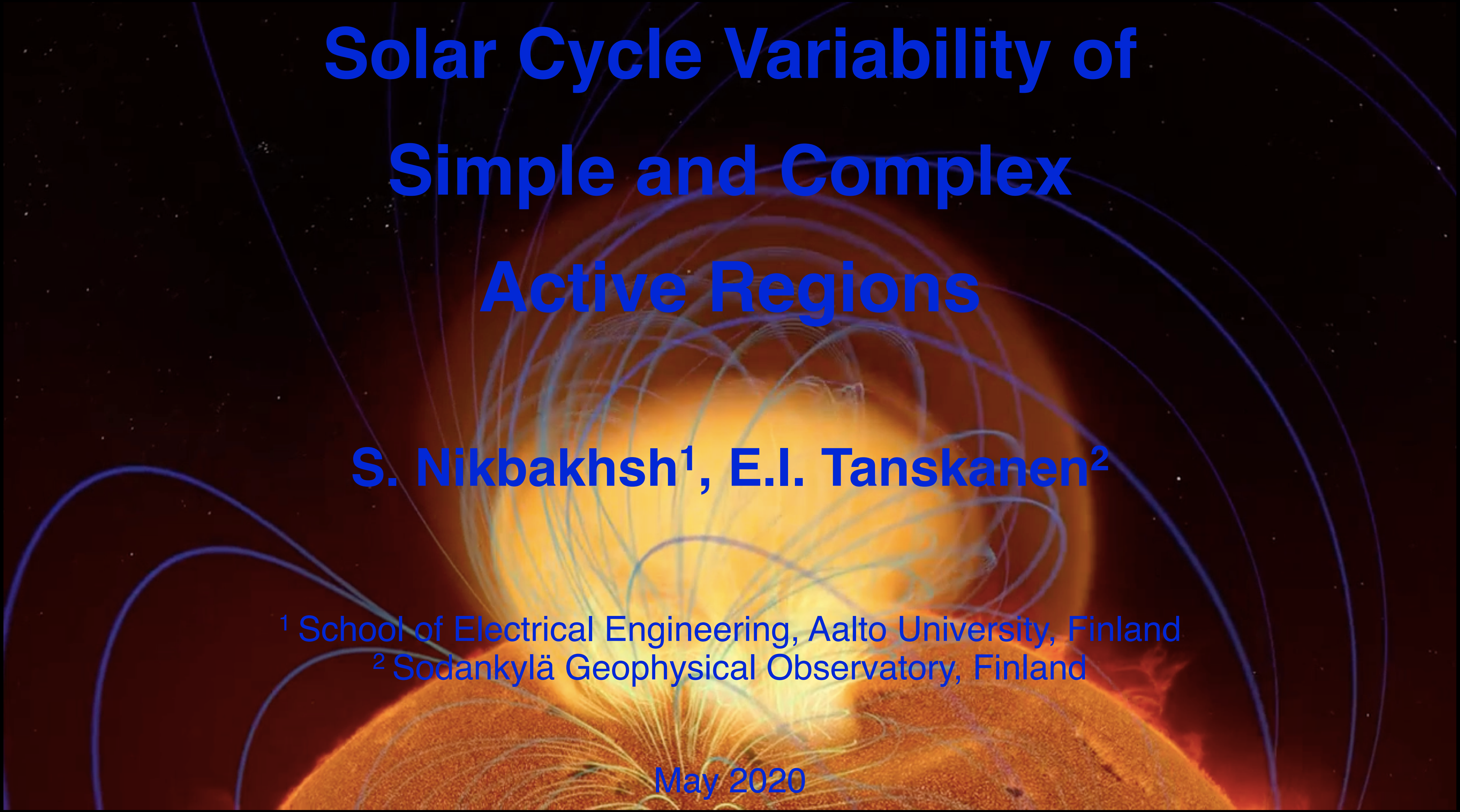


Solar Cycle Variability of Simple and Complex Active Regions

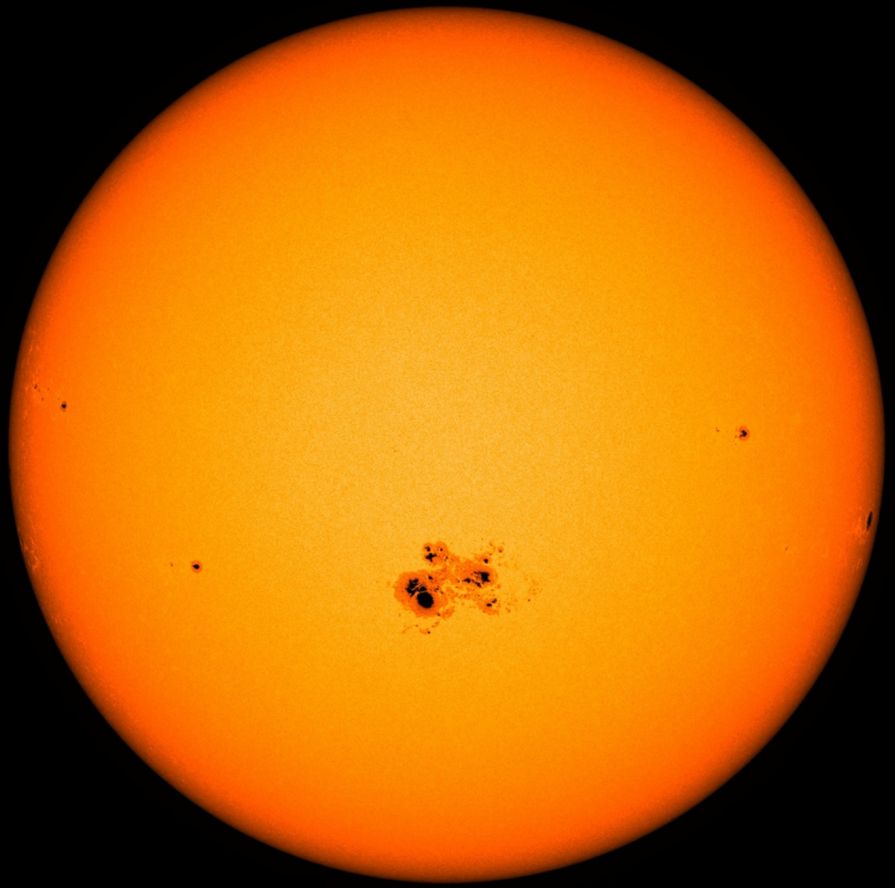
S. Nikbakhsh[1], E.I. Tanskanen[2]

[1] School of Electrical Engineering, Aalto University, Finland
[2] Sodankylä Geophysical Observatory, Finland

May 2020

Solar Active Region

- Appear in photosphere
- Location of strong magnetic field
- Frequently host various solar activity such as flares and CMEs

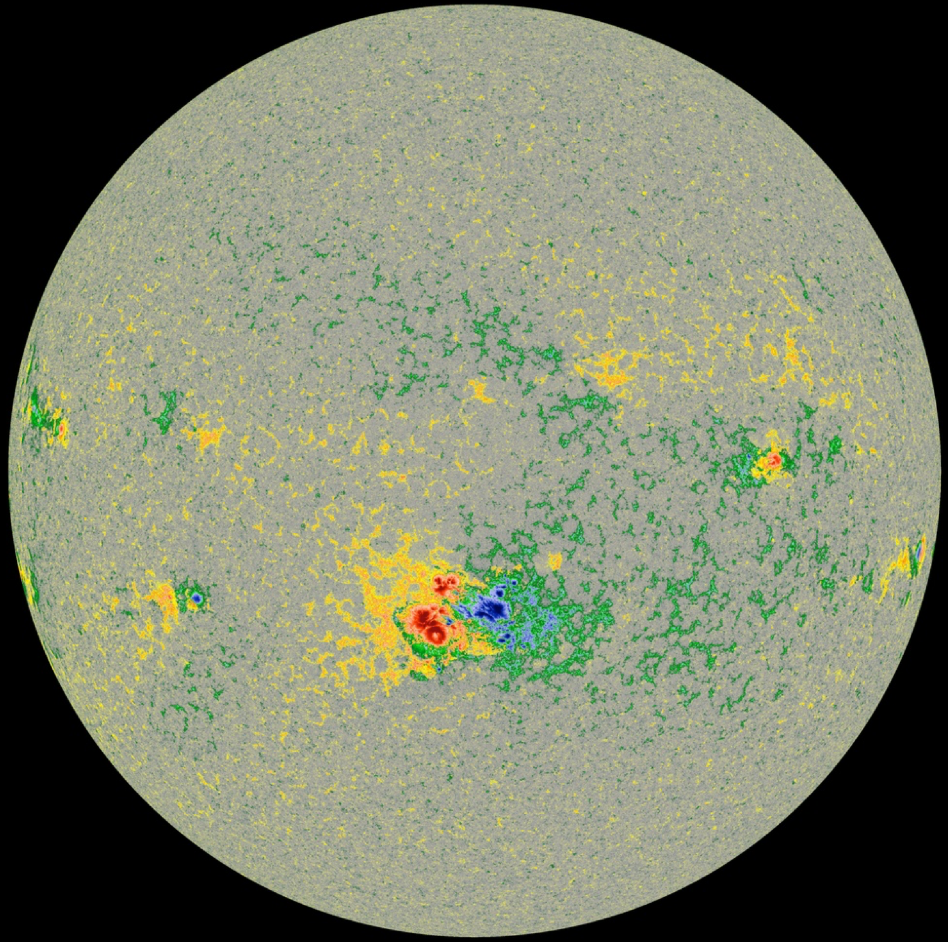


AR 12192
October 2014

Credit: SDO/NASA

Magnetogram Data

- A magnetograph detects the strength and location of the magnetic field
- Applies Zeeman effect
- Blue/red color presents positive/negative polarity



AR 12192
October 2014

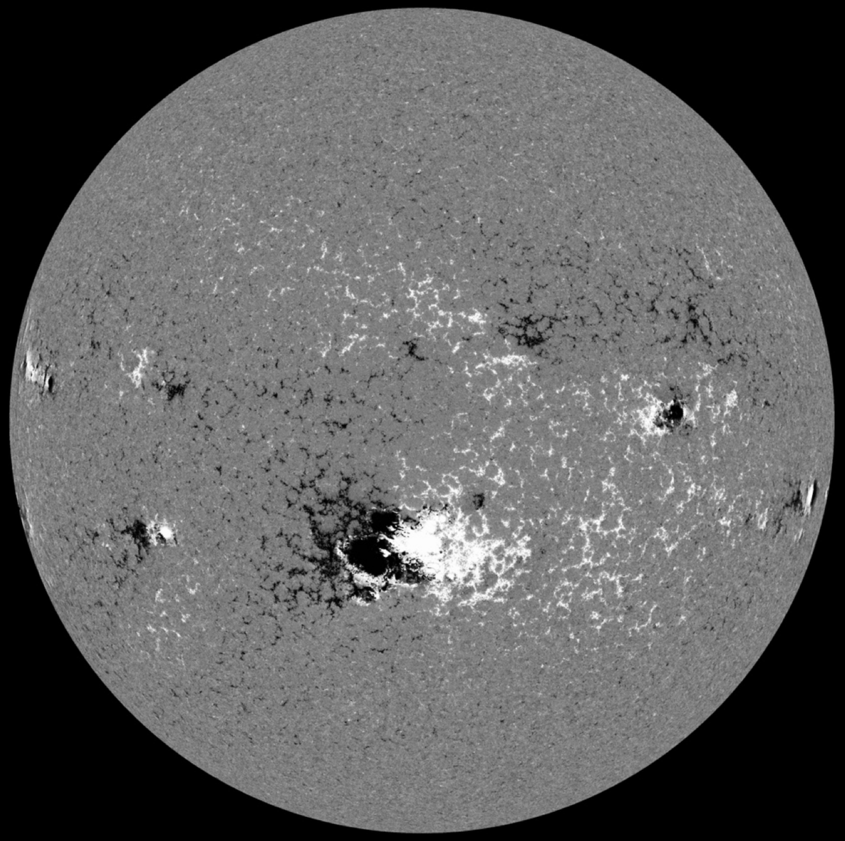
Credit: SDO/NASA

Magnetic Classification of ARs

- **Mount Wilson Classification**
  (Hale et al. 1919): α, β, βγ, βγδ, …

- **Zurich Classification**
  (Waldmeier 1947): I, II, III, …

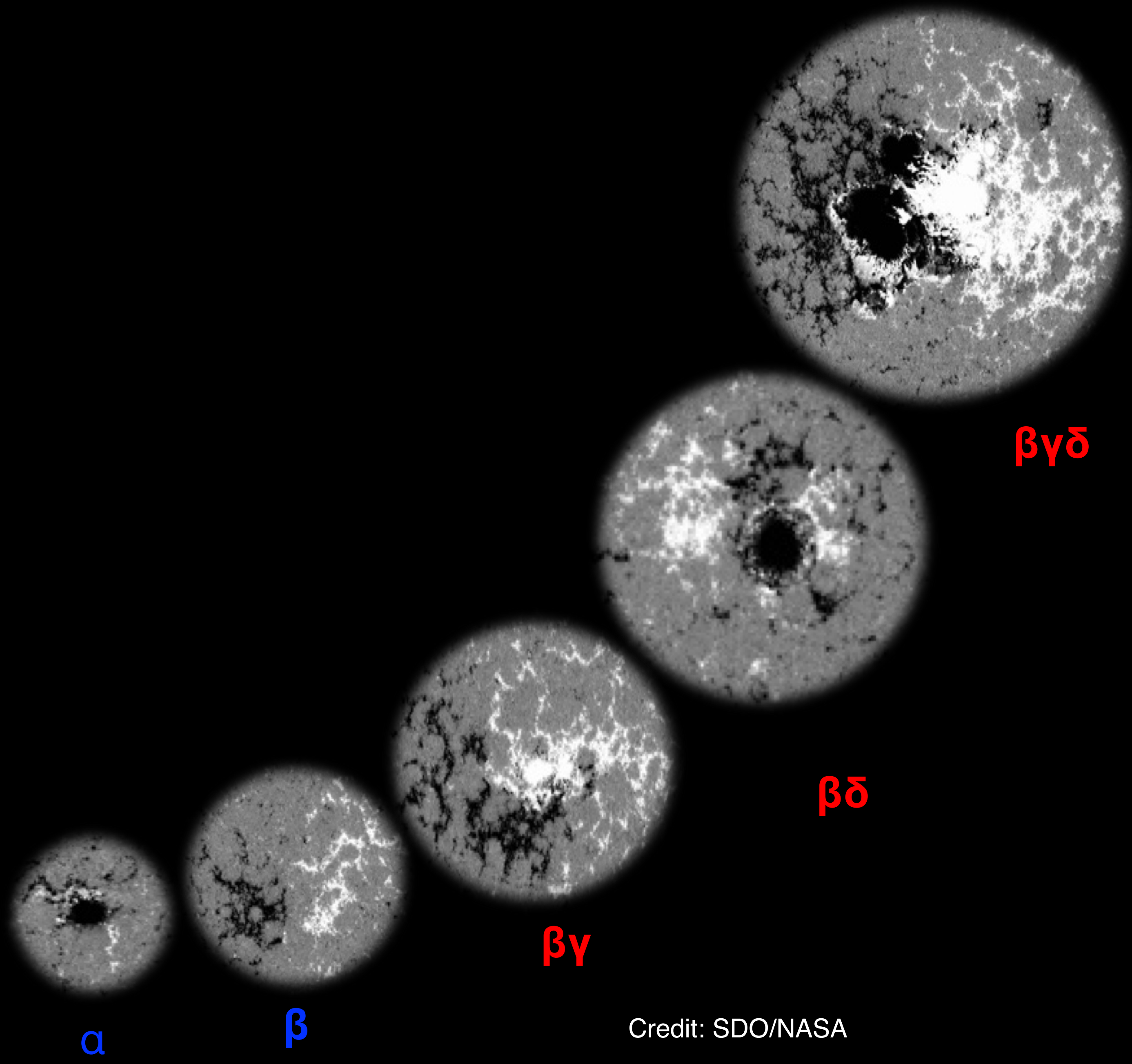
- **McIntosh Classification**
  (McIntosh 1990): Axx, Cro, Eac, …



Credit: SDO/NASA

Mount Wilson Classification

- Classifies ARs into 5 major groups
- Class symbols: α, β, βγ, γ, δ
- Each AR may be classified with one or a combination of two major classes



Credit: SDO/NASA

Our Data

- Ground-based
- Solar Observing Optical Network (SOON)
- January 1996 to December 2018
- SOON reports daily details of ARs on the visible solar disk, including:
    - Heliographic latitude/longitude
    - Mount Wilson Classification
    - Number of spot in each AR

SOON telescope

Holloman AFB, New Mexico, USA

The Evolution of Magnetic Complexity

- The magnetic complexity of an AR might change during its lifetime
- Example: AR 12192

25 day

$$\underbrace{\beta\gamma \ldots \beta\gamma\delta \ldots \beta\gamma \qquad ? \ldots ? \qquad \emptyset,\ \emptyset,\ \emptyset}_{}$$

14 days on the visible disk	8 days on the far side	8 days with no associated Magnetic class

Hale & Nicholson (1938):

- Average magnetic class was used
- No correlation with sunspot cycle

TABLE 4. PERCENTAGE OF SPOT-GROUPS IN EACH CLASS

Year	α	αp	αf	β	βp	βf	$\beta\gamma$	γ	Unclassified
1915	10	20	5	23	30	5	5	2	8
1916	16	17	4	20	31	8	4	0	5
1917	11	20	4	21	32	9	3	0	6
1918	17	20	3	22	27	9	2	0	5
1919	19	20	4	17	28	8	3	1	7
1920	13	21	6	19	29	7	3	2	5
1921	10	30	4	23	24	7	2	1	18
1922	17	23	5	23	25	4	0	3	6
1923	3	21	6	15	49	6	0	0	11
1924	9	21	4	27	27	8	2	2	9
1915–1924	14	20	4	21	29	8	3	1	7

Jaeggli & Norton (2016):

- Magnetic complexity was selected when an AR achieved its maximum area.
- Magnetic complexity of ARs varied with the solar cycle

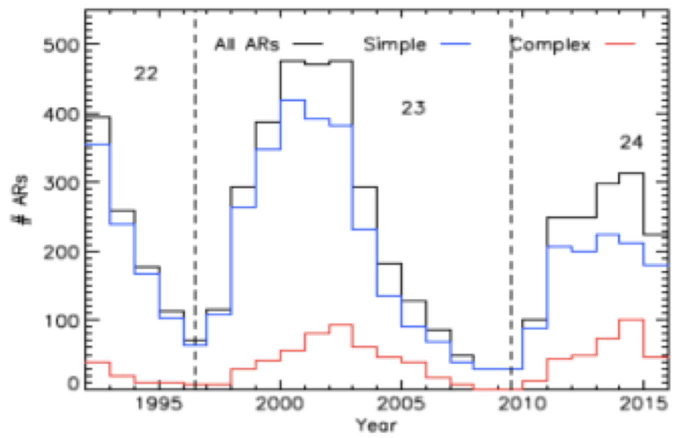
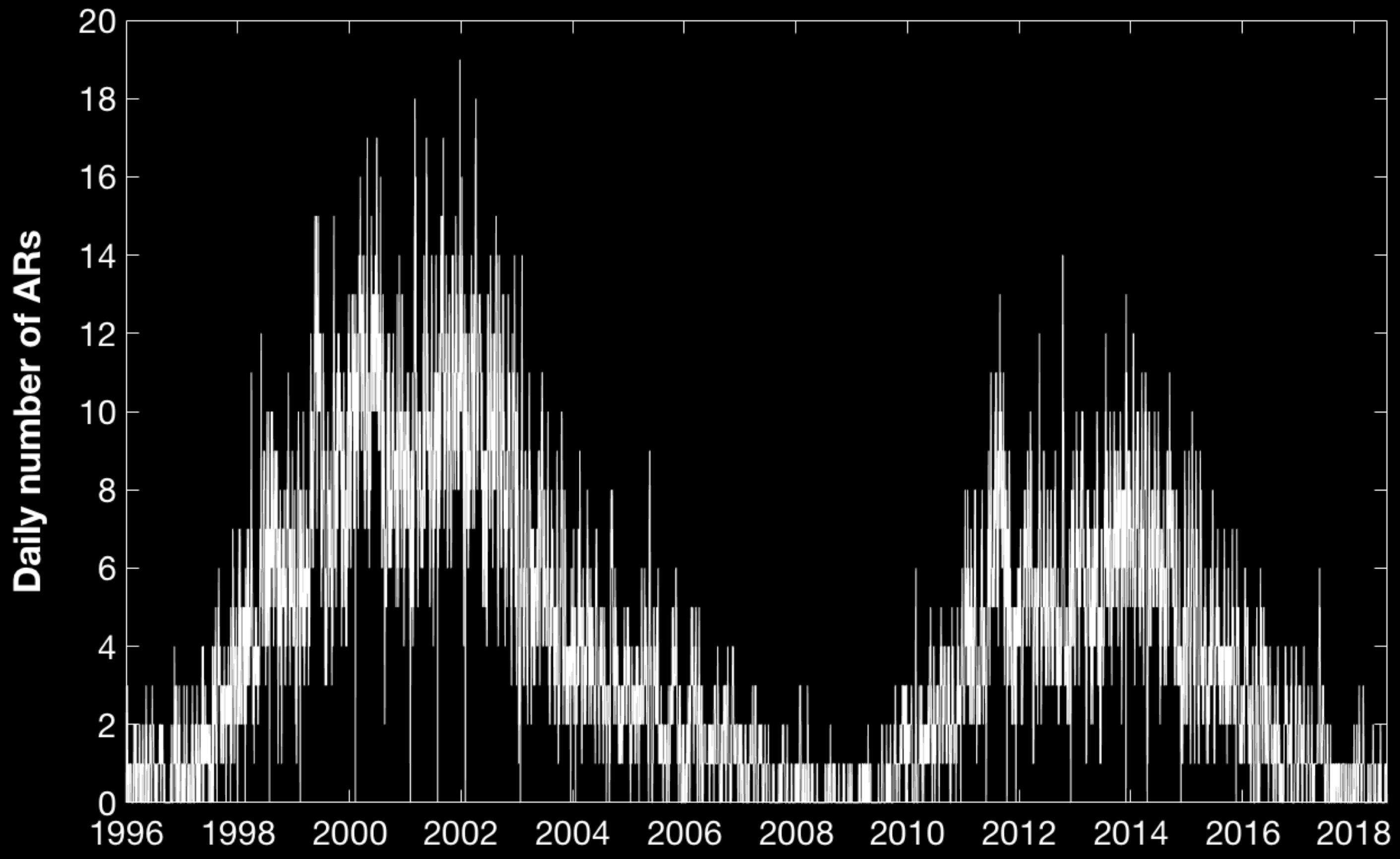


Figure 3. Histograms of all ARs (black), ARs with simple configurations (blue), and ARs with complex configurations (red) binned by year. For solar cycles 23 and 24, the highest number of complex configurations is reached the same year as the total number of ARs, but the peak in simple configurations occurs 1–2 years earlier.

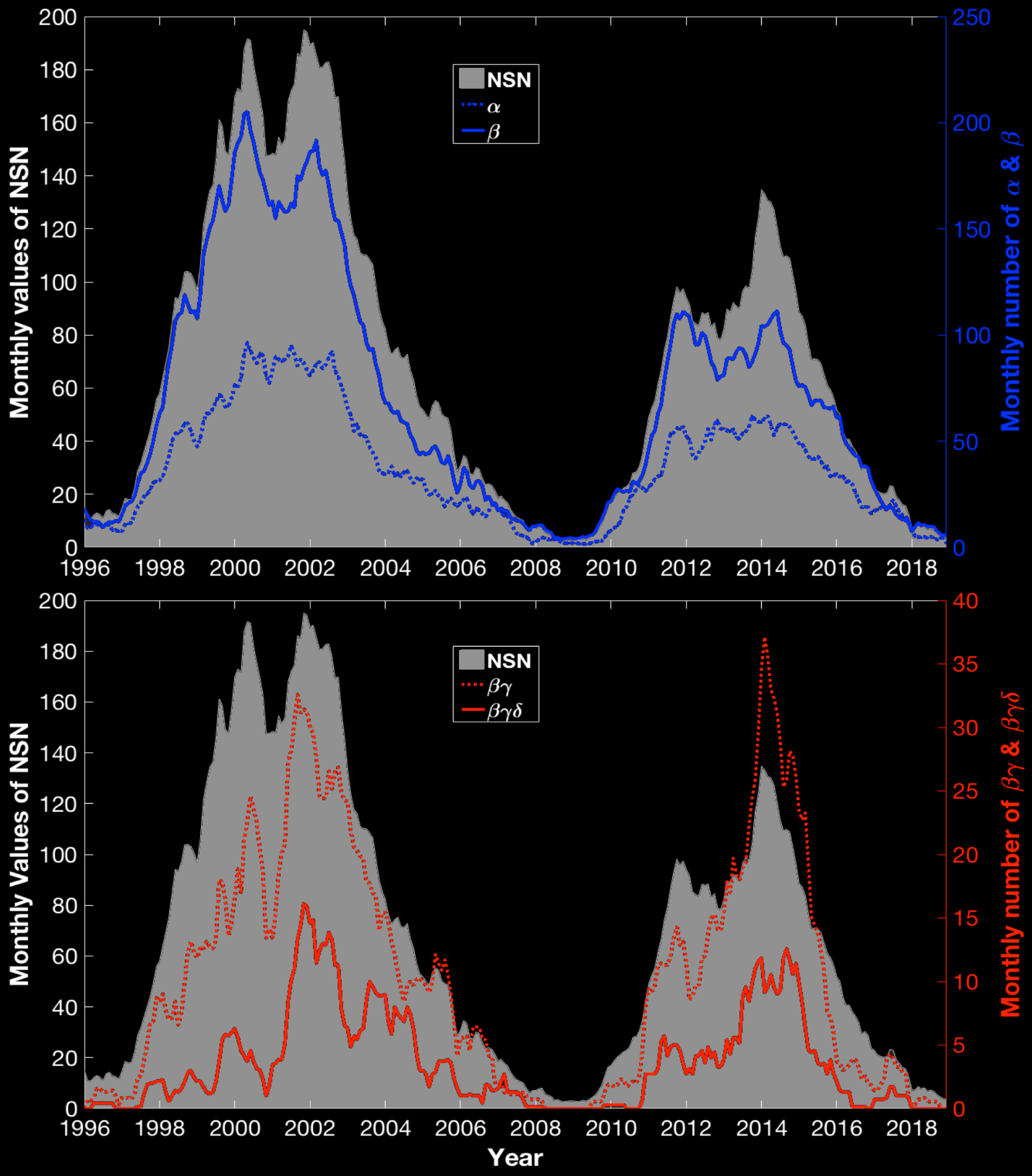
Our Methods

- We used the daily number of each magnetic complexity
- Similar to the Sunspot number calculation
- Easy to compare the results with daily variation of the Sunspot Number
- It includes information about lifetime of each AR’s magnetic complexity



- The total daily count of ARs was 33,496
- A Majority of ARs were β and α regions
- βδ, γ and γδ have only total occurrence rate of 0.51%, so we excluded them from the further analysis

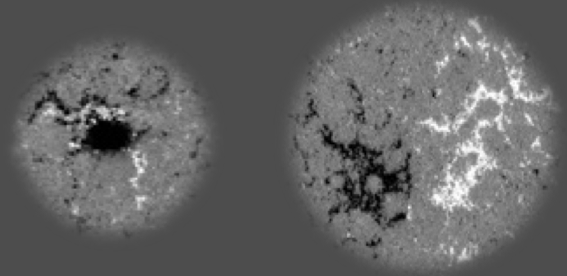
Complexity class	Count [number]	Relative abundance [%]
α	10296	30.73
β	19284	57.57
βγ	2919	8.71
βγδ	997	2.97
βδ	166	0.49
γ	4	0.01
γδ	5	0.01



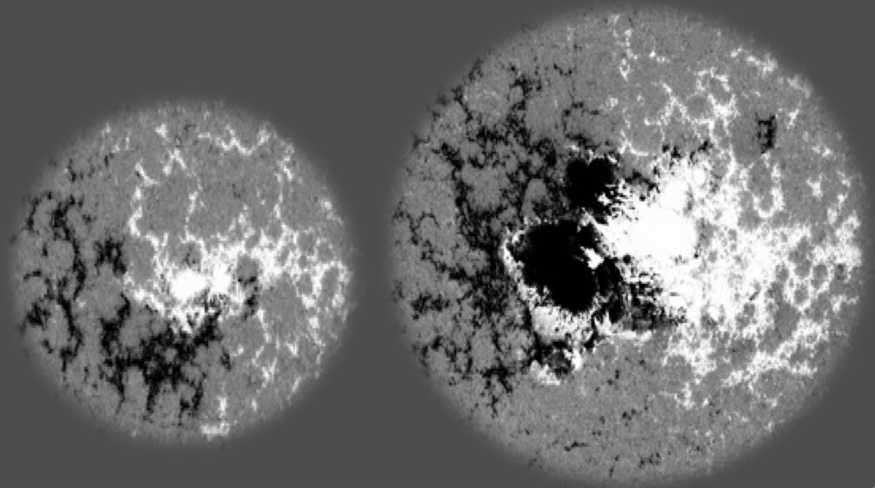
NSN
α
β
Monthly values of NSN
Monthly number of α & β
$\beta\gamma$
$\beta\gamma\delta$
Monthly Values of NSN
Monthly number of $\beta\gamma$ & $\beta\gamma\delta$
Year

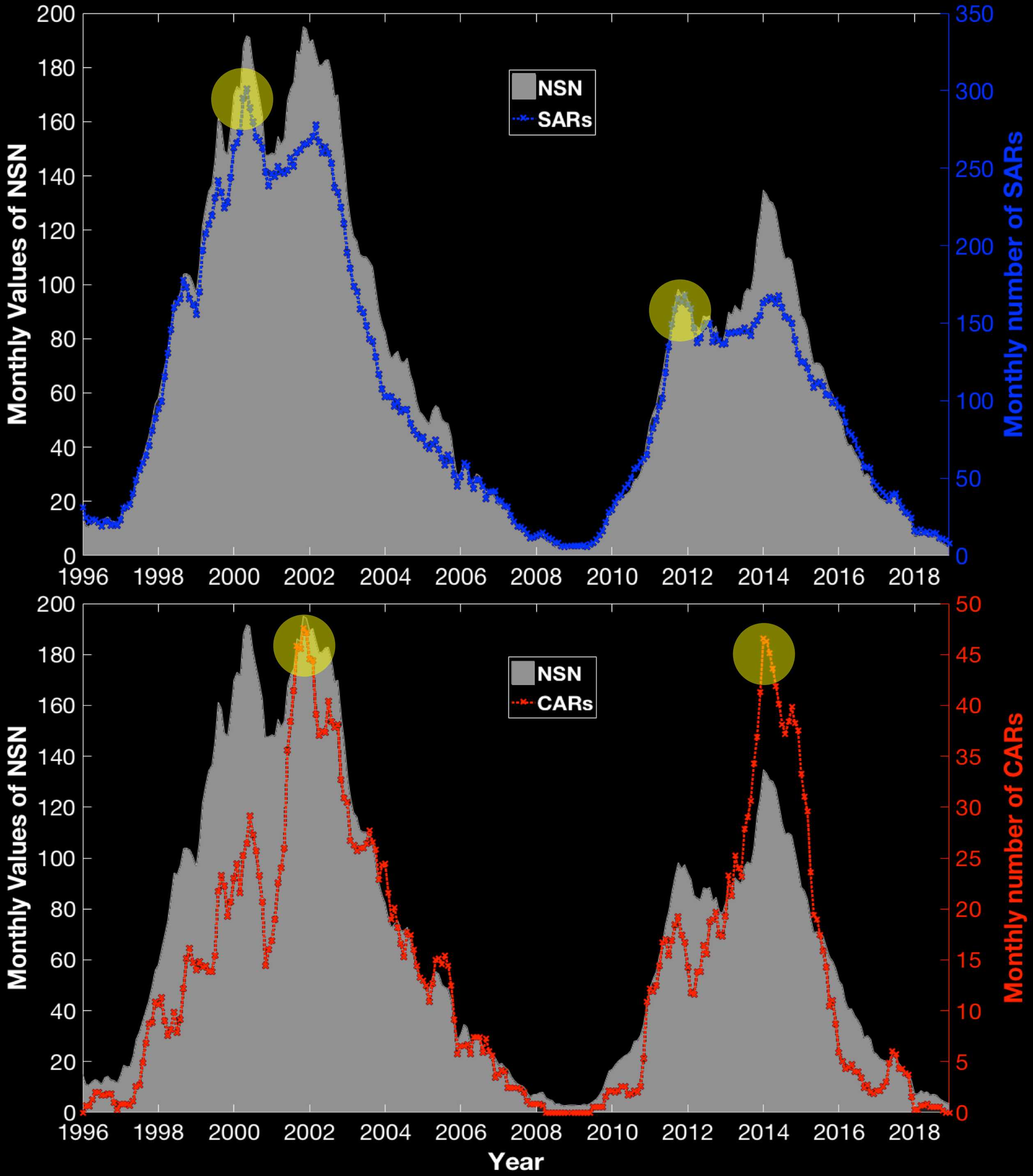
We divided ARs into two groups

Simple active regions (SARs): α and β



Complex active regions (CARs): βγ and βγδ

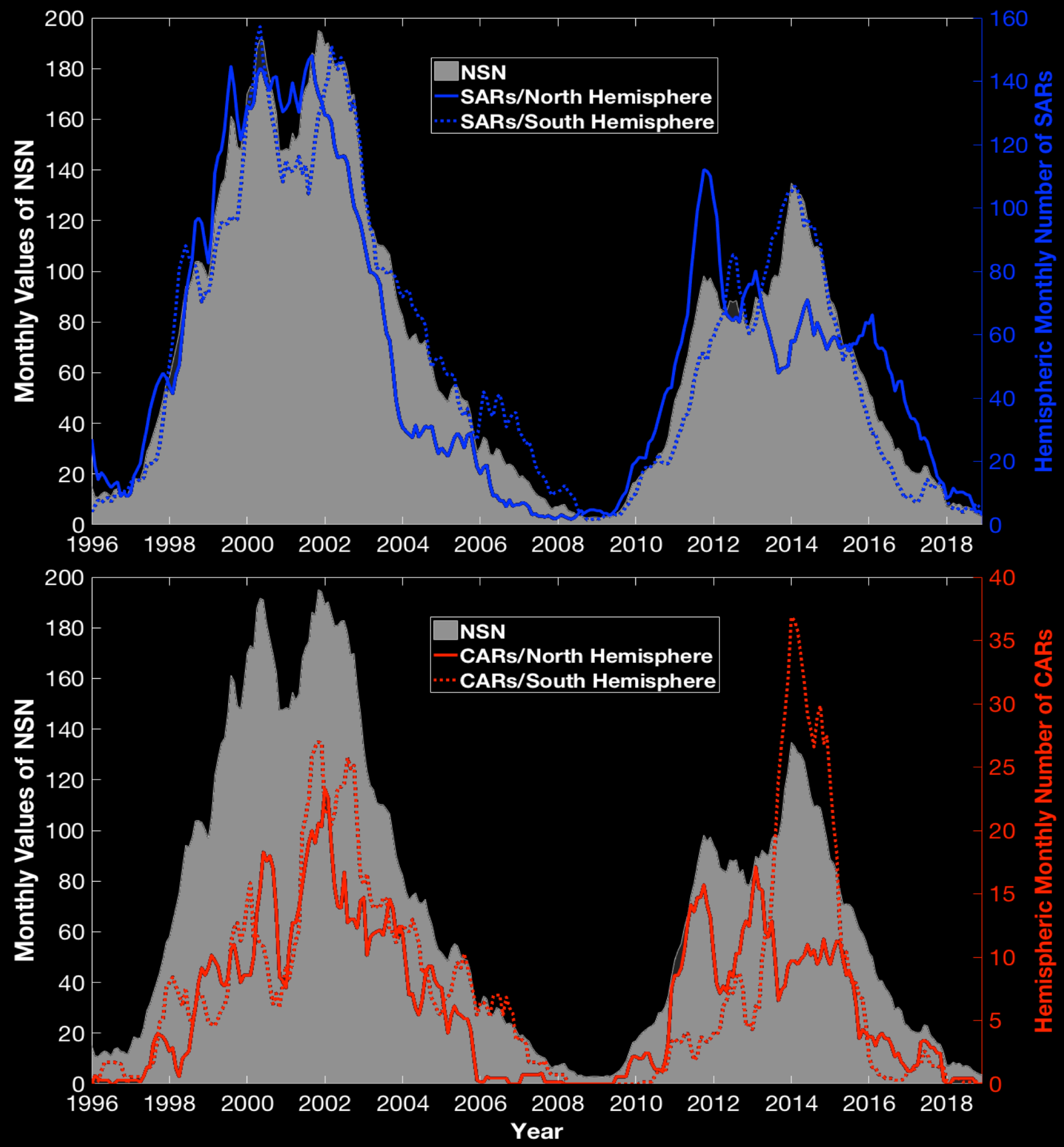




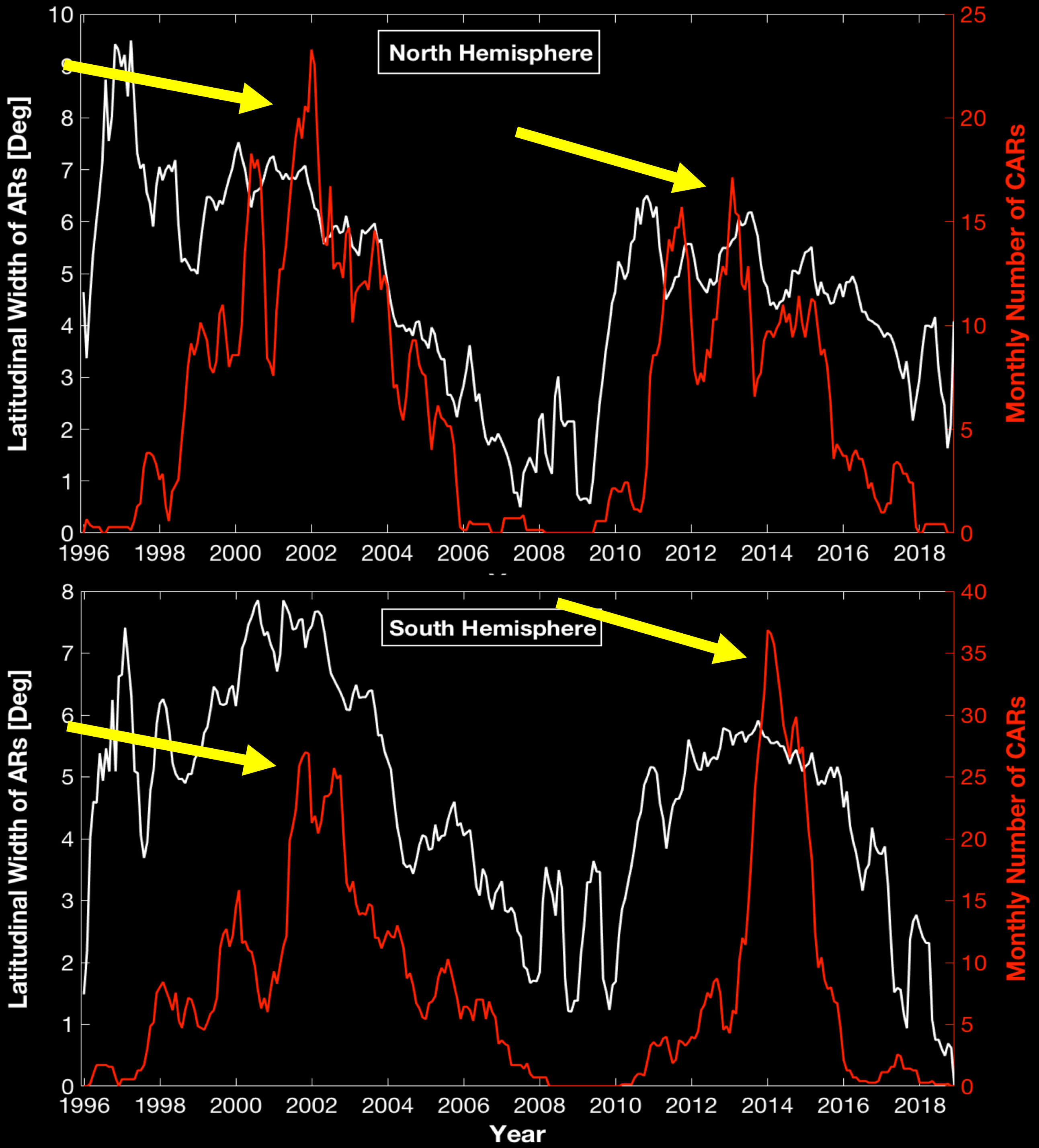
NSN
SARs
Monthly Values of NSN
Monthly number of SARs
NSN
CARs
Monthly Values of NSN
Monthly number of CARs
Year

Complexity class	Peak SARs Cycle 23 [Number]	Peak SARs Cycle 24 [Number]	Rate of change [%]
SARs	11523	5607	51

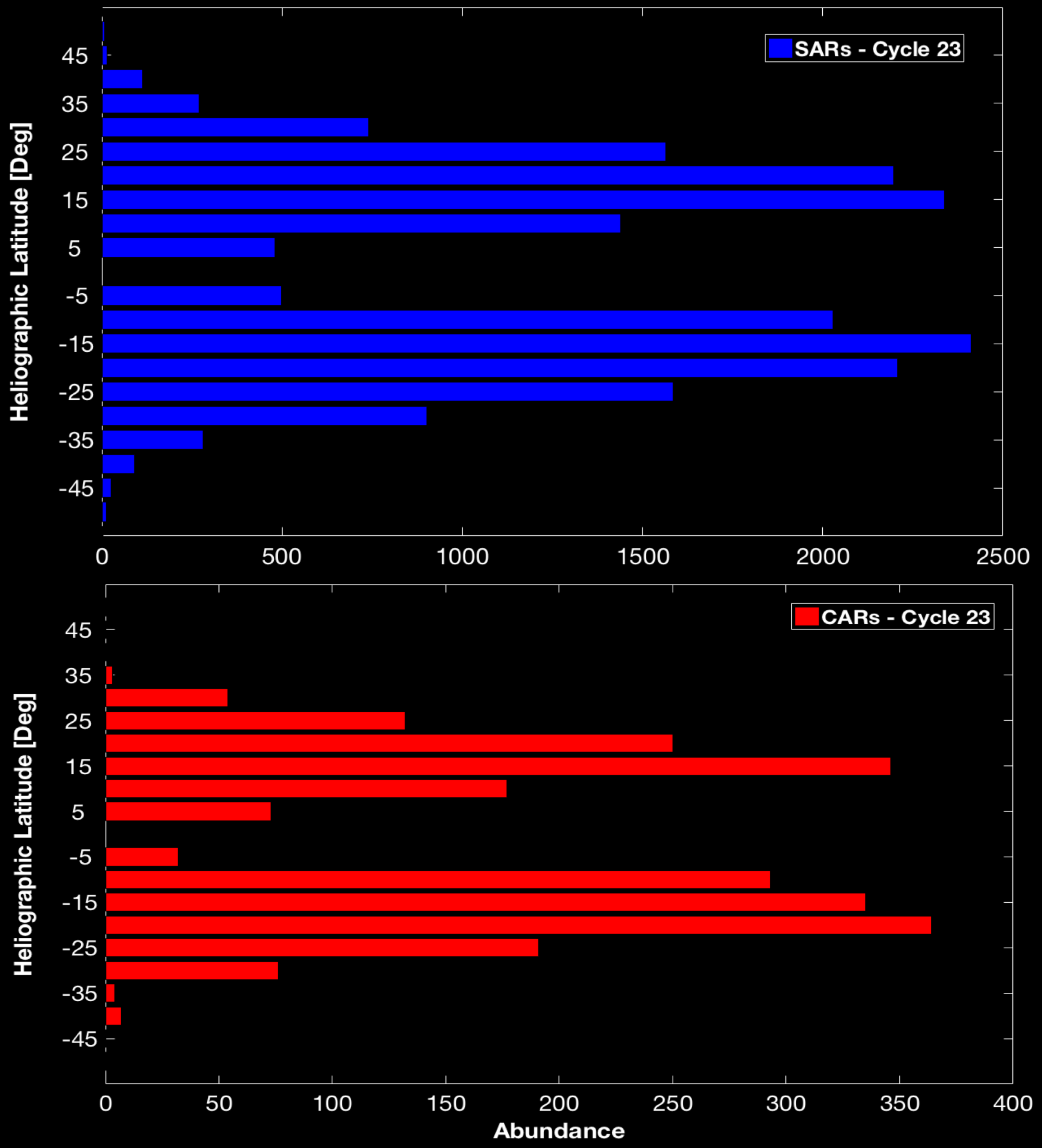
Complexity class	Peak SARs Cycle 23 [Number]	Peak SARs Cycle 24 [Number]	Rate of change [%]
CARs	1476	1258	15



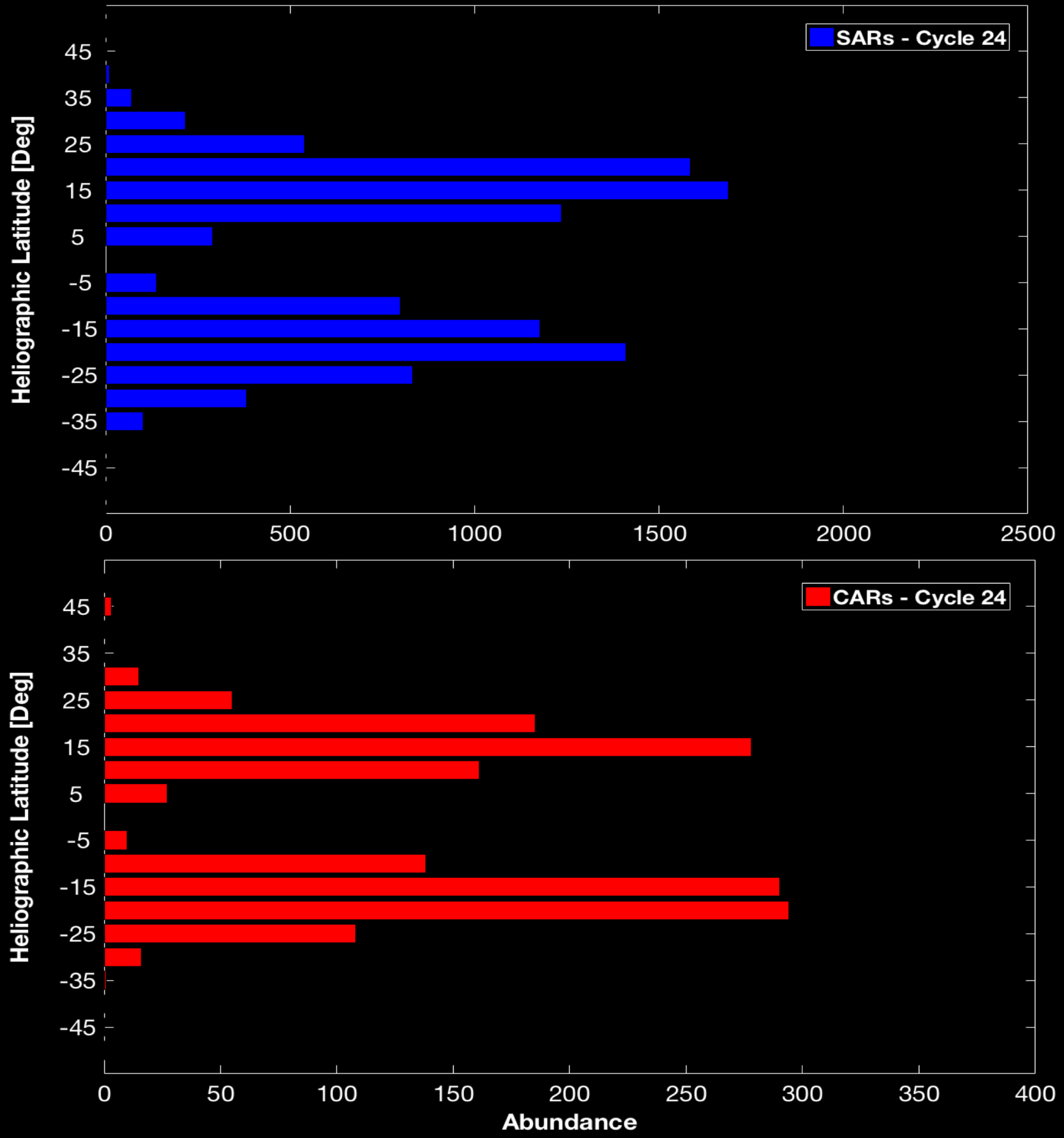
NSN
SARs/North Hemisphere
SARs/South Hemisphere
Monthly Values of NSN
Hemispheric Monthly Number of SARs
NSN
CARs/North Hemisphere
CARs/South Hemisphere
Monthly Values of NSN
Hemispheric Monthly Number of CARs
Year



North Hemisphere
South Hemisphere
Latitudinal Width of ARs [Deg]
Monthly Number of CARs
Year



SARs - Cycle 23
CARs - Cycle 23
Heliographic Latitude [Deg]
Abundance
45
35
25
15
5
-5
-15
-25
-35
-45
0
500
1000
1500
2000
2500
50
100
150
200
250
300
350
400



SARs - Cycle 24
Heliographic Latitude [Deg]
45
35
25
15
5
-5
-15
-25
-35
-45
0
500
1000
1500
2000
2500
CARs - Cycle 24
Heliographic Latitude [Deg]
45
35
25
15
5
-5
-15
-25
-35
-45
0
50
100
150
200
250
300
350
400
Abundance

Conclusion

- β regions and SARs closely follow NOAA sunspot number.
- SARs reach their maximum value during the first peak of the cycle, whereas CARs attain their maximum later and during the second peak
- Abundance of CARs is almost equal in cycle 23 and 24 for the period of 2 years before and after their maximum value
- We interpret the behavior of SARs & CARs in terms of the competition between the two different solar dynamo processes: large scale and small scale dynamos
- Latitudinal distribution of SARs and CARs were almost the same during both cycles, suggesting that they could originated from the same origin within the solar interior.