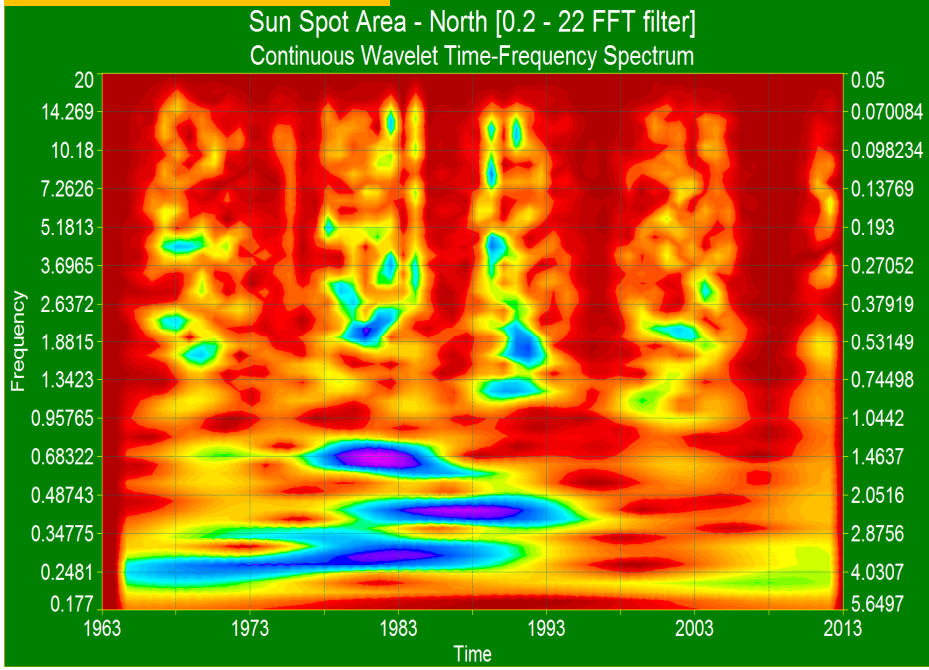

Solar activity - WN
Continuous Wavelet Time-Frequency Spectrum
Frequency
100
56.234
31.623
17.783
10
5.6234
3.1623
1.7783
1
0.56234
Period
0.01
0.017783
0.031623
0.056234
0.1
0.17783
0.31623
0.56234
1
1.7783
Solar activity - WS
Continuous Wavelet Time-Frequency Spectrum
Frequency
50
31.757
20.17
12.81
8.1362
5.1676
3.2821
2.0845
1.324
0.84089
0.53407
0.33921
0.21544
Period
0.02
0.03149
0.04958
0.078062
0.12291
0.19352
0.30469
0.47972
0.75531
1.1892
1.8724
2.9481
4.6417
1996
1998.2
2000.4
2002.6
2004.8
2007
Time

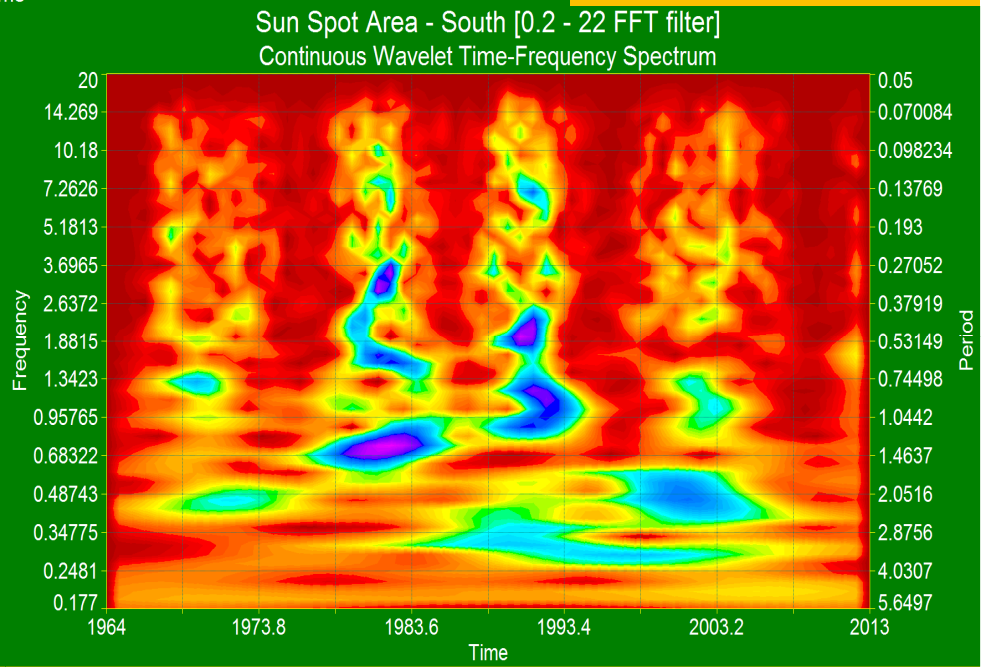

Solar activity - SpN
Continuous Wavelet Time-Frequency Spectrum
Frequency
100
56.234
31.623
17.783
10
5.6234
3.1623
1.7783
1
0.56234
Period
0.01
0.017783
0.031623
0.056234
0.1
0.17783
0.31623
0.56234
1
1.7783
Solar activity - SpS
Continuous Wavelet Time-Frequency Spectrum
Frequency
100
56.234
31.623
17.783
10
5.6234
3.1623
1.7783
1
0.56234
0.31623
0.17783
0.1
Period
0.01
0.017783
0.031623
0.056234
0.1
0.17783
0.31623
0.56234
1
1.7783
3.1623
5.6234
10
1996
1998.2
2000.4
2002.6
2004.8
2007
Time


Solar activity - FlyreN mod
Continuous Wavelet Time-Frequency Spectrum
Frequency
100
56.234
31.623
17.783
10
5.6234
3.1623
1.7783
1
0.56234
0.31623
0.17783
0.1
Period
0.01
0.017783
0.031623
0.056234
0.1
0.17783
0.31623
0.56234
1
1.7783
3.1623
5.6234
10
1996
1999.7
2003.3
2007
Time
Solar activity - FlyreS mod
Continuous Wavelet Time-Frequency Spectrum
Frequency
100
56.234
31.623
17.783
10
5.6234
3.1623
1.7783
1
0.56234
0.31623
0.17783
0.1
Period
0.01
0.017783
0.031623
0.056234
0.1
0.17783
0.31623
0.56234
1
1.7783
3.1623
5.6234
10
1996
1998.2
2000.4
2002.6
2004.8
2007
Time

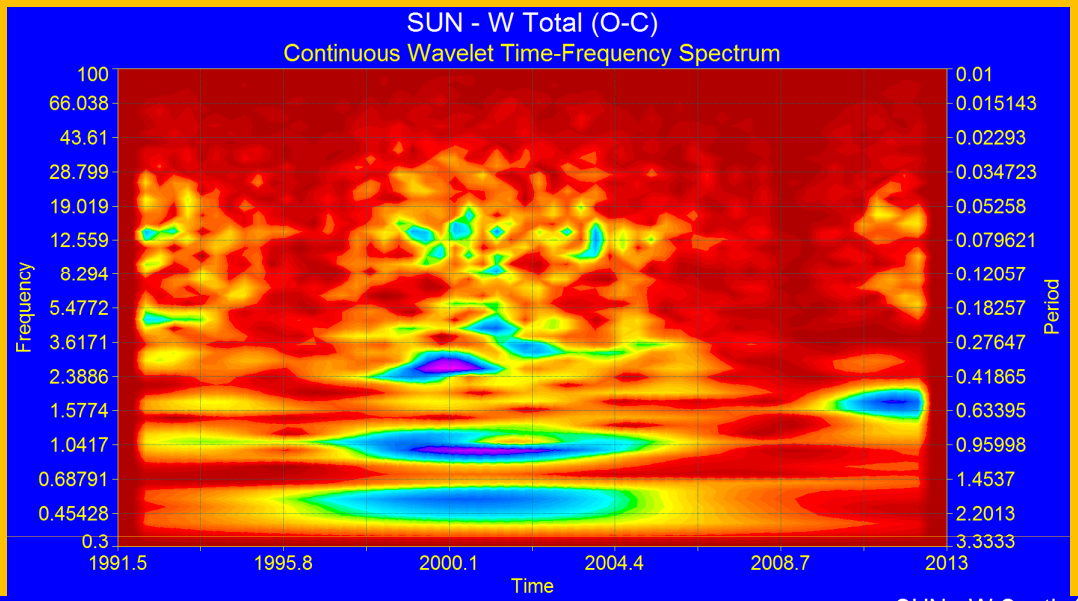
Wavelet spectrum for Sp (Total, N and S)
(1964 – 2013 гг.)

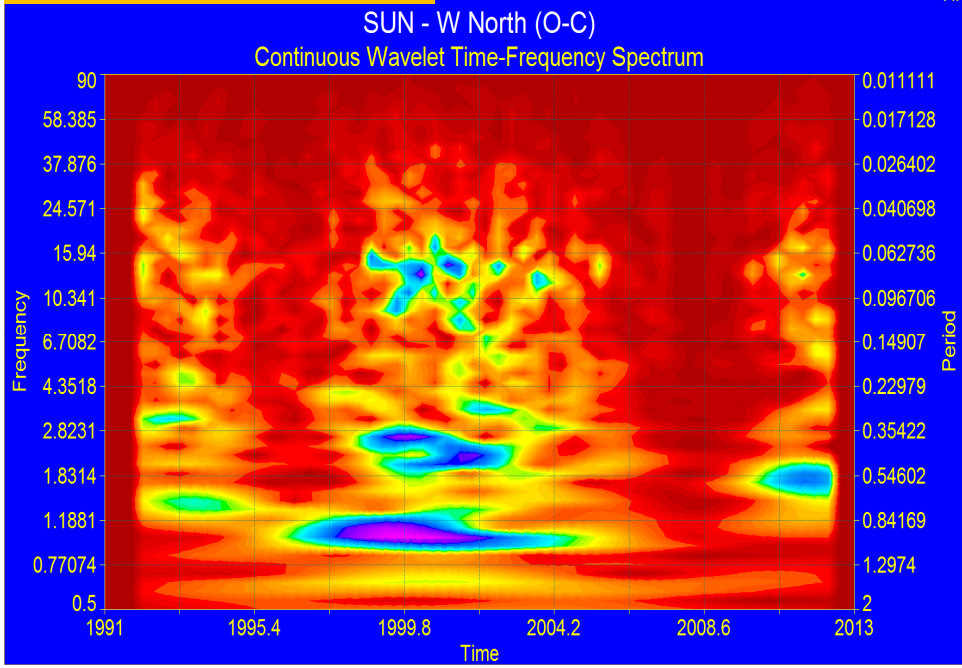


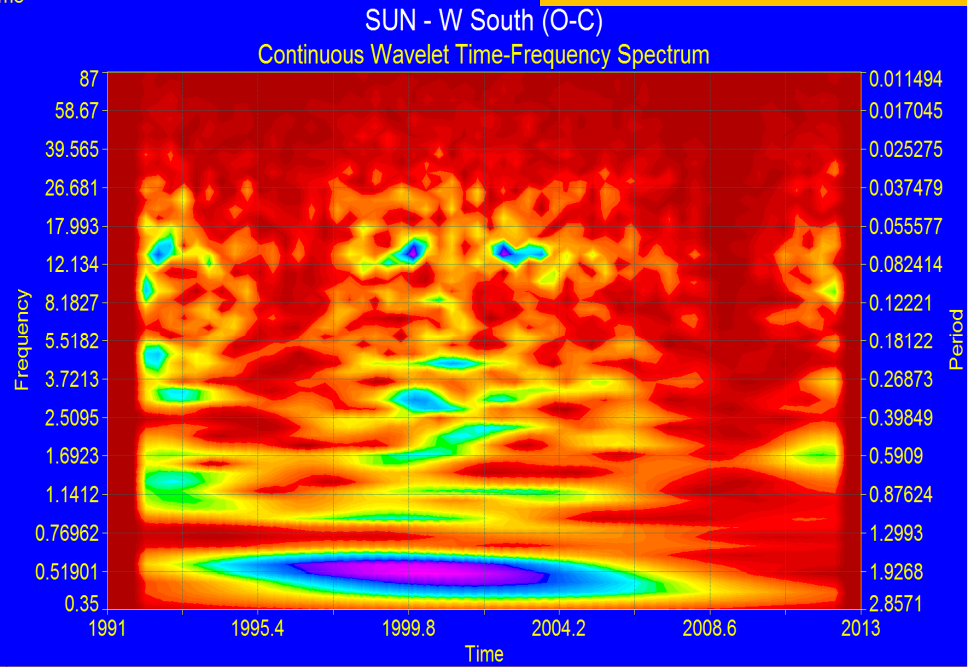




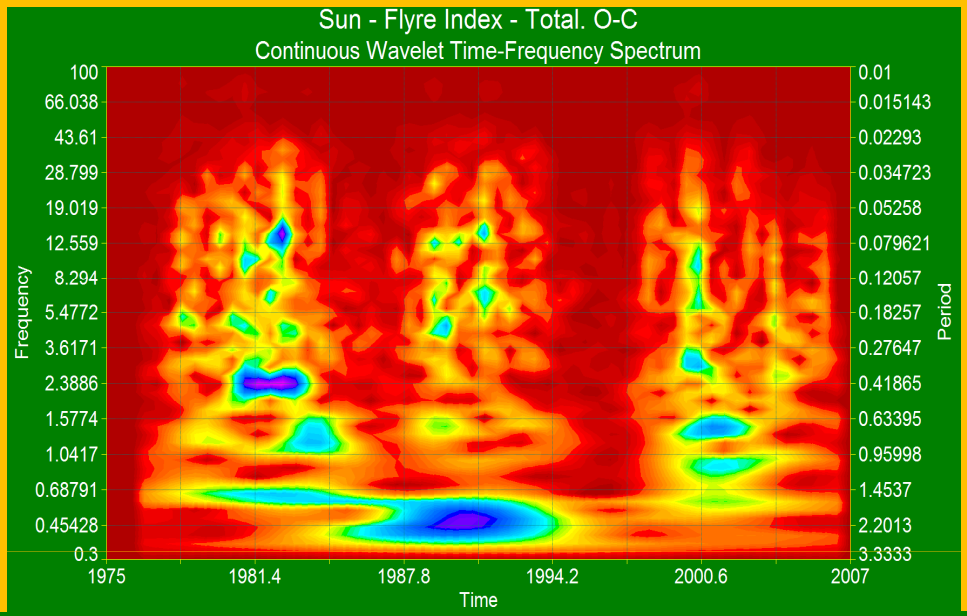
Wavelet spectrum for W (O-C Total , N and S)
(1992 – 2013 years.)

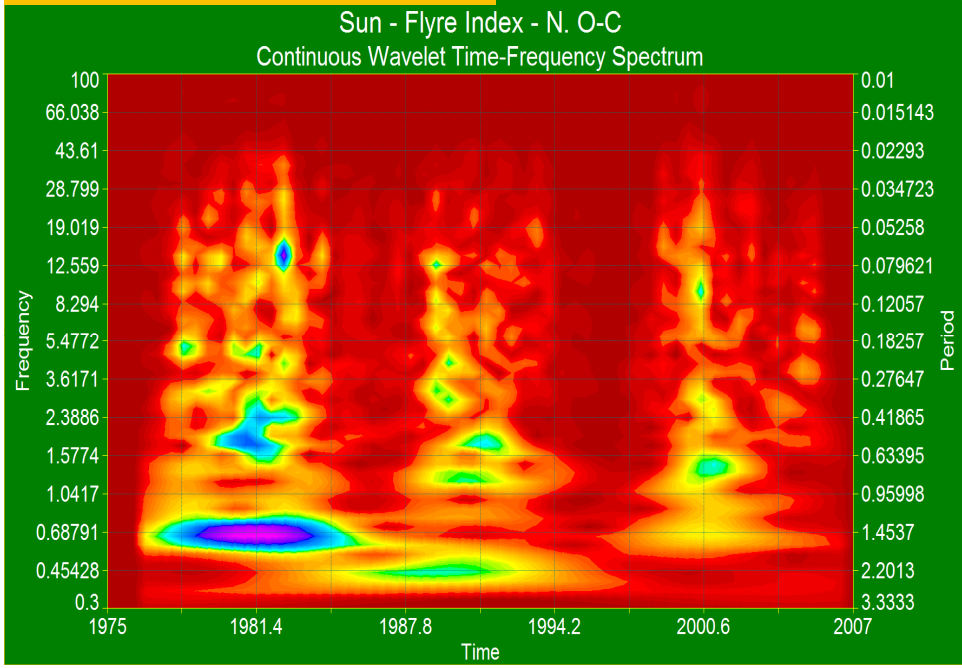


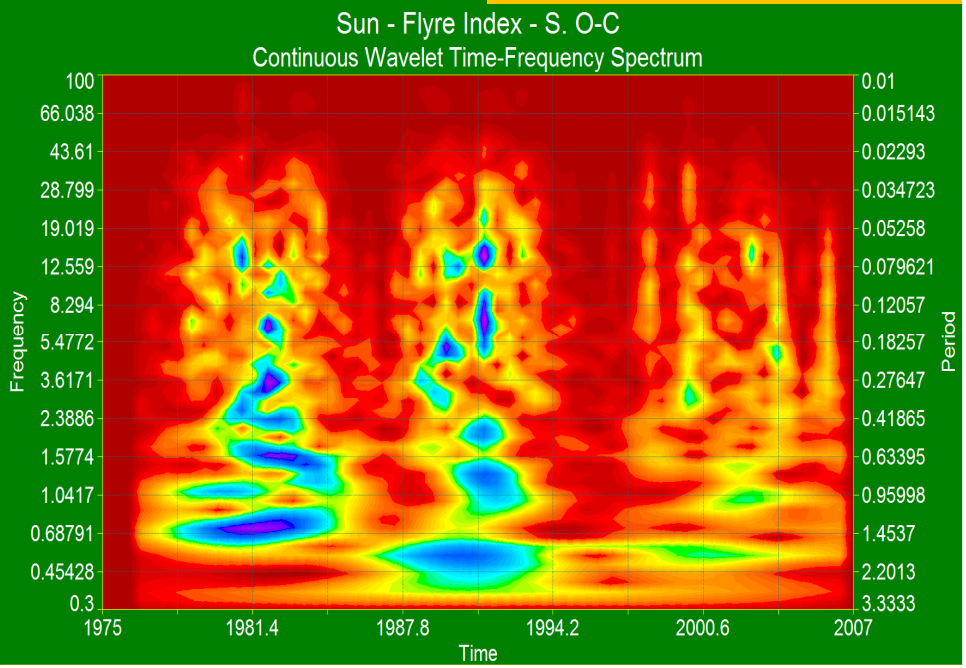




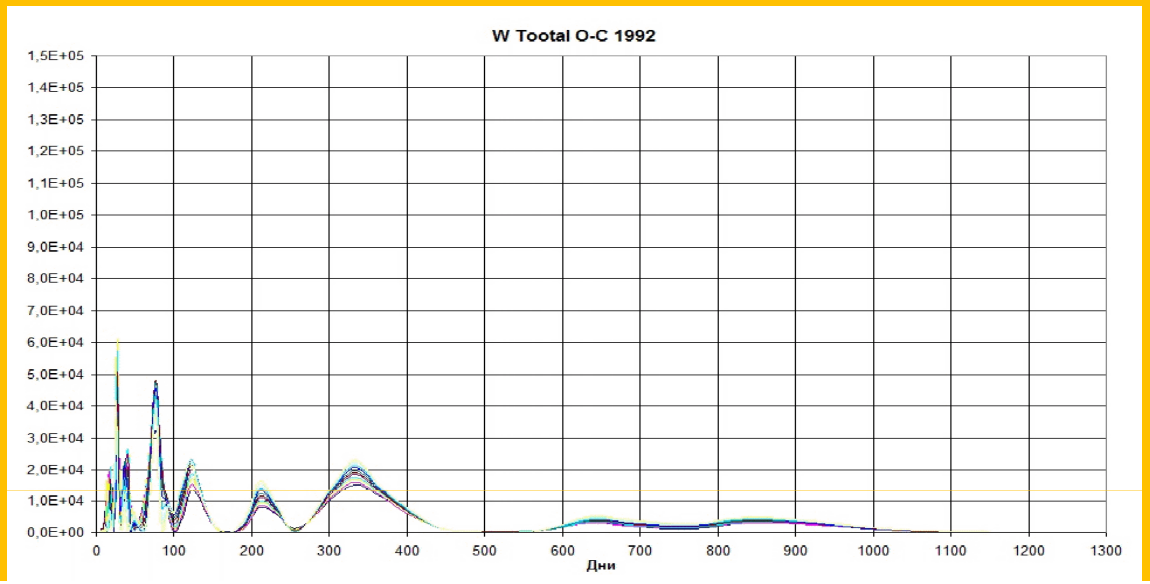
Wavelet spectrum Flare Index (Total, N and S)
(1975 – 2007 years.)

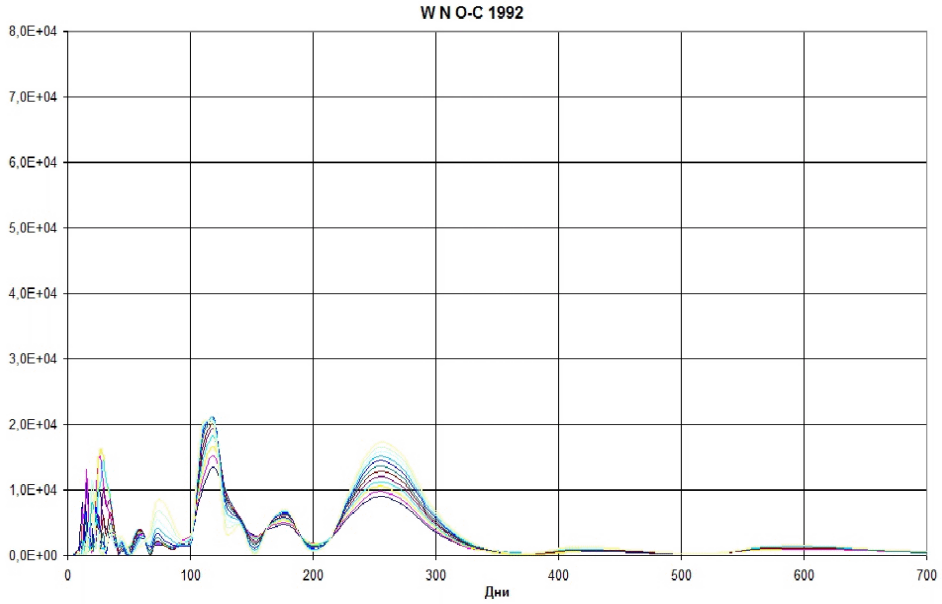


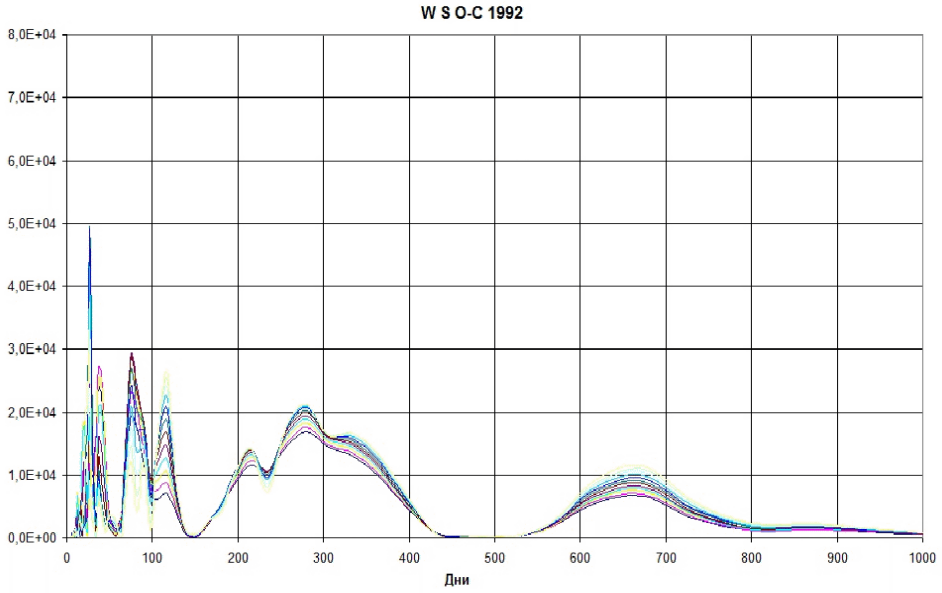




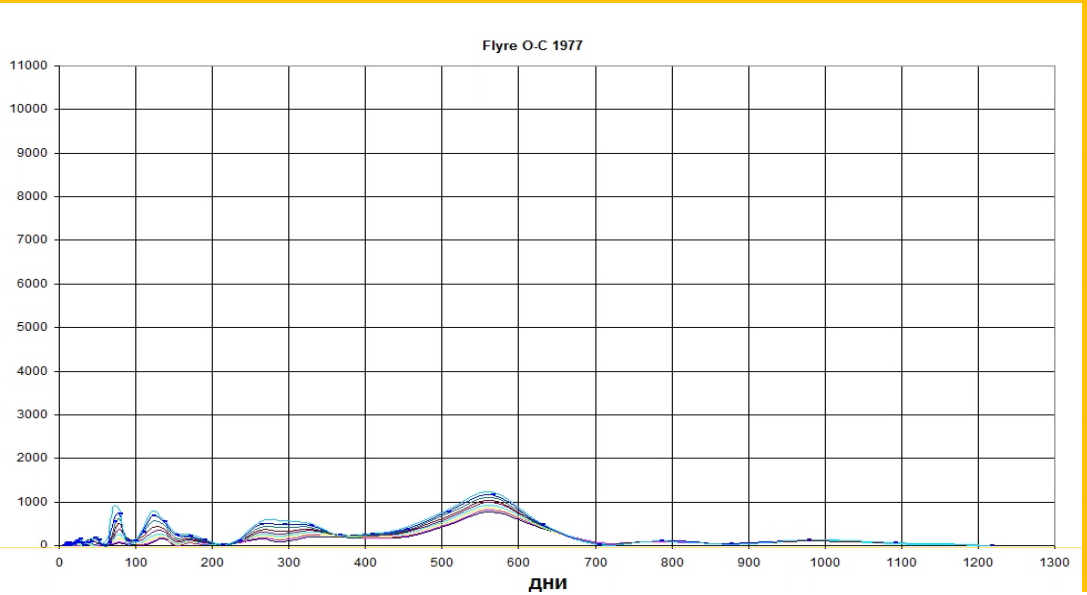
Evolution of spectr periods W (Total, N and S)

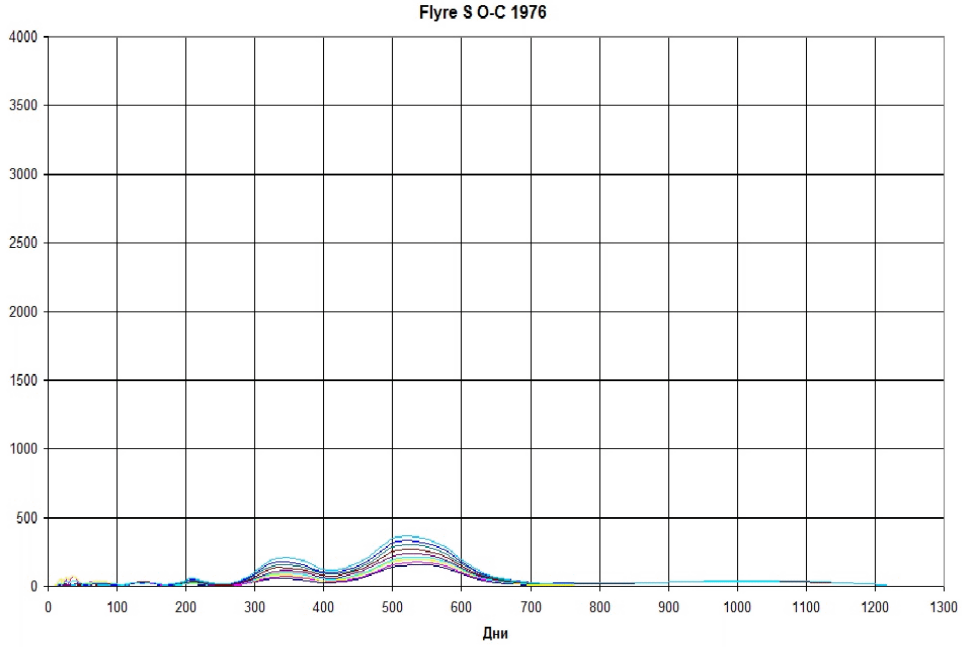


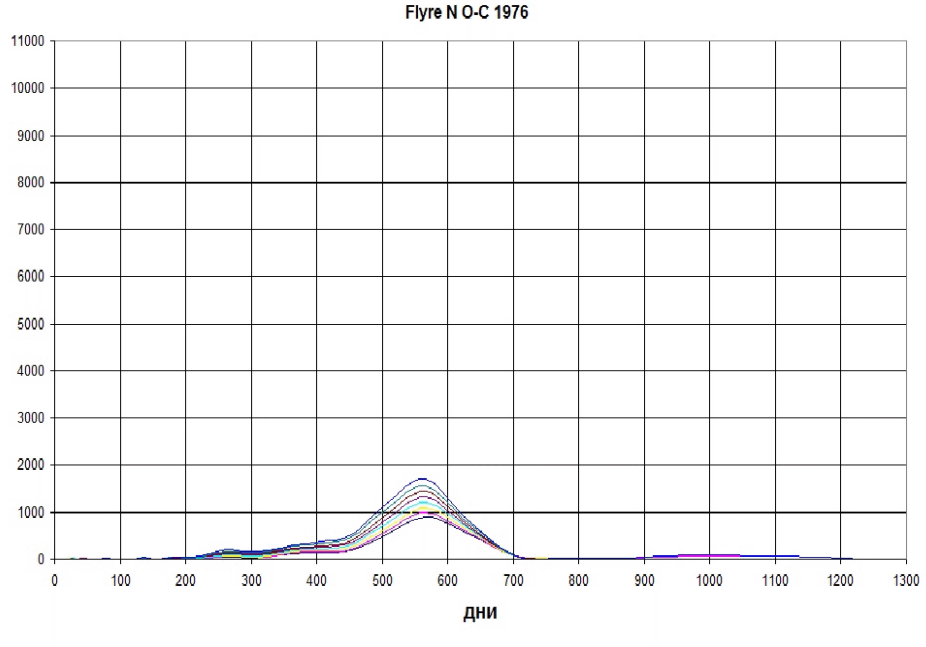


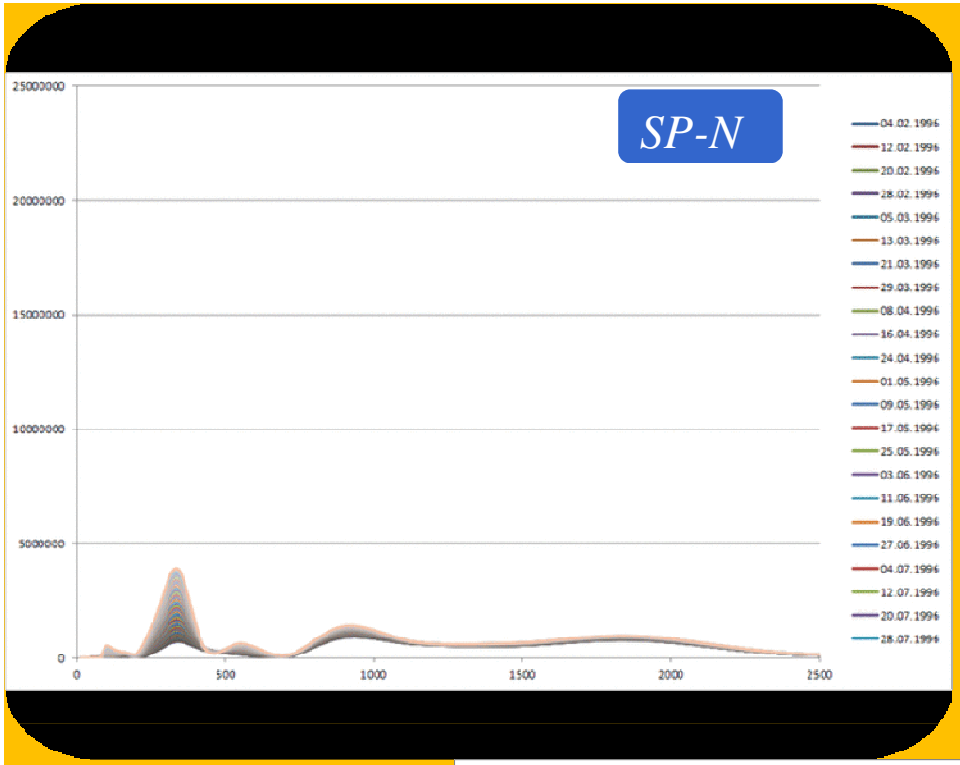


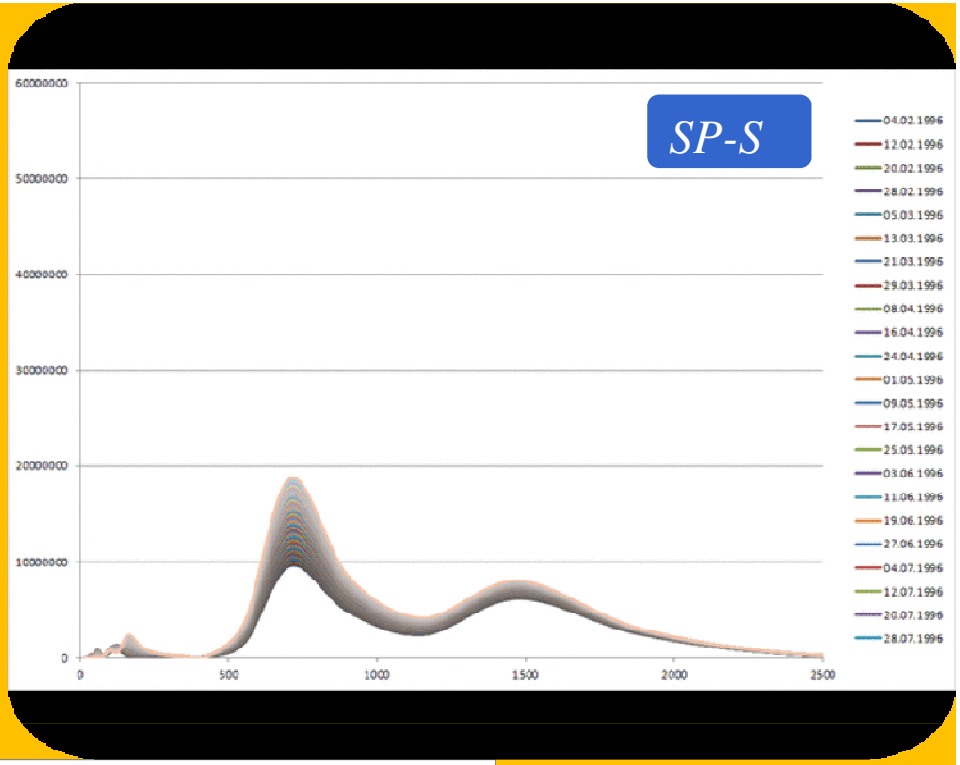
Evolution spectr periods Flare index (Total, N and S)

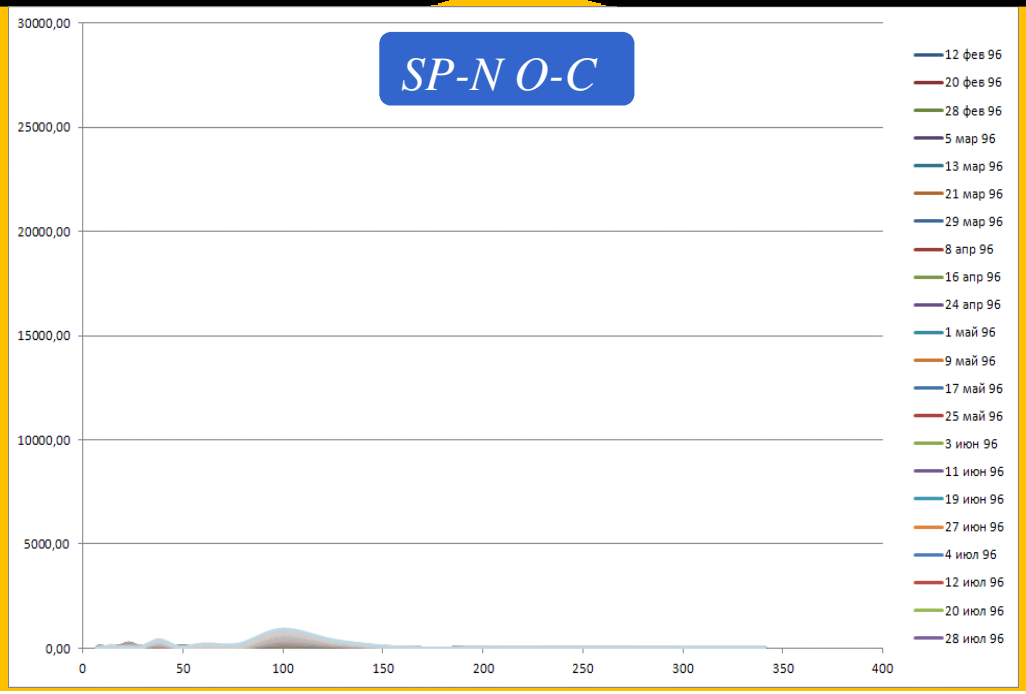






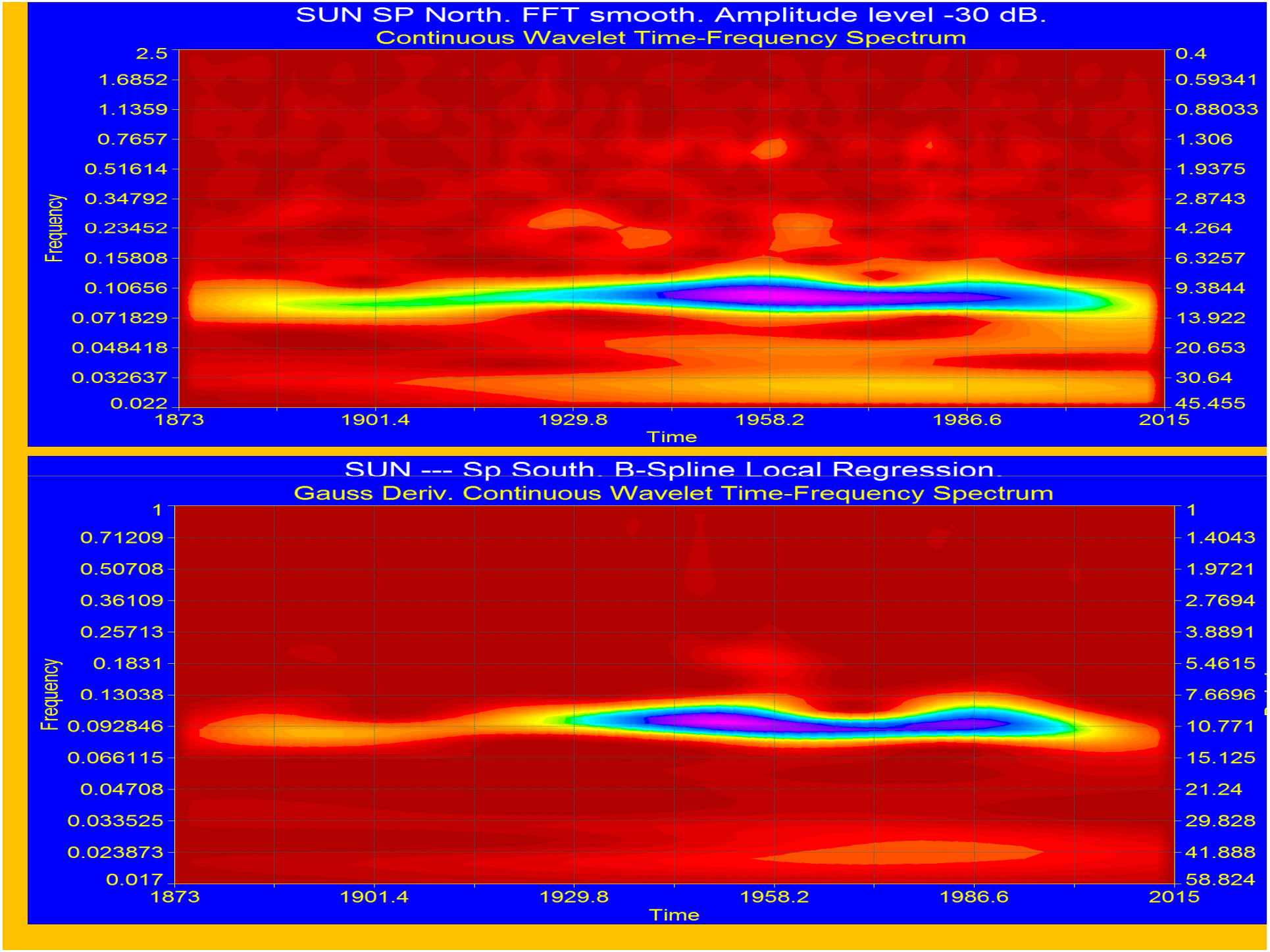

SP-N
25000000
20000000
15000000
10000000
5000000
0
0
500
1000
1500
2000
2500
04.02.1996
12.02.1996
20.02.1996
28.02.1996
05.03.1996
13.03.1996
21.03.1996
29.03.1996
08.04.1996
16.04.1996
24.04.1996
01.05.1996
09.05.1996
17.05.1996
25.05.1996
03.06.1996
11.06.1996
19.06.1996
27.06.1996
04.07.1996
12.07.1996
20.07.1996
28.07.1996

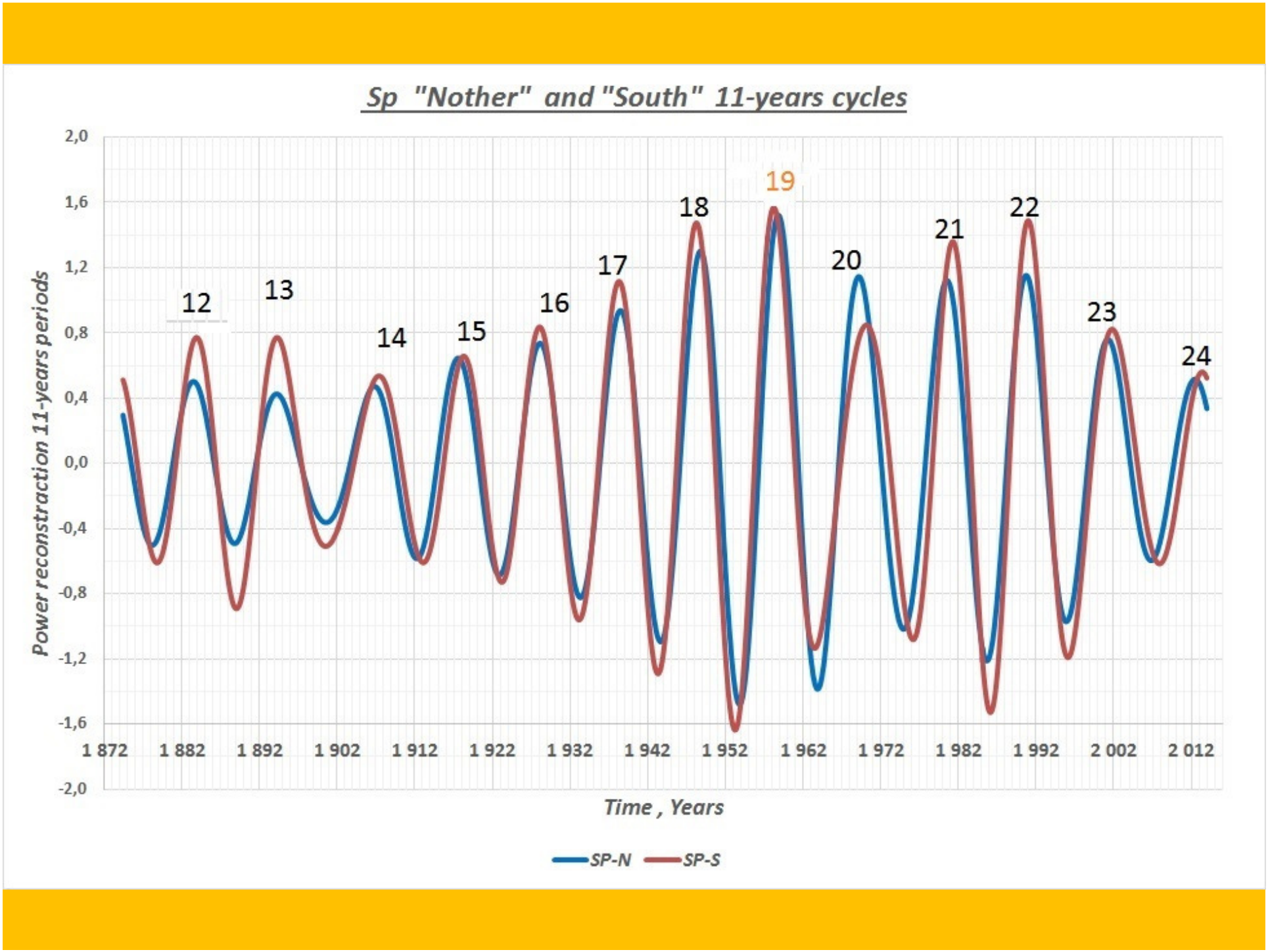

SP-S
60000000
50000000
40000000
30000000
20000000
10000000
0
0
500
1000
1500
2000
2500
04.02.1996
12.02.1996
20.02.1996
28.02.1996
05.03.1996
13.03.1996
21.03.1996
29.03.1996
08.04.1996
16.04.1996
24.04.1996
01.05.1996
09.05.1996
17.05.1996
25.05.1996
03.06.1996
11.06.1996
19.06.1996
27.06.1996
04.07.1996
12.07.1996
20.07.1996
28.07.1996


SP-N O-C
30000,00
25000,00
20000,00
15000,00
10000,00
5000,00
0,00
0
50
100
150
200
250
300
350
400
12 фев 96
20 фев 96
28 фев 96
5 мар 96
13 мар 96
21 мар 96
29 мар 96
8 апр 96
16 апр 96
24 апр 96
1 май 96
9 май 96
17 май 96
25 май 96
3 июн 96
11 июн 96
19 июн 96
27 июн 96
4 июл 96
12 июл 96
20 июл 96
28 июл 96

«11 year» cycle

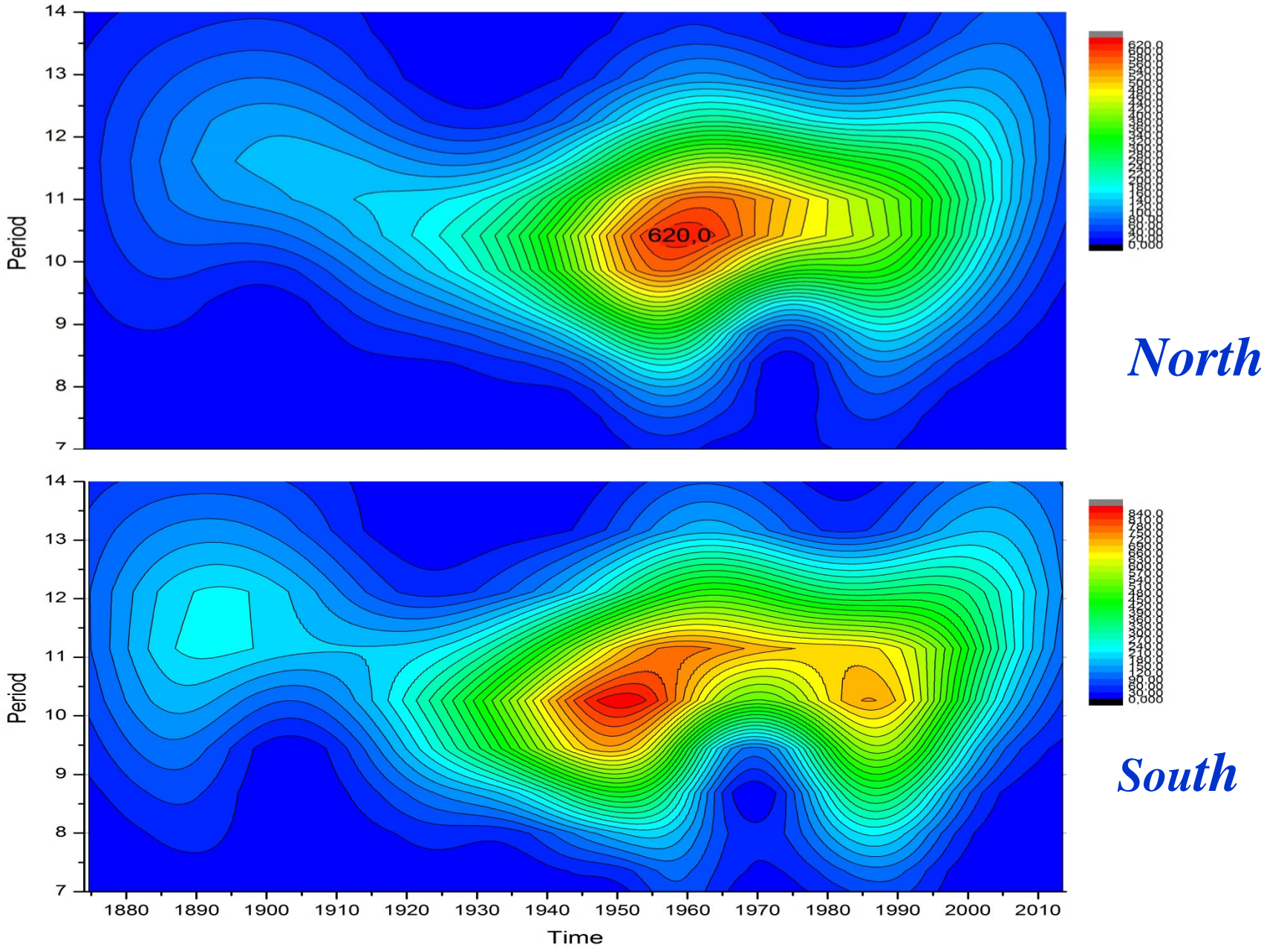
- Investigation properties Nothern and Southern solar cycles

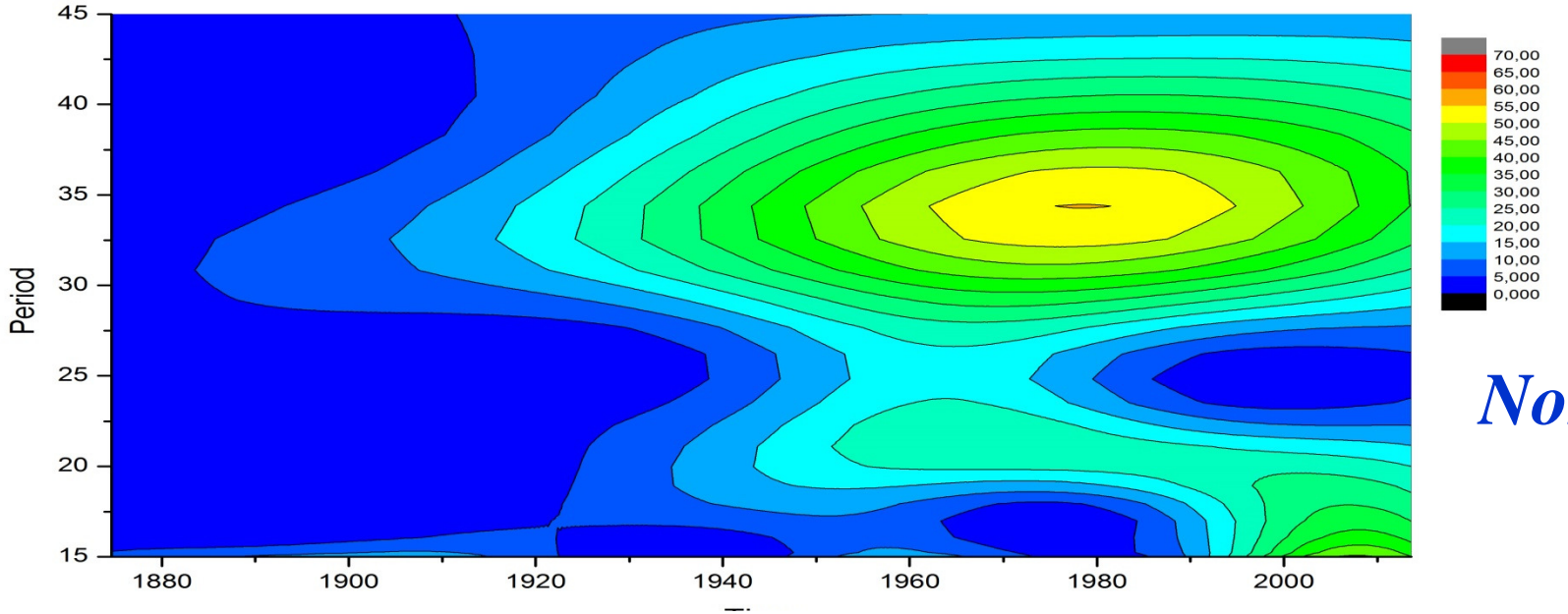

SUN SP North. FFT smooth. Amplitude level -30 dB.
Continuous Wavelet Time-Frequency Spectrum
Frequency
2.5
1.6852
1.1359
0.7657
0.51614
0.34792
0.23452
0.15808
0.10656
0.071829
0.048418
0.032637
0.022
0.4
0.59341
0.88033
1.306
1.9375
2.8743
4.264
6.3257
9.3844
13.922
20.653
30.64
45.455
1873
1901.4
1929.8
1958.2
1986.6
2015
Time
SUN --- Sp South. B-Spline Local Regression.
Gauss Deriv. Continuous Wavelet Time-Frequency Spectrum
Frequency
1
0.71209
0.50708
0.36109
0.25713
0.1831
0.13038
0.092846
0.066115
0.04708
0.033525
0.023873
0.017
1
1.4043
1.9721
2.7694
3.8891
5.4615
7.6696
10.771
15.125
21.24
29.828
41.888
58.824
1873
1901.4
1929.8
1958.2
1986.6
2015
Time


Sp "Nother" and "South" 11-years cycles
Power reconstraction 11-years periods
2,0
1,6
1,2
0,8
0,4
0,0
-0,4
-0,8
-1,2
-1,6
-2,0
12
13
14
15
16
17
18
19
20
21
22
23
24
1 872
1 882
1 892
1 902
1 912
1 922
1 932
1 942
1 952
1 962
1 972
1 982
1 992
2 002
2 012
Time , Years
SP-N
SP-S

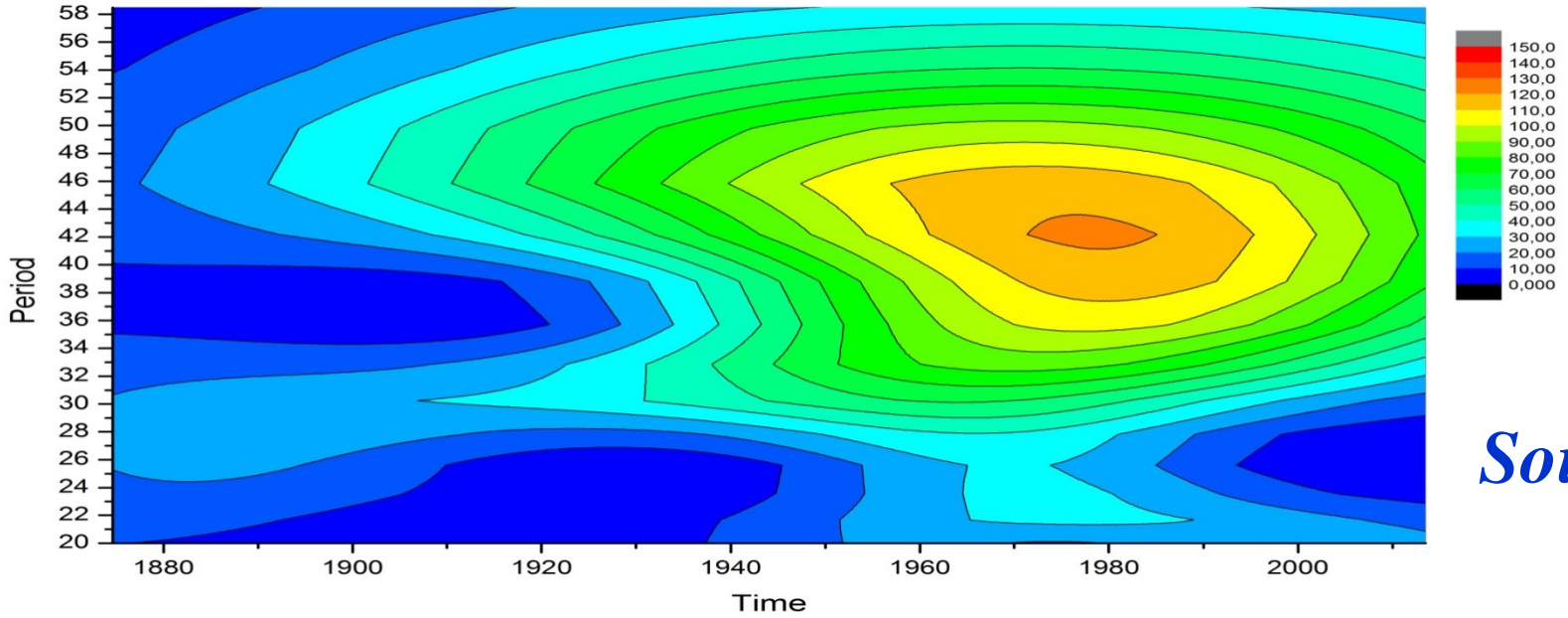
N and S cycles activity

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	


Period
14
13
12
11
10
9
8
7
620,0
620,0
600,0
580,0
560,0
540,0
520,0
500,0
480,0
460,0
440,0
420,0
400,0
380,0
360,0
340,0
320,0
300,0
280,0
260,0
240,0
220,0
200,0
180,0
160,0
140,0
120,0
100,00
80,000
60,000
40,000
20,000
0,000
North
Period
14
13
12
11
10
9
8
7
840,0
810,0
780,0
750,0
720,0
690,0
660,0
630,0
600,0
570,0
540,0
510,0
480,0
450,0
420,0
390,0
360,0
330,0
300,0
270,0
240,0
210,0
180,0
150,0
120,0
90,00
60,000
30,000
0,000
South
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Time

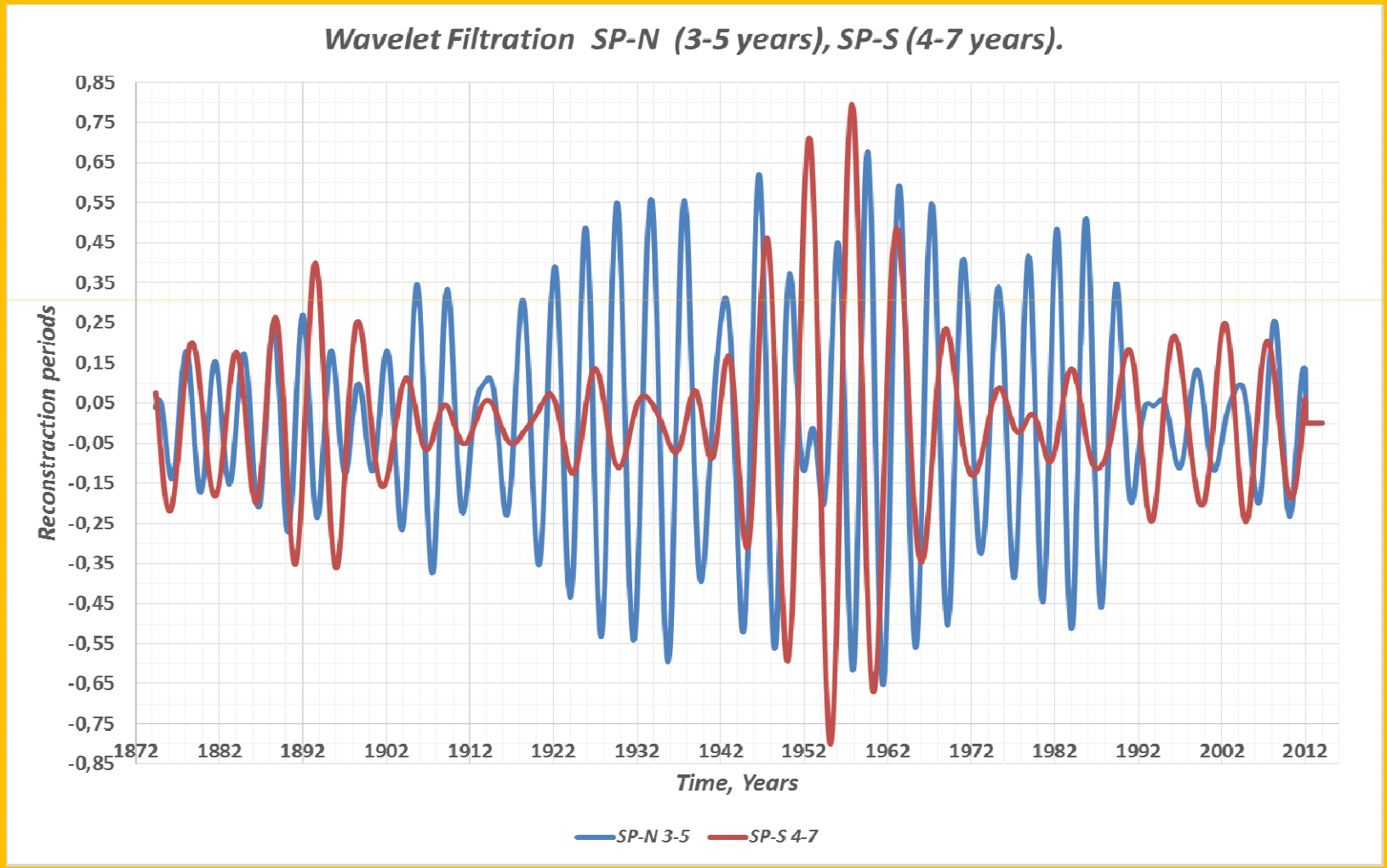

Period
45
40
35
30
25
20
15
1880
1900
1920
1940
1960
1980
2000
70,00
65,00
60,00
55,00
50,00
45,00
40,00
35,00
30,00
25,00
20,00
15,00
10,00
5,000
0,000

North

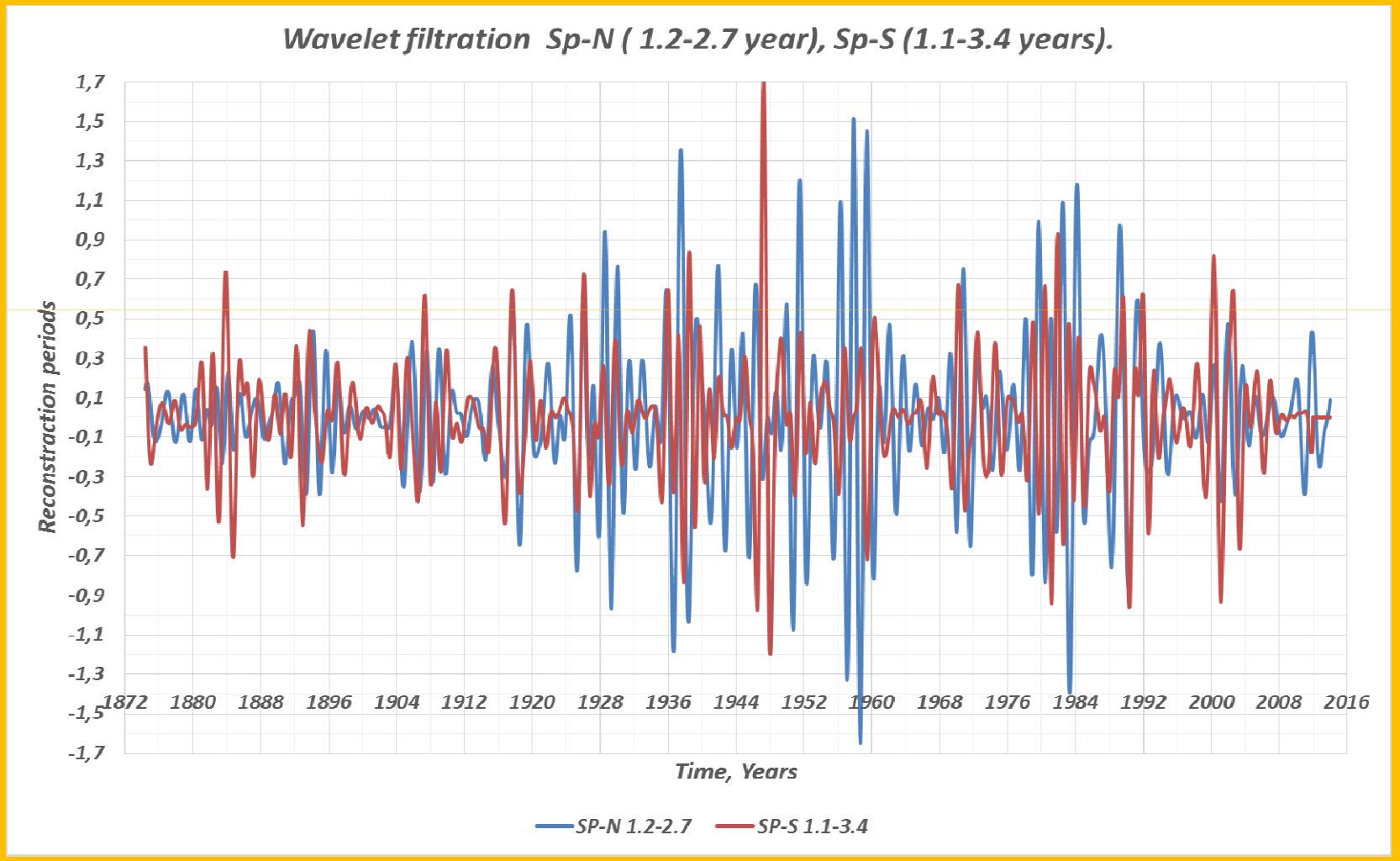

Period
58
56
54
52
50
48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
1880
1900
1920
1940
1960
1980
2000
Time
150,0
140,0
130,0
120,0
110,0
100,0
90,00
80,00
70,00
60,00
50,00
40,00
30,00
20,00
10,00
0,000

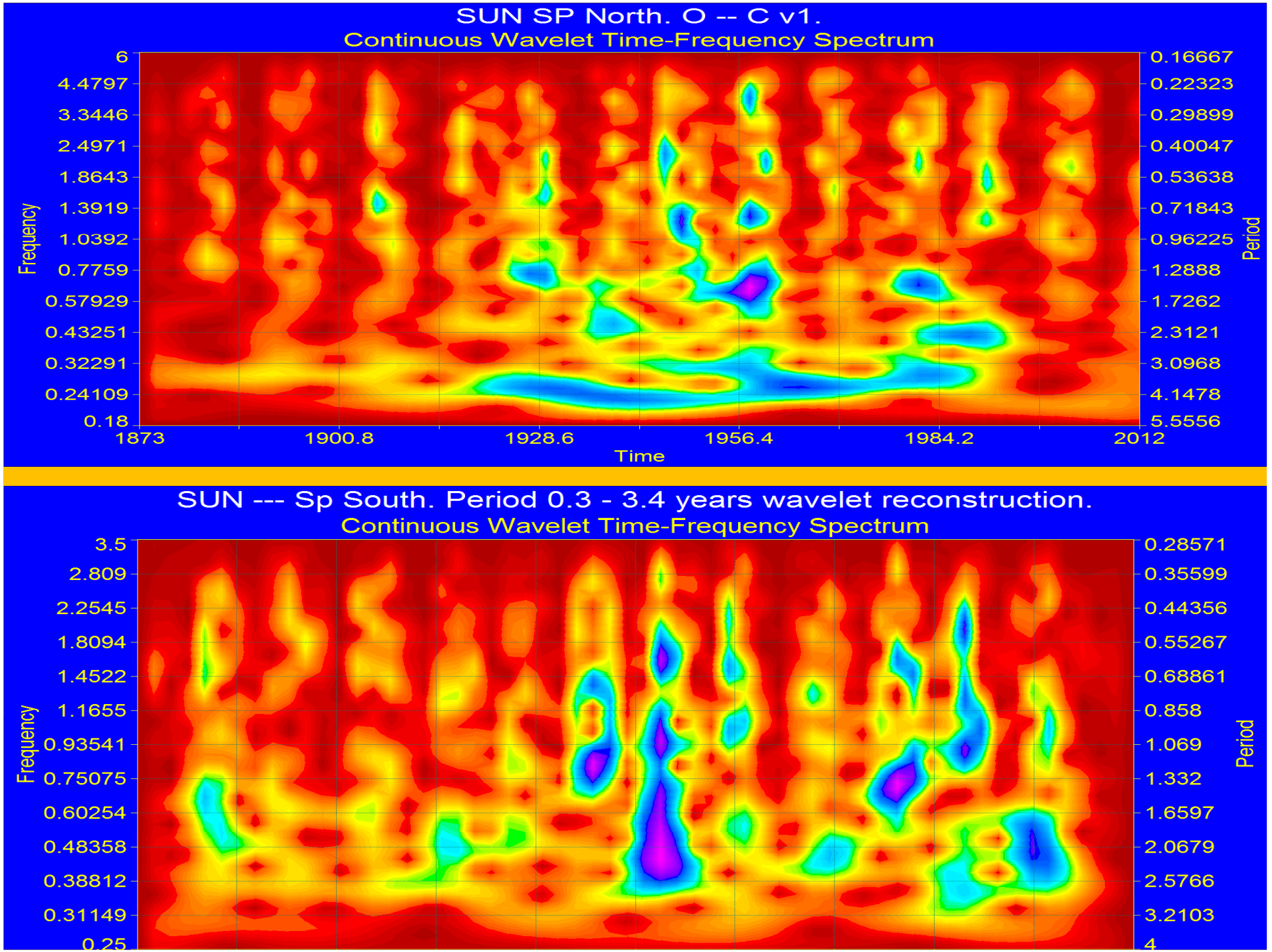
South

N and S cycles (period 3-7 years)



N and S cycle (1-3 years)




SUN SP North. O -- C v1.
Continuous Wavelet Time-Frequency Spectrum
Frequency
6
4.4797
3.3446
2.4971
1.8643
1.3919
1.0392
0.7759
0.57929
0.43251
0.32291
0.24109
0.18
Period
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
1873
1900.8
1928.6
1956.4
1984.2
2012
Time
SUN --- Sp South. Period 0.3 - 3.4 years wavelet reconstruction.
Continuous Wavelet Time-Frequency Spectrum
Frequency
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
Period
0.28571
0.35599
0.44356
0.55267
0.68861
0.858
1.069
1.332
1.6597
2.0679
2.5766
3.2103
4

Conclusion-1

1. As a result of the work done was calculated the wavelet spectra of major indices of solar activity.
2. Constructed the Spectra periods indexes showing their evolution over time.
3. Based on these calculations, the properties of the northern and southern hemisphere
4. The results show significant differences between periods of activity indexes in different hemispheres of the Sun.

Conclusion - 2

- Different manifestations of solar activity in the northern and the southern hemisphere is fundamental solar cycle and should be taken into account in the various models and forecasting.

- Based on the analysis of "trend" and "fluctuation" component for the northern and southern hemispheres on the various indices of activity can be determined by the basic properties of the solar cycle .
- .

Results - 1

- Application of Fourier filtering shows that the length of the 11-year cycle in the northern hemisphere on the Sp index varies in the range of 10.2-11.5-year and southern hemisphere 9.7- 13.2 years. The existence of the 35-year-old «Northern» and 42-year-old "Southern" cycles was revealed.

Results - 2

- The formation of each cycle is defined as a result of the combined effect of long-period (2-5 years) and short-period (less than 2 years).
- Long-period processes in the transition from cycle to cycle show merger, separation, modulation and recurrent attenuation.

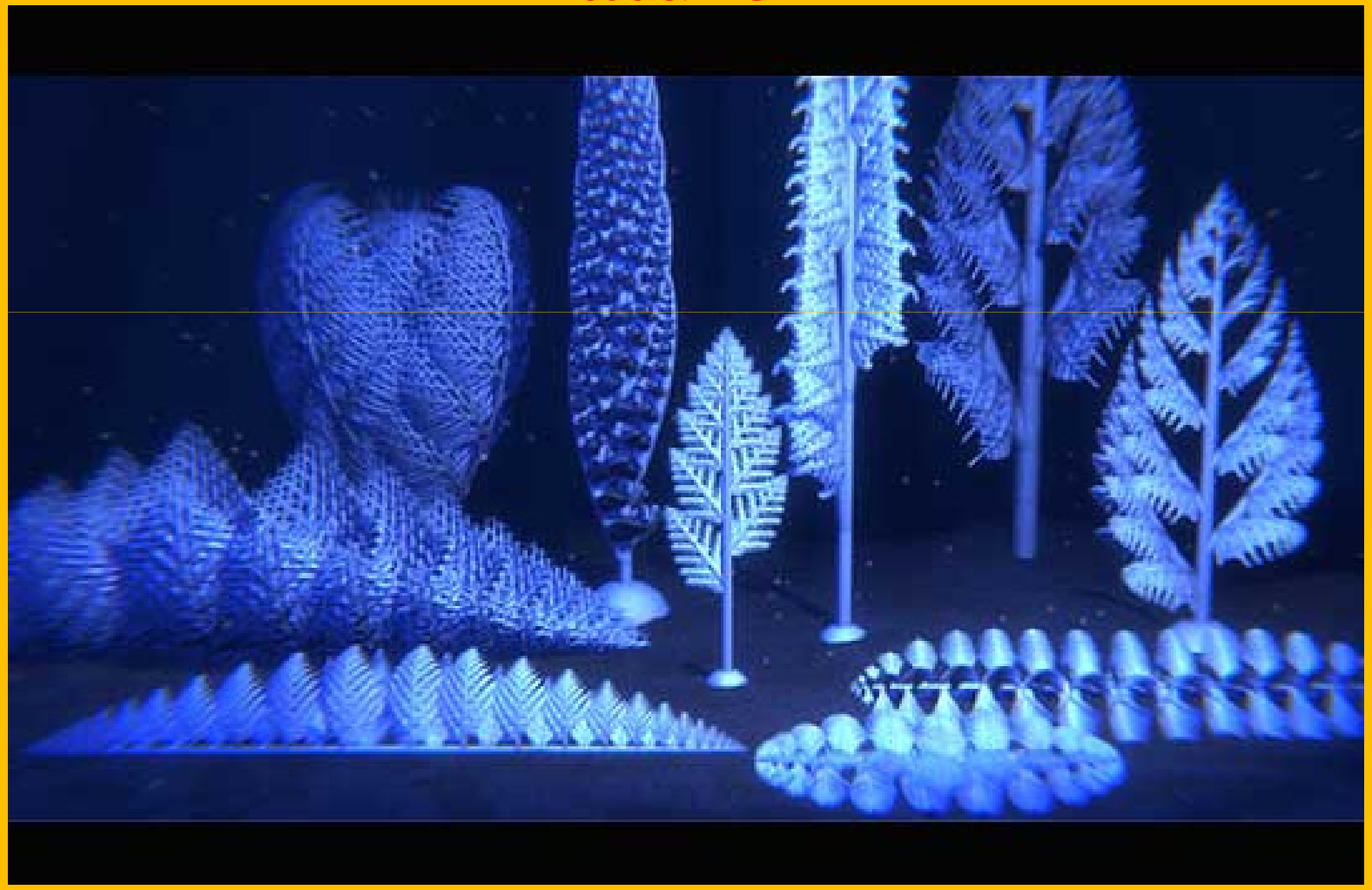
Results - 3

- Manifestation of abnormal activity in the increase phase, maximum and decrease phase of solar cycle is formed by simultaneous intensifying of the short-period processes.
- The spectra of these periods are markedly different in the northern and southern hemispheres.

Results - 4

- The effect of a "key" which presupposes the existence of the Centre management processes increase the cycles of the northern and southern hemisphere.
- Management takes place at different time scales from 11-year cycles to interim periods and short term changes.

Symmetry and asymmetry in nature



Many thanks for your attention !