The Olsen Rotating Dipole Revisited

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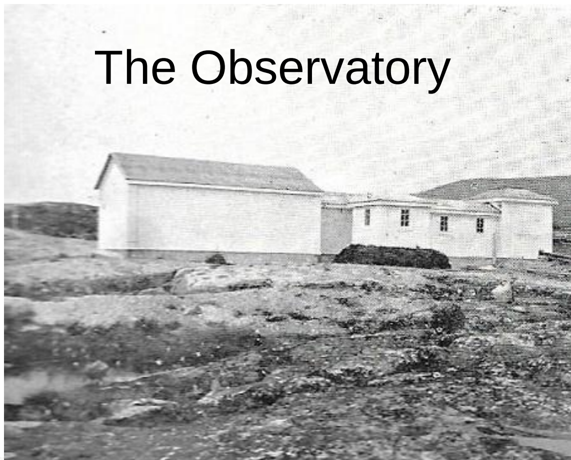
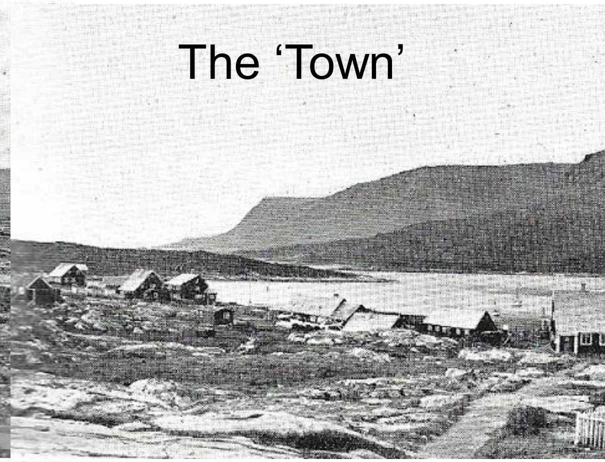
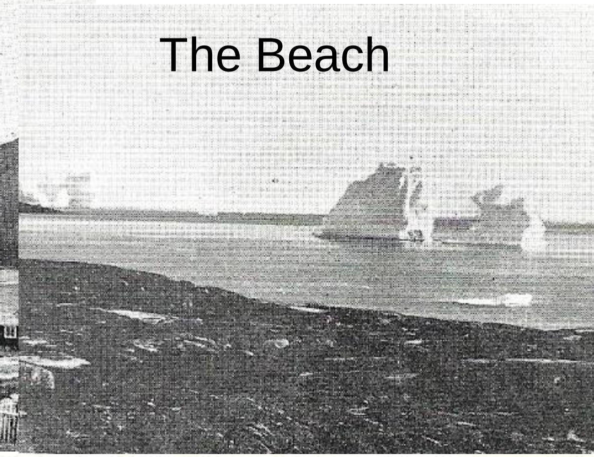
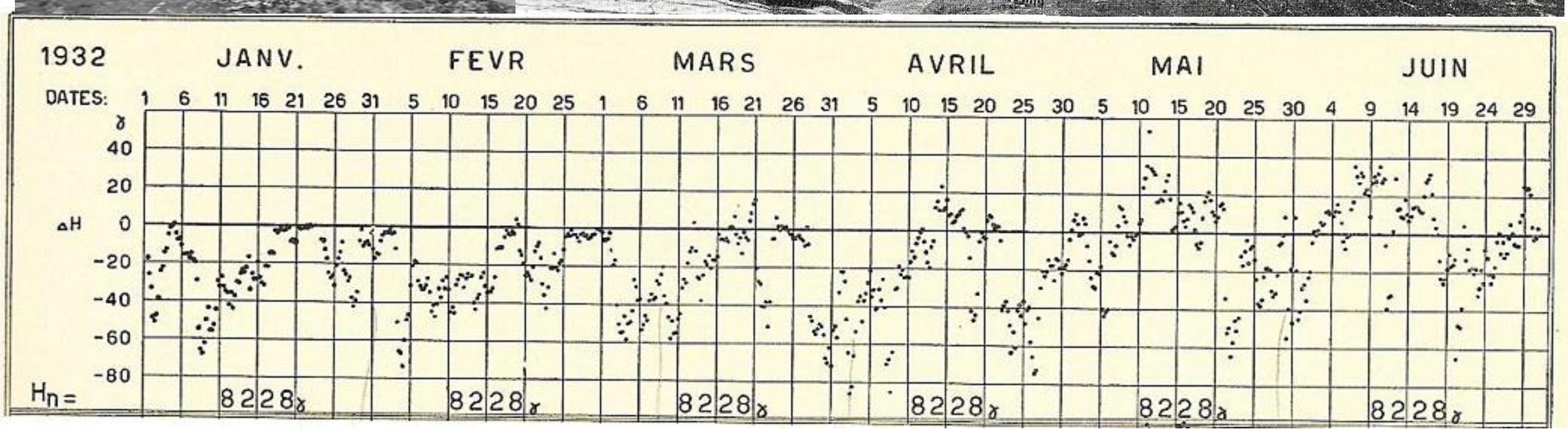
AGU Fall 2016, SH31B-2548, 14 Dec. 2016

The Story Begins Here at Godhavn, Greenland in 1926









The variation of the Horizontal Component in the minimum year 1932. The recurring 'dips' are not magnetic storms. In fact, nobody knew what they were at the time.

Johannes Olsen (1894-1991) drew Attention to those Recurrent Dips

PERSISTENT SOLAR ROTATION-PERIOD OF 26 7/8 DAYS AND SOLAR-DIURNAL VARIATION IN TERRESTRIAL MAGNETISM

BY JOHANNES OLSEN

Summary—An examination of the daily means of the horizontal force at Godhavn Greenland, during the years 1926 to 1941 shows that there seems to exist a recurrence-tendency for the mean values of *H* with a period of 26 7/8 days during that epoch, the values being rather low in the first half of the period and rather high in the latter half.

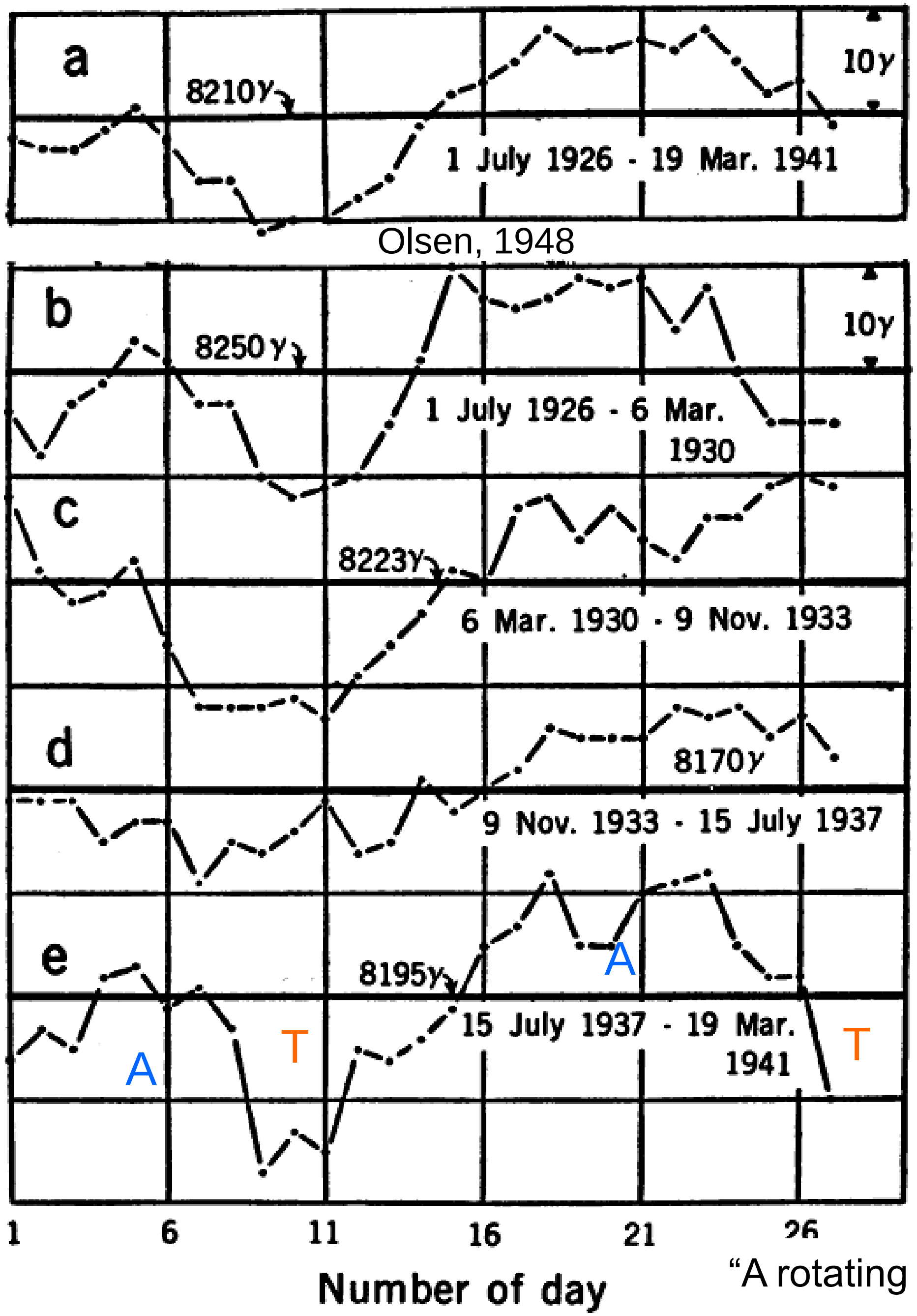
Terrestrial Magnetism and Atmospheric Electricity [now JGR], **53**(2), 123-134, doi:10.1029/te053i002p00123

Olsen concluded:

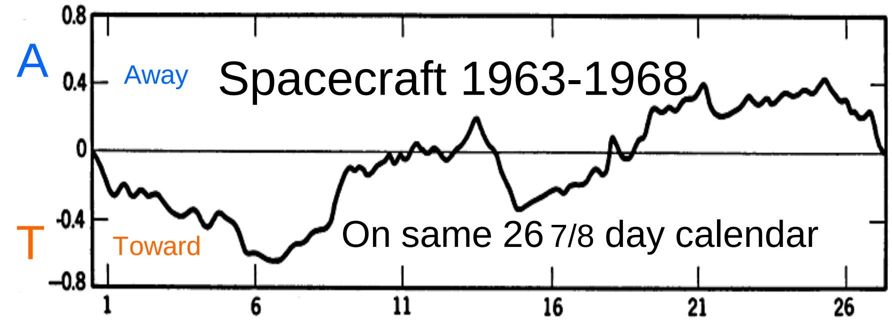
The persistence of a fixed period during 15 years points to the possibility that the origin of the effect is to be found in a layer on the Sun with a fixed rotation-period during a long time.

And there the finding languished for 23 years with no citations at all

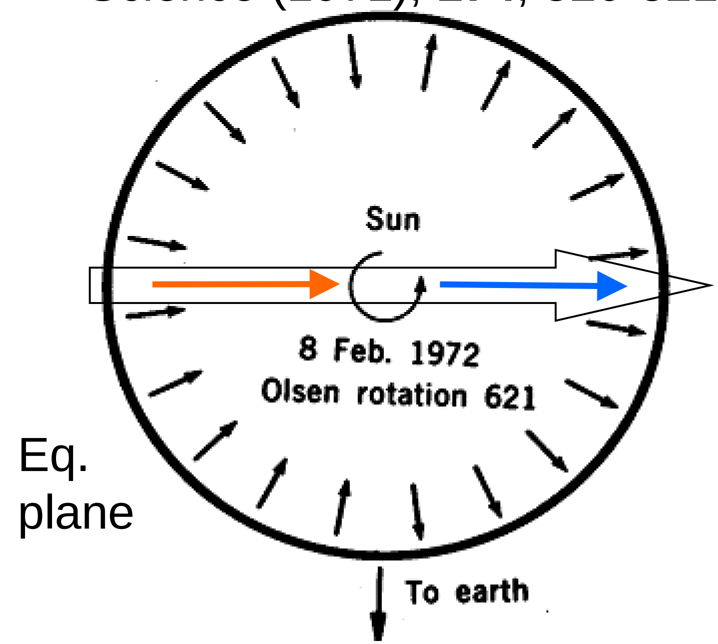
Enter Wilcox & Gonzales, 1971



Olsen, 1948



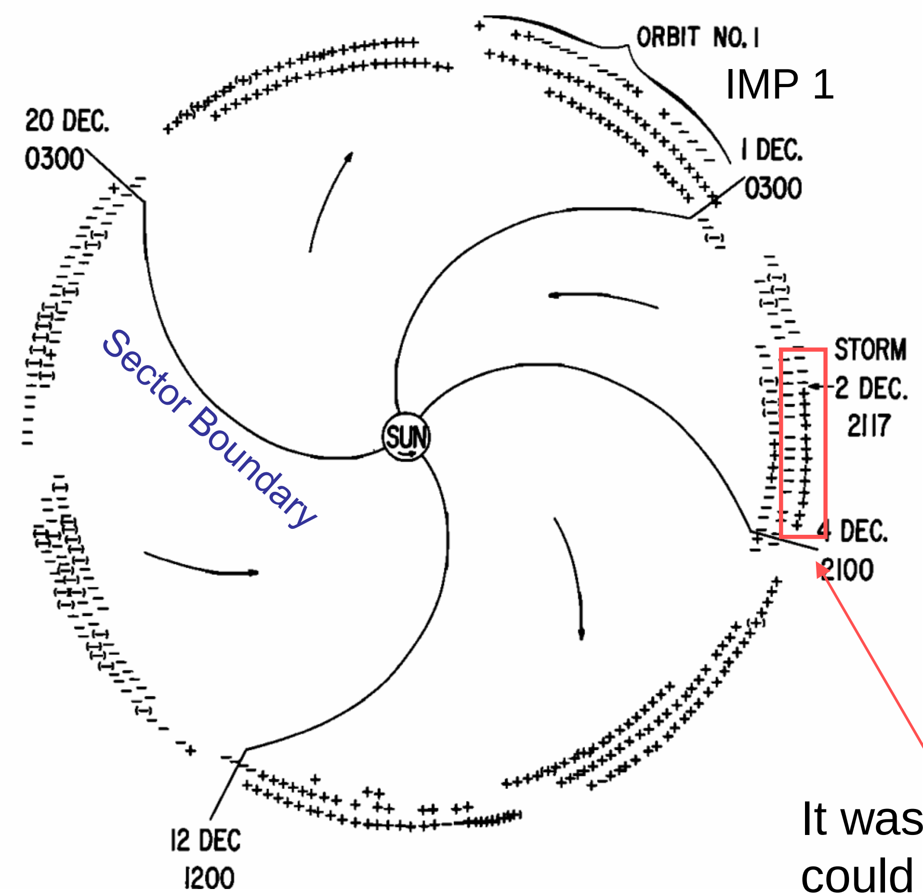
Science (1971), **174**, 820-821



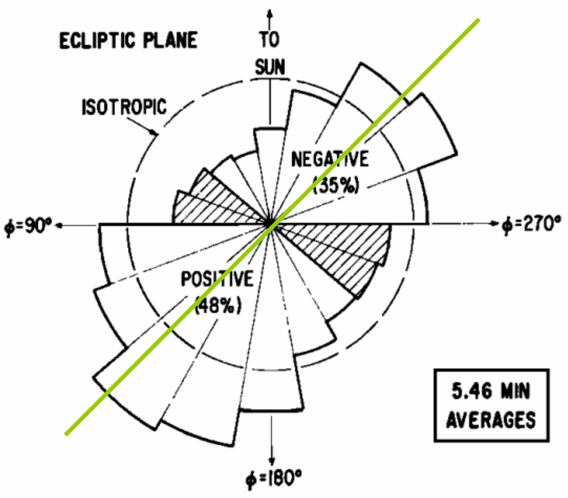
"A rotating magnetic dipole may be lurking within the sun"

Discovery of Sector Structure

Quasi-Stationary Corotating Structure in the Interplanetary Medium
John M. Wilcox & Norman F. Ness (1965), JGR, **70**, 5793.

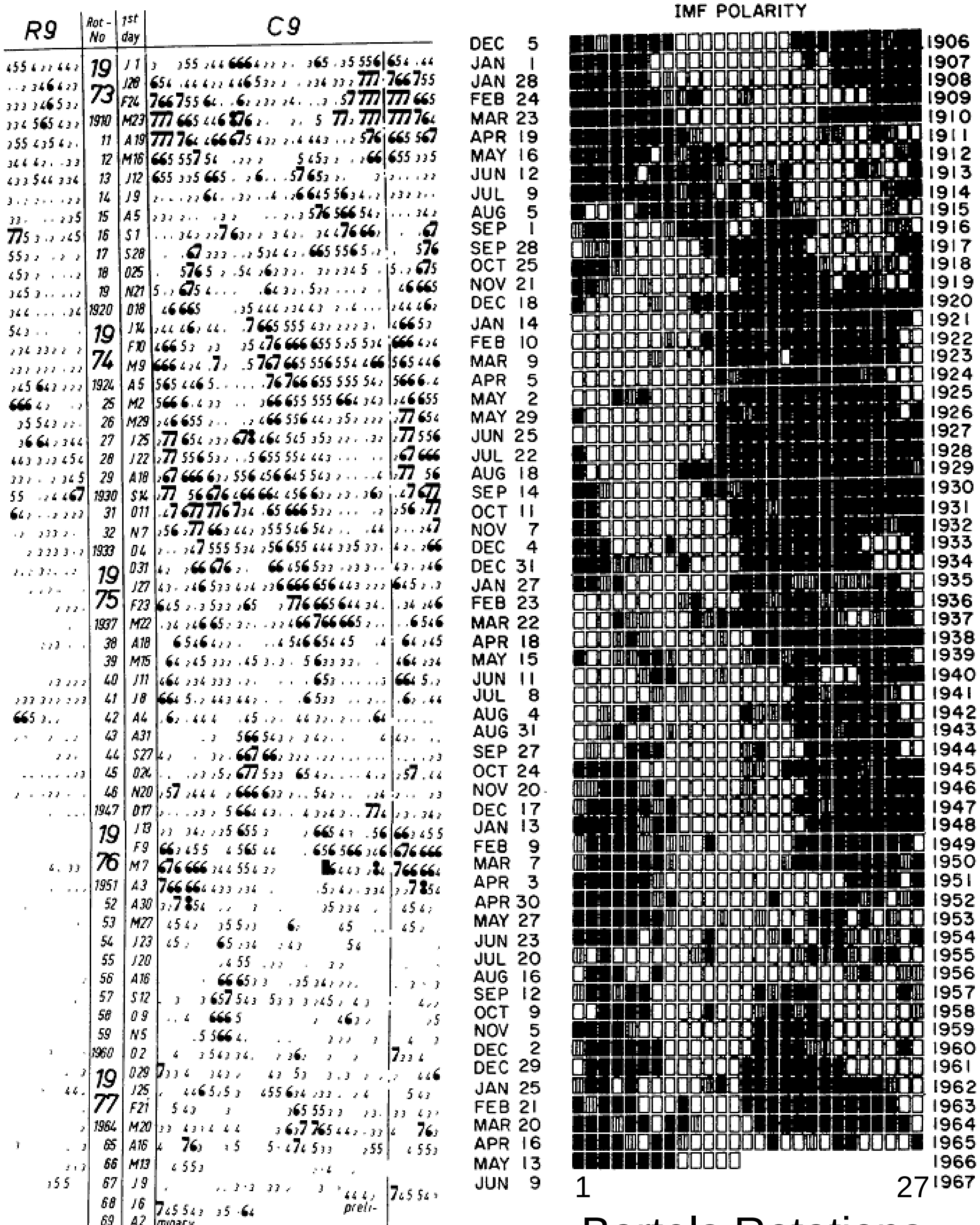


The large-scale structuring of the IMF was a surprise at the time

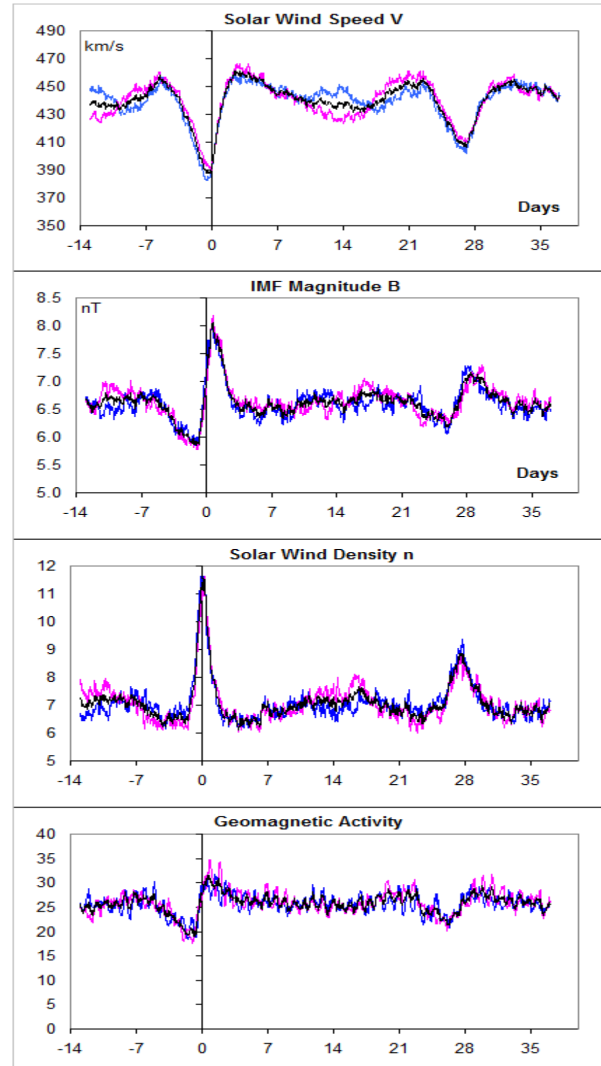


It was also noted that solar storms could briefly disrupt the structure

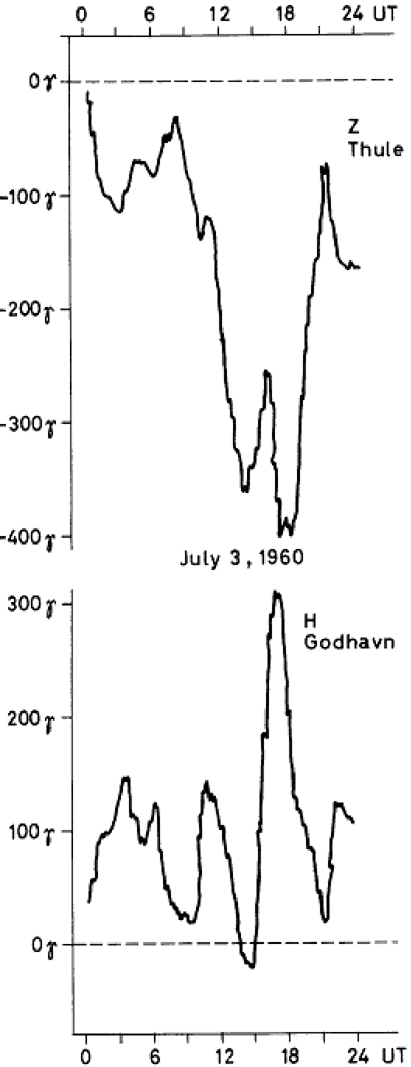
Rotation Plots of the Sector Polarity

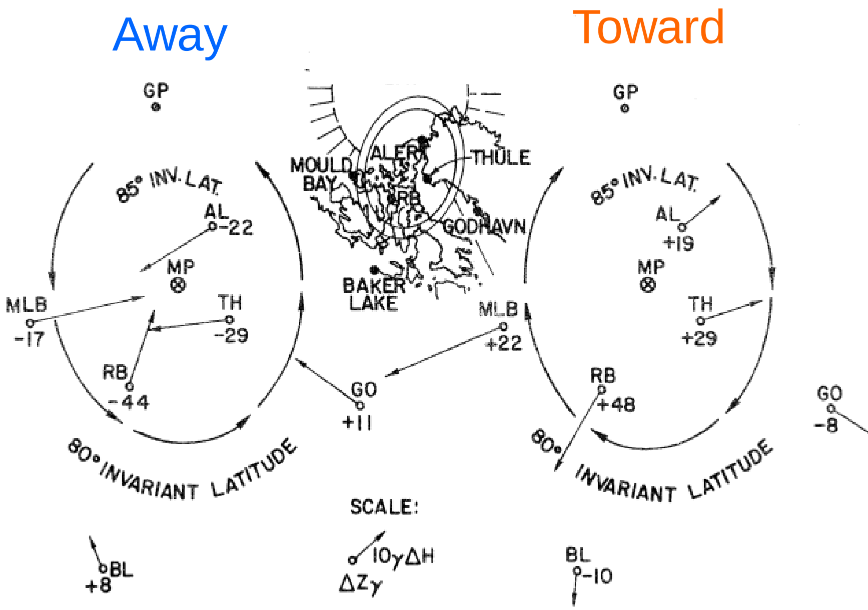


Bartels Rotations



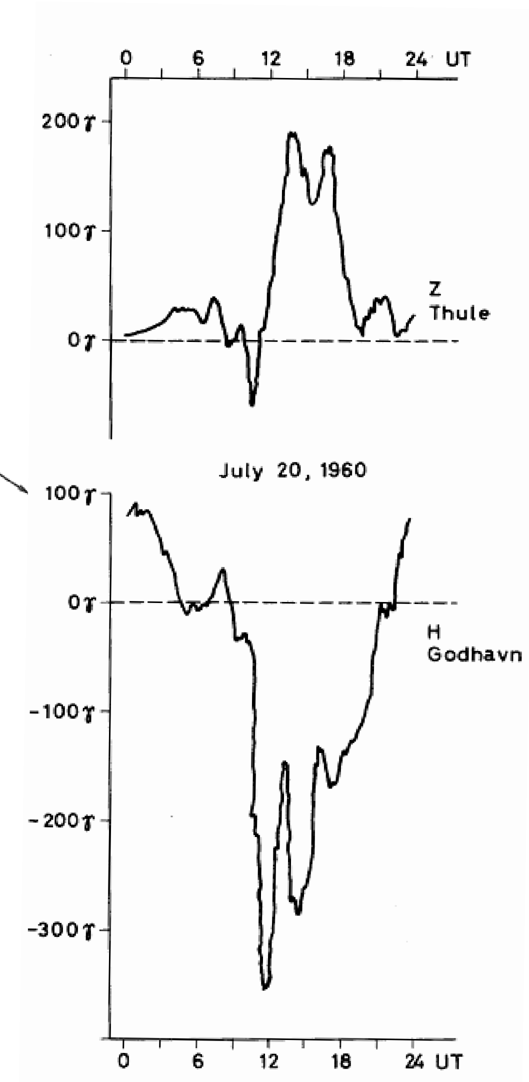
Where did W&G get the Idea to look at the IMF Polarity?





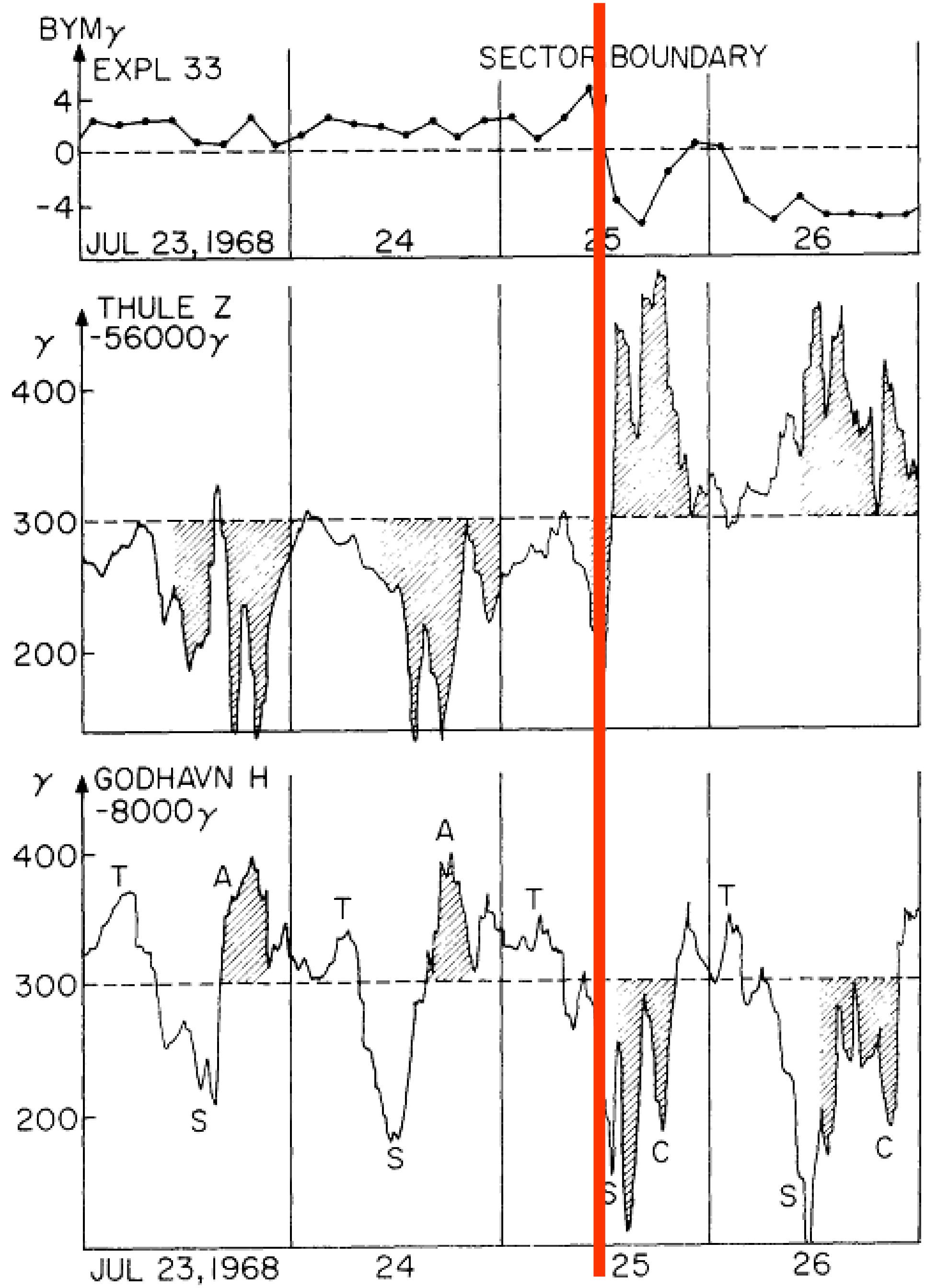
POLAR CAP DISTURBANCES AT 18^{h} UT FOUND DURING IMF AWAY POLARITY.

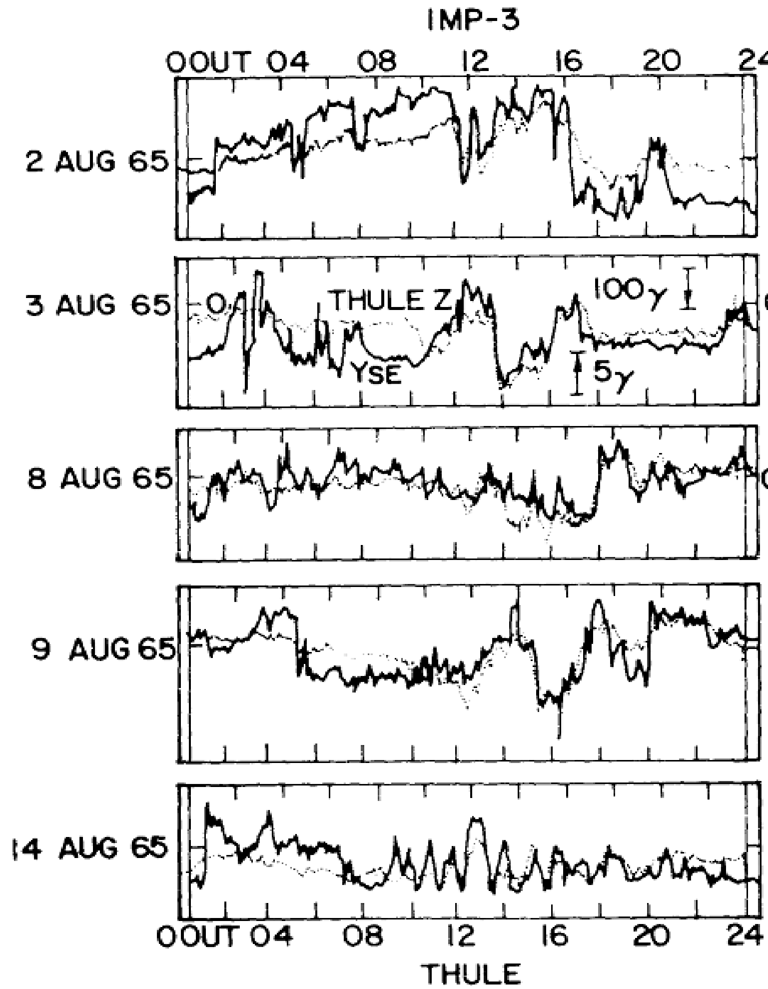
POLAR CAP DISTURBANCES AT 18^{h} UT FOUND DURING IMF TOWARD POLARITY.



From the then recently (1968) discovered Svalgaard-Mansurov Effect caused by a current circulating around the magnetic pole, changing direction when the IMF polarity changes.

A Very Direct Relationship

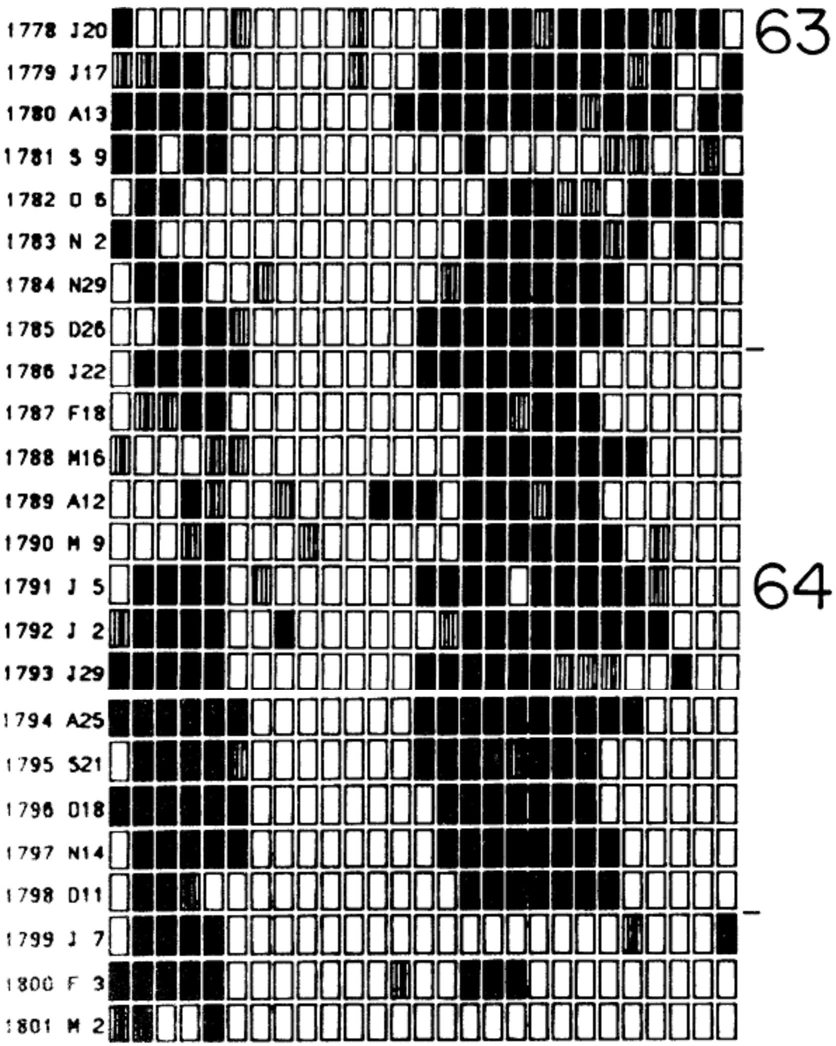


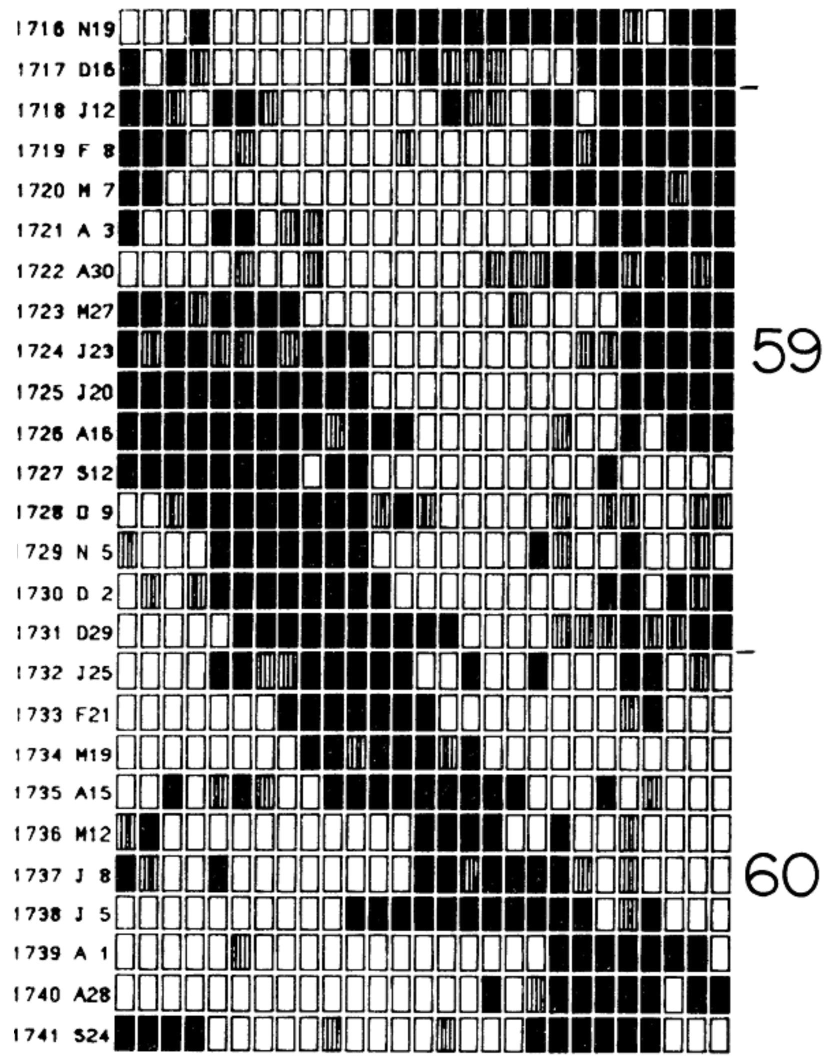


20 minute Lag, adjusted for

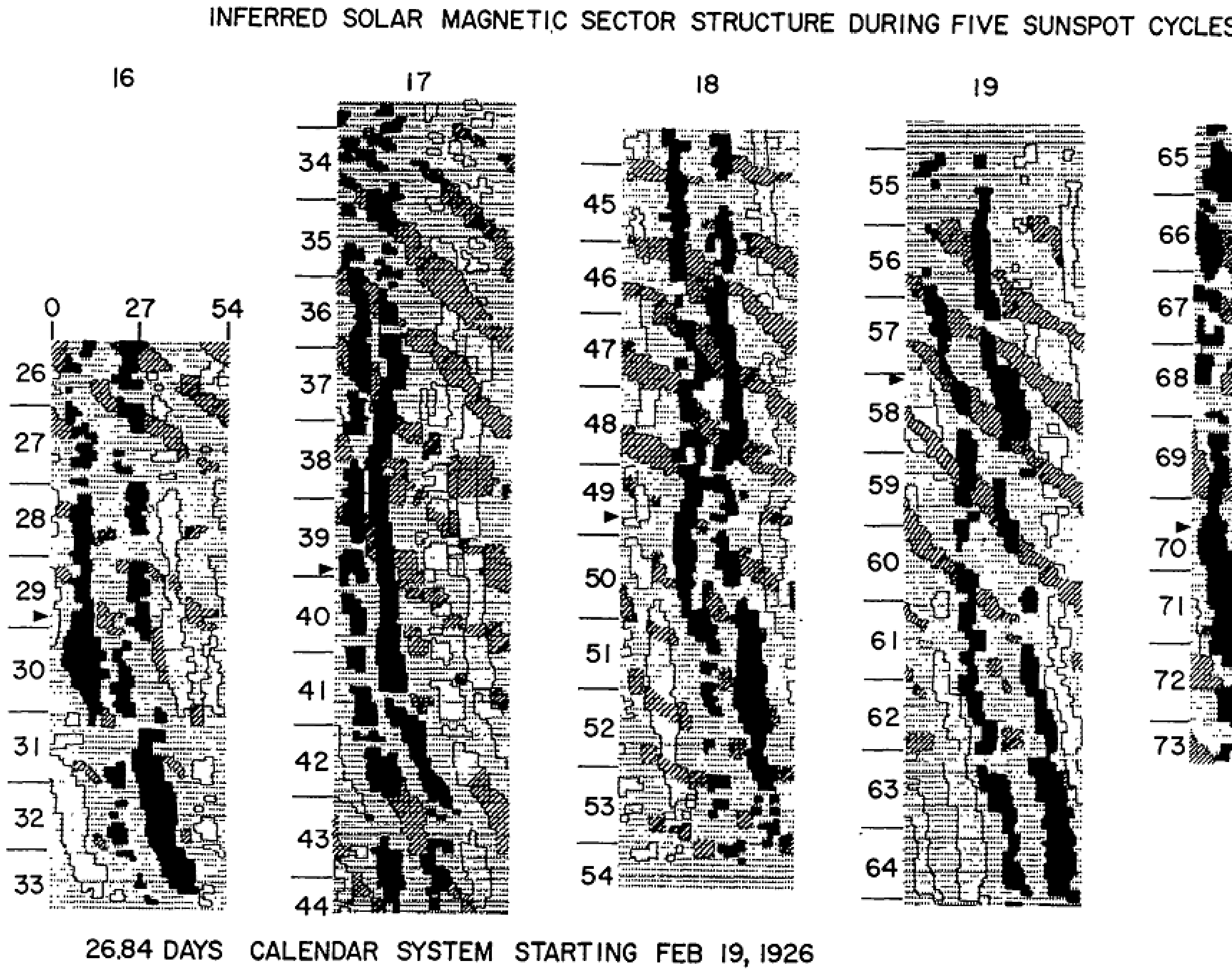
Two Common Recurrence periods:

27-day 28.5-day





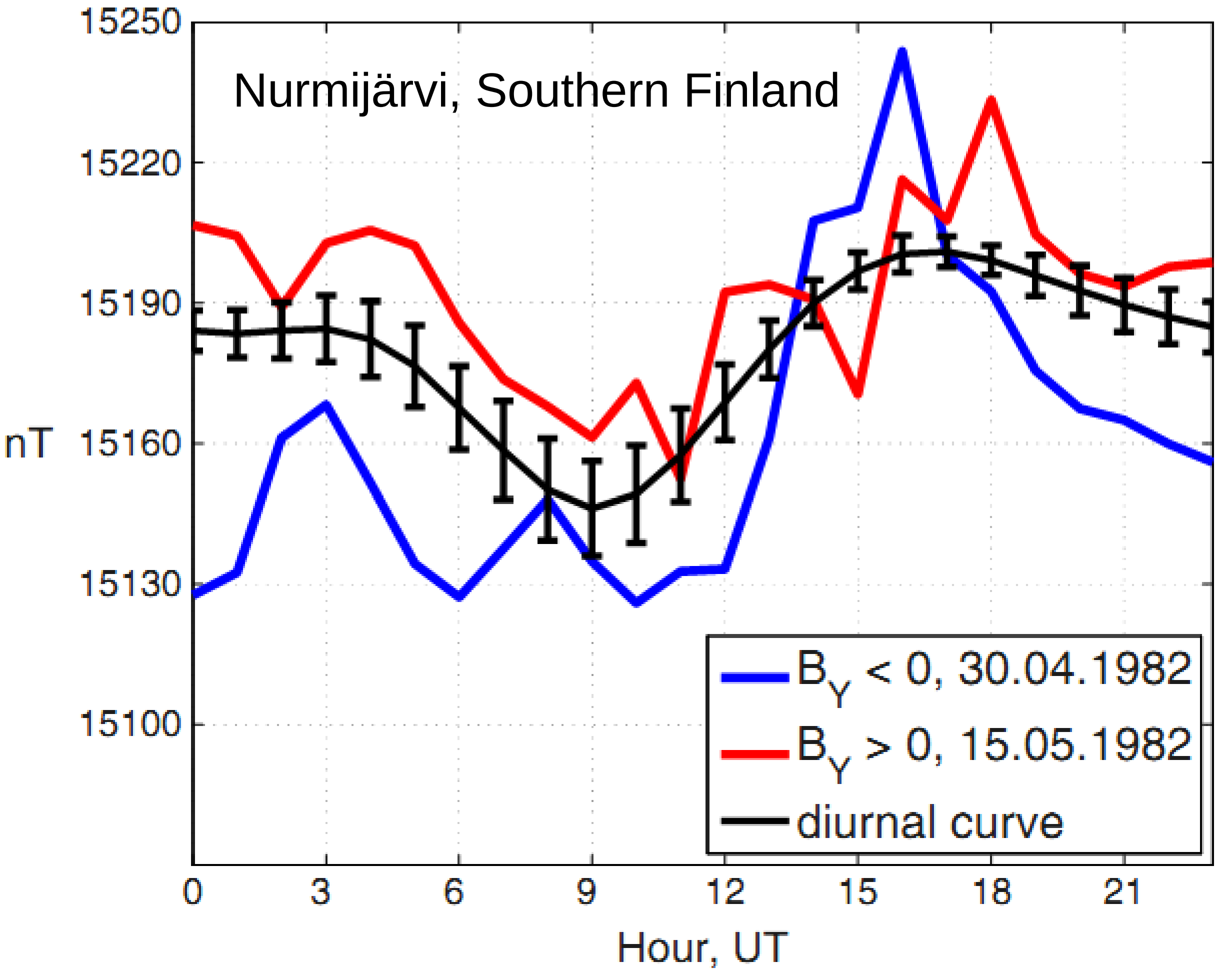
Long-term Evolution of Sector Structure (Hand-drawn)

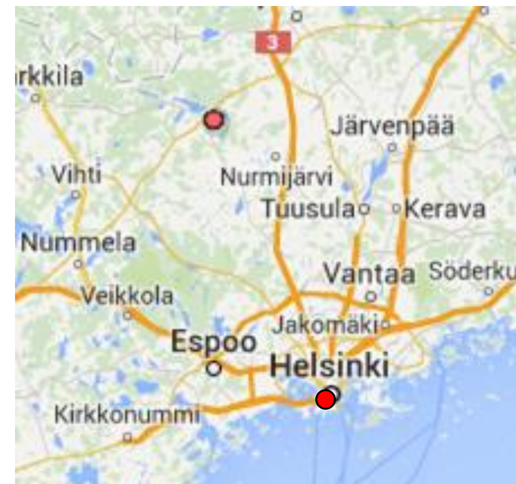


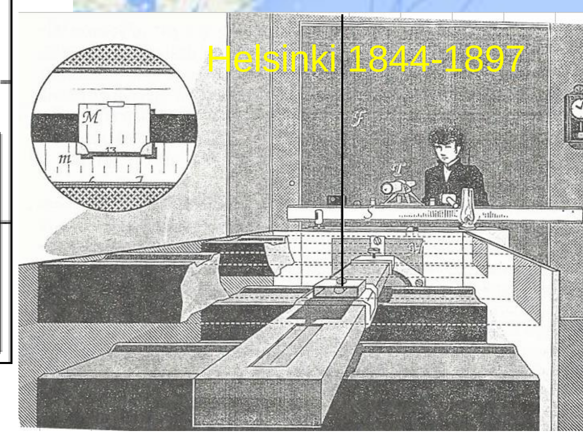
Can We Extend the Sector Data to Before 1926?

Yes: M. V. Vokhmyanin and D. I. Ponyavin

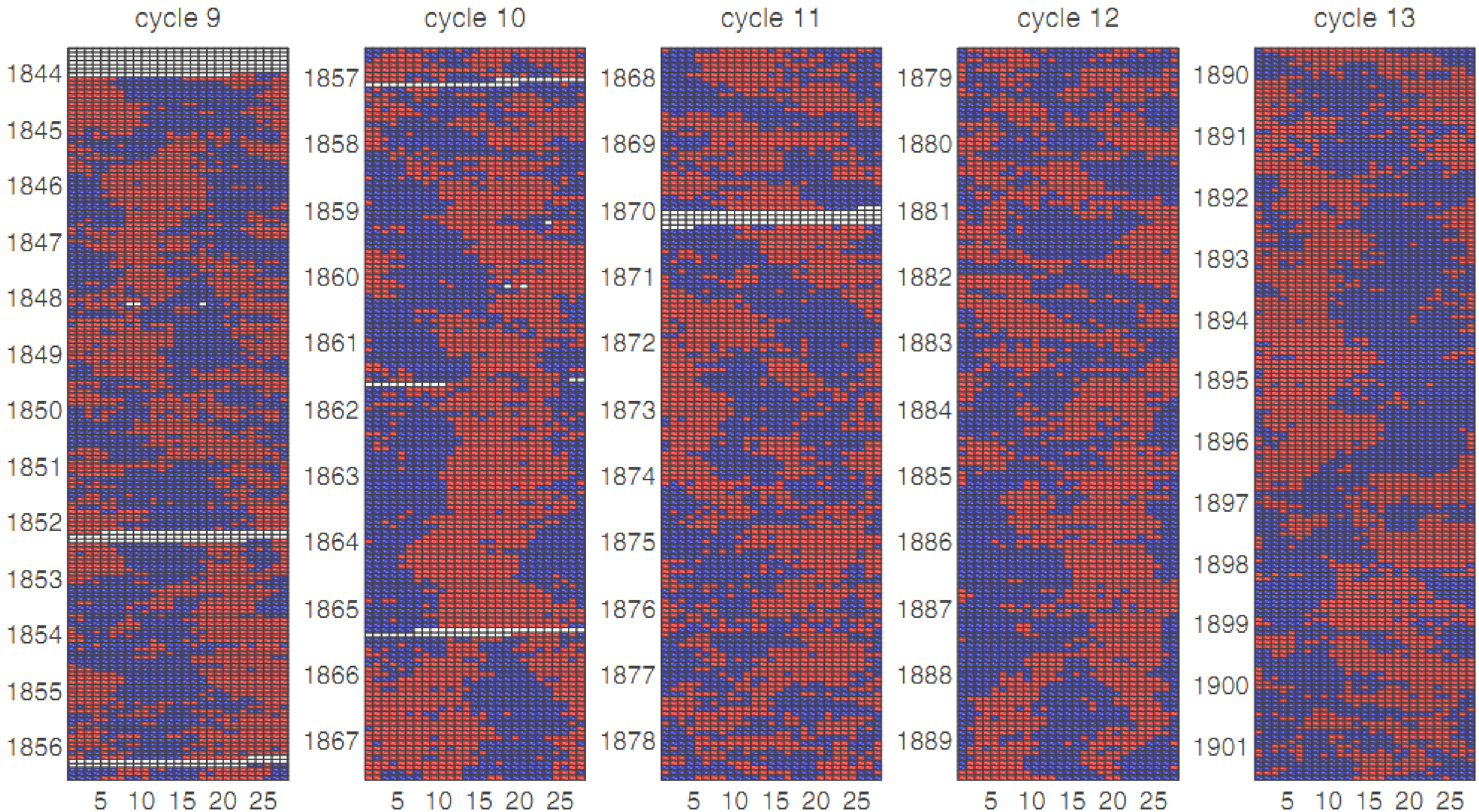
Sector structure of the interplanetary magnetic field in the nineteenth century, Geophysical Research Letters, **40**, 3512–3516, doi:10.1002/grl.50749, 2013







Both ‘27-day’ and ‘28.5-day’ Structures in the Early Data



Are the early data (including mine) reliable? This we investigate next

Using the Inferred Sector Structure we [the computer] can make a List of Well-Defined Sector Boundaries

+,-	1844	07	14	21	9	-,+	2016	02	26	11	9
-,+	1844	07	23	9	8	+,-	2016	03	06	9	6
+,-	1844	08	09	7	14	-,+	2016	03	22	7	11
-,+	1844	08	23	14	14	+,-	2016	04	02	11	6
+,-	1844	09	06	14	14	-,+	2016	04	08	6	4
+,-	1844	10	04	10	17	+,-	2016	04	12	4	6
-,+	1844	10	21	17	10	-,+	2016	04	18	6	12
+,-	1844	10	31	10	16	+,-	2016	04	30	12	15
-,+	1844	11	16	16	11	-,+	2016	05	15	15	12
+,-	1844	11	27	11	17	+,-	2016	05	27	12	15
-,+	1844	12	14	17	13	-,+	2016	06	11	15	11
+,-	1844	12	27	13	4	+,-	2016	06	22	11	9
-,+	1845	01	11	9	11	-,+	2016	07	07	4	13
+,-	1845	01	22	11	13	+,-	2016	07	20	13	

Covering the entire period from 1844 to the present (2016)

Geomagnetic Activity Data

P.-N. Mayaud has derived the well-known aa-index using magnetograms from two antipodal observatories. The index is available from 1868 to the present (2016).

H. Nevanlinna has extended the series back in time to 1844-1897 using the data from Helsinki, Finland.

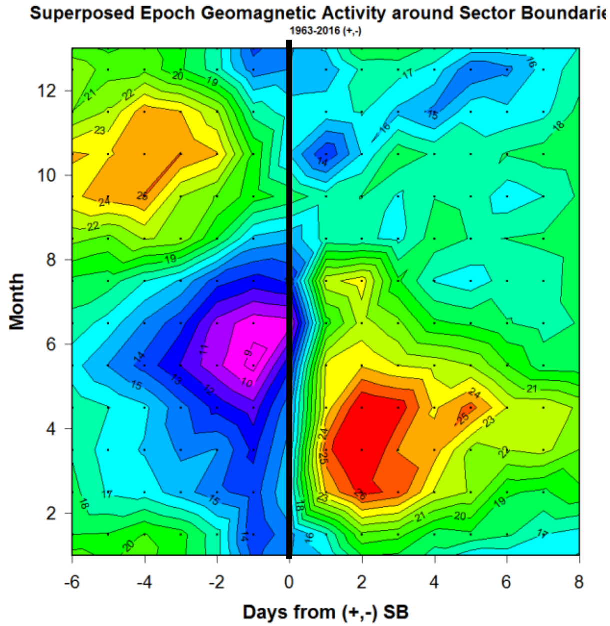
Data from Russian observatories 1850-1862 is also available, although slightly less reliable.

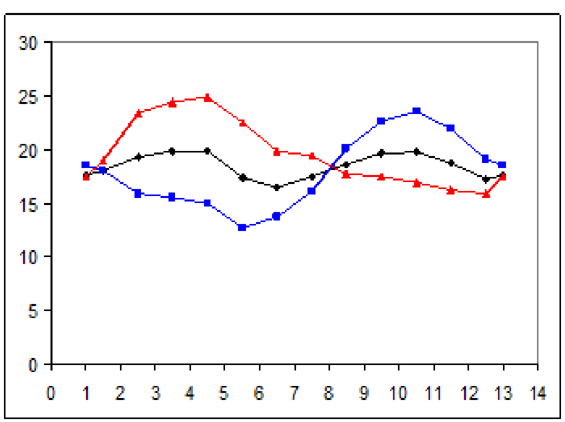
Mayaud’s superb am-index (1959-Present) is available too.

I have constructed a composite of all available data for the entire interval 1844-2016. The data consists of 3-hour K-values with a third-unit resolution (0o, 0+, 1-, 1o, 1+, 2-, 2o, 2+, …, 8-, 8o, 8+, 9-, 9o).

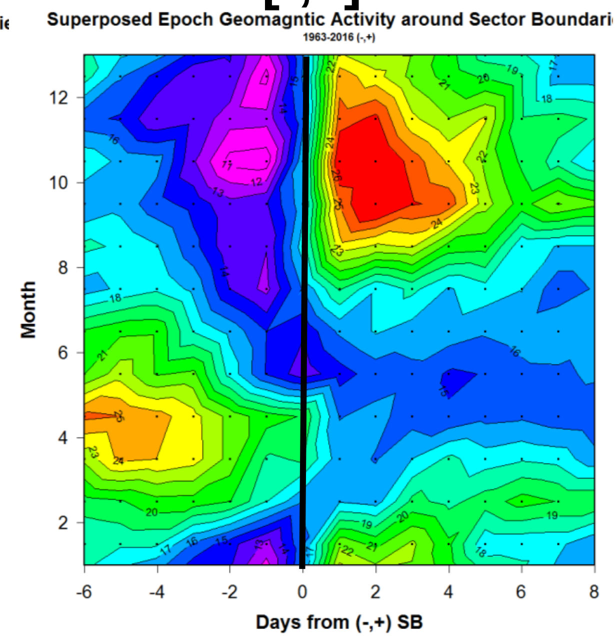
Superposed Epoch of Semiannual Geomagnetic Activity around Sector Boundaries During Space Age 1963-2016

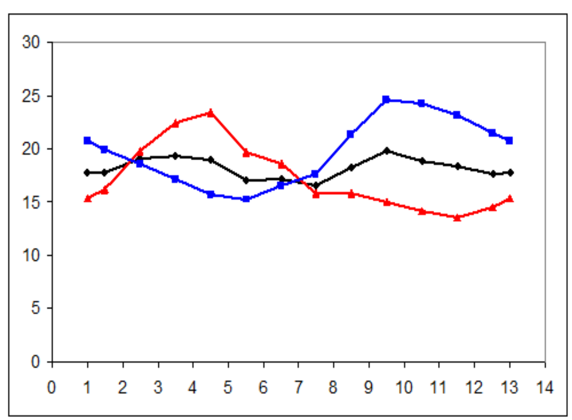
[+,-]



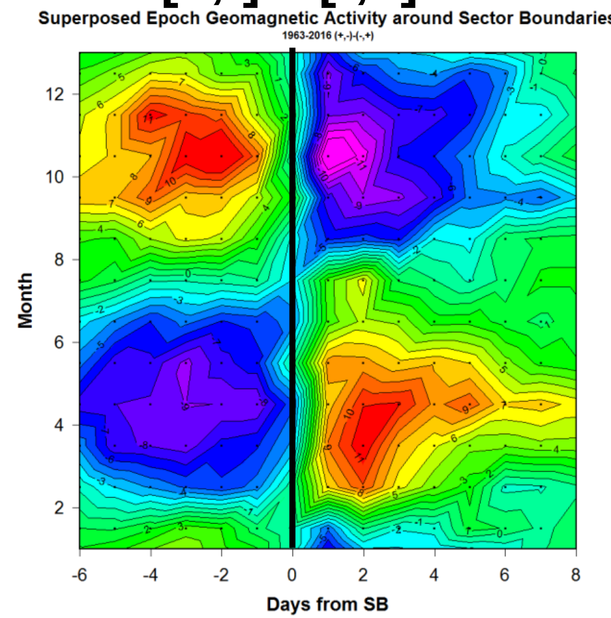


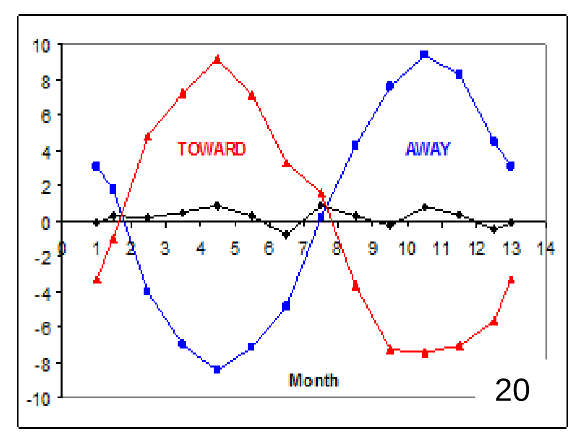
[-,+]



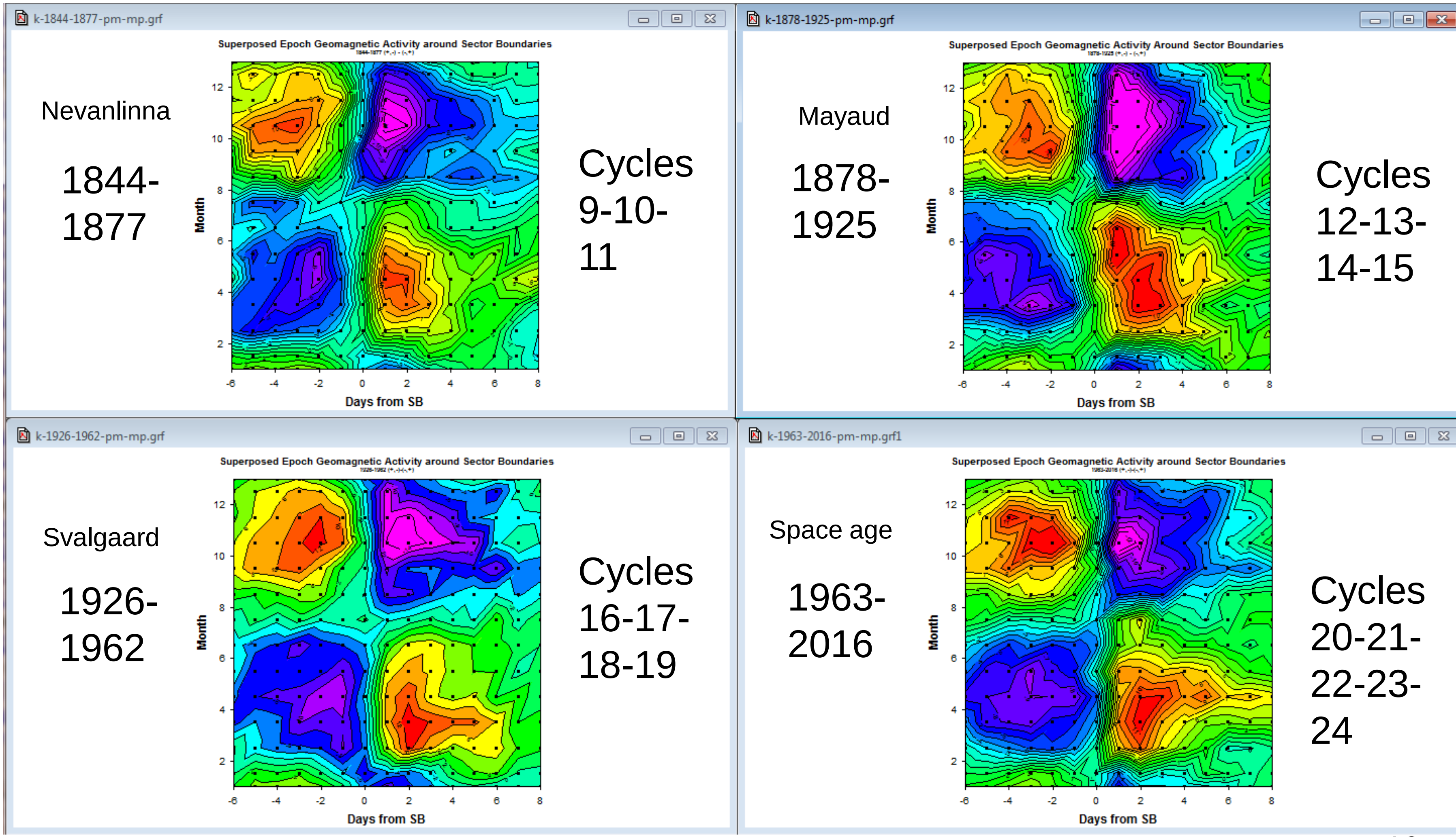


[+,-] – [-,+]



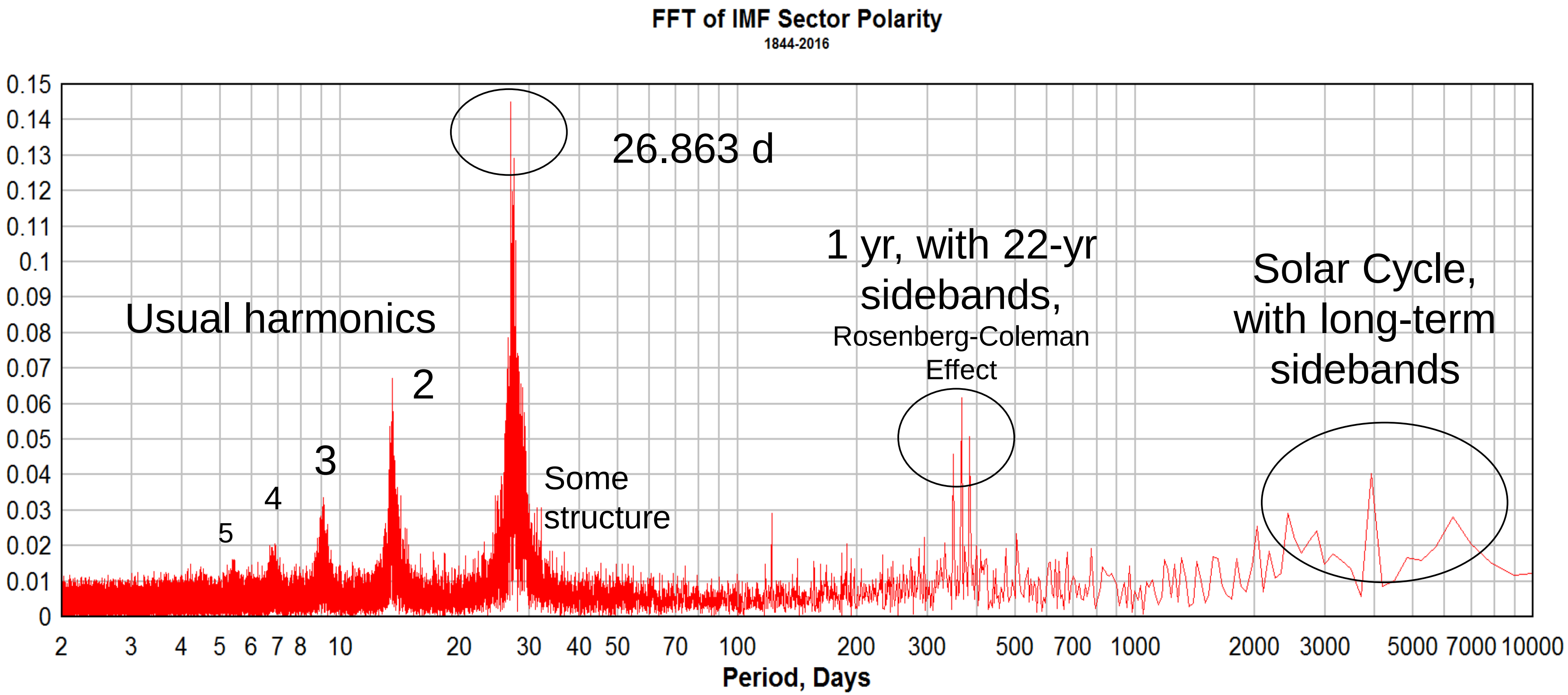


We see the same pattern in each subset of the Sector Polarity Data



I interpret that to mean that the data is good

Justifying Calculating the FFT



For the entire interval 1844-2016

Average Recurrence Period in Solar Wind Data

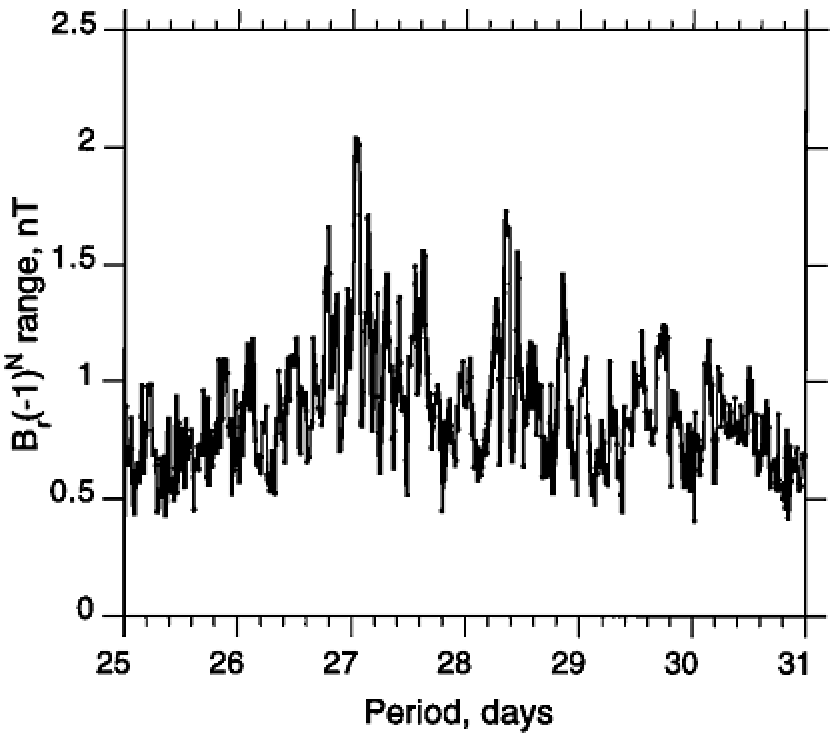
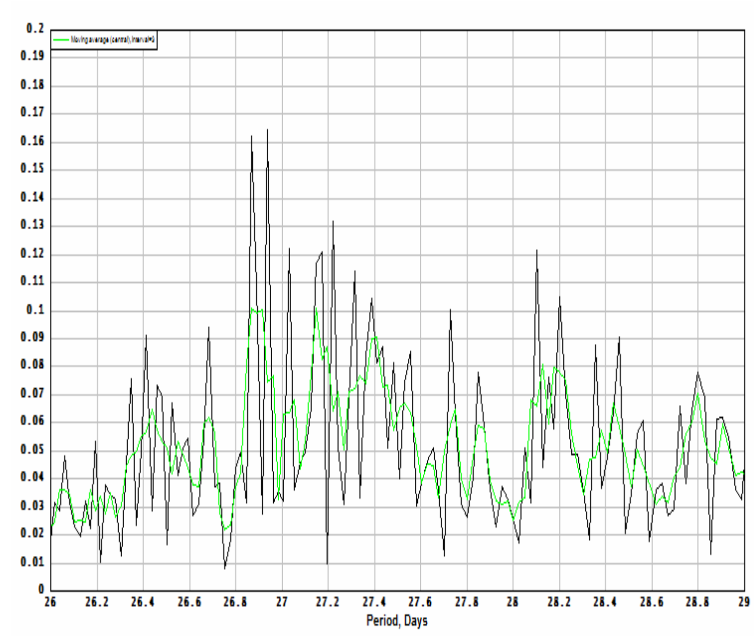


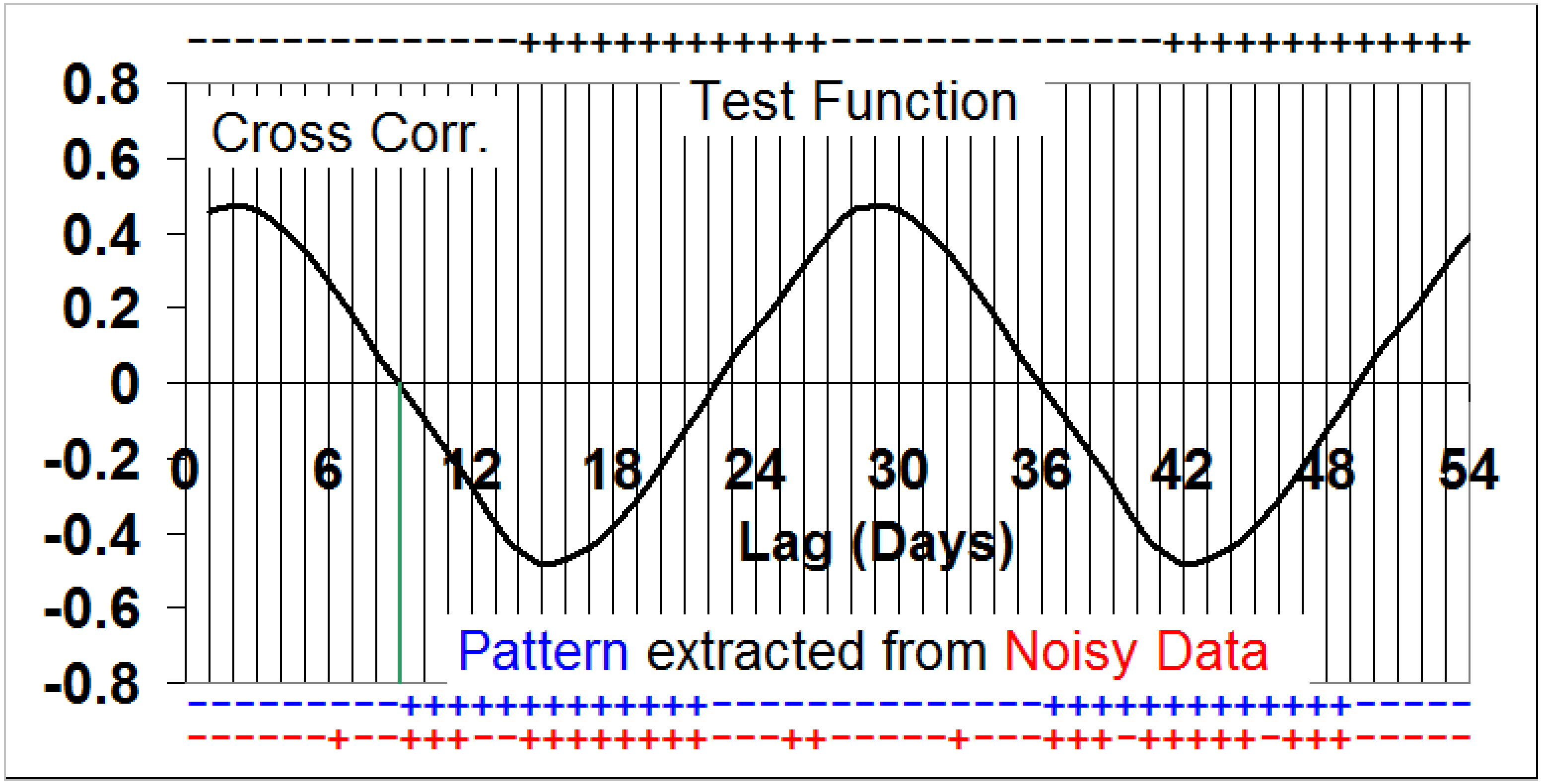
Figure 5. The difference between the highest and the lowest values of $B_r(-1)^N$ for the time-averaged $B_r(-1)^N$ versus longitude curves as a function of solar rotation period from 25 to 31 days.

Neugebauer et al., 2000

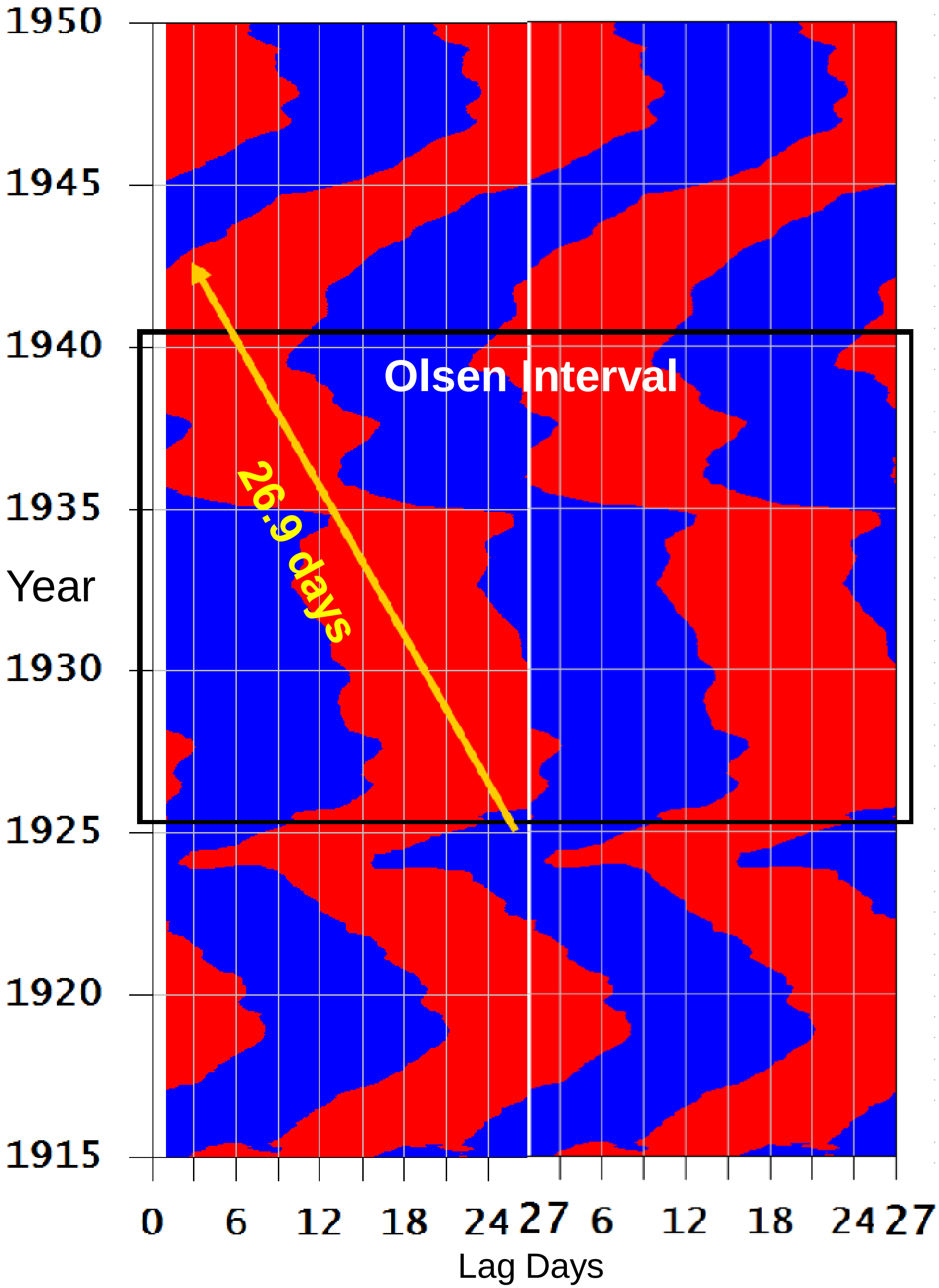


"On average, solar magnetic field lines in the ecliptic plane point outward on one side of the Sun and inward on the other, reversing direction approximately every 11 years while maintaining the same phase. The data are consistent with a model in which the [equatorial] solar magnetic dipole returns to the same longitude after each reversal."

Using a 'Test Function' to Ferret out Persistent Patterns



We construct a time series of 37 27-day rotations with a two-sector structure and cross-correlate that with the [noisy] observed sector polarities sliding one day at a time. Where the observed structure matches the synthetic structure the correlation coefficient will be high. The 'nodes' of zero correlation mark the sector boundaries [the phase of the structure within the 27-day system].



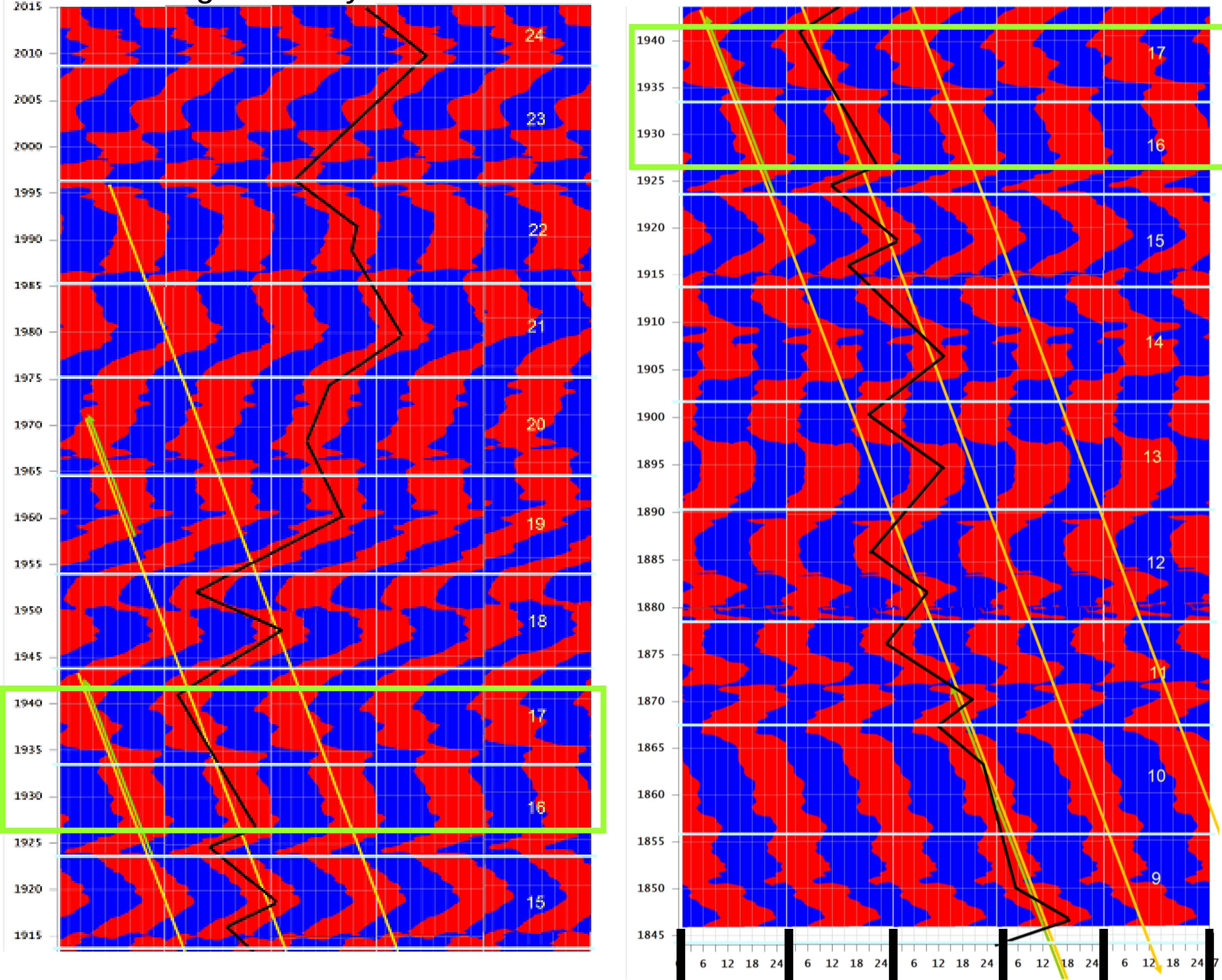
The Test Function Approach finds the Olsen Pattern

Red = Match Test function (-) polarity

Blue = Match Test Function (+) polarity

In this plot we show two rotations side-by-side. As the matching areas with high correlation slants to the left as we move forward [up] in time, the ‘ridge’ of correlation has a recurrence time of less than 27 days. From the Figure we readily find 26.9 days, compatible with Olsen.

Extending the analysis to all the data 1844-2016 we find intermittent matches



Alignments are Easy, but not always Meaningful

Conclusions

- The ‘Olsen’ Dipole can be seen intermittently
- Instances of the Dipole may ‘line-up’, but are interrupted by times where the Dipole is not prevalent
- The Dipole seems to be long-lasting through solar cycles 9-10-11, 16-17, and 21-22
- At all times the sector structure lives longer than random variations would suggest and may have a deep-rooted cause
- A long list of sector polarities for each day since 1844 is available for critical analysis at http://www.leif.org/research/POLDAT.TXT

Abstract

Olsen (1948) and Wilcox & Gonzales (1971) reported evidence of a solar equatorial magnetic dipole with a stable (synodic) rotation period of 26 7/8 days maintaining its phase over 15 years (1926-1941, Olsen) and possibly to 1968 as well (1963-1968, Wilcox & Gonzales). Using a composite series of Interplanetary Magnetic Sector Polarities covering the interval 1844-2016 (derived from geomagnetic data before the space age and direct measurements during 1963-2016) we find that

1) the response of geomagnetic activity to passage (at Earth) of a sector boundary has been consistently the same in every solar cycle from 9 through 24, thus validating the inferred times of sector boundary passages over the past 173 years, and

2) the 'Olsen' dipole can be traced back **intermittently** the 16 cycles to the year 1844, albeit with a slightly different synodic rotation period of 26.86 days (431 nHz). Olsen ended his paper with "The persistence of a fixed period during 15 years points to the possibility that the origin of the effect is to be found in a layer on the Sun with a fixed rotation-period during a long time" and Wilcox & Gonzales noted that "A rotating magnetic dipole may be lurking within the sun". We revisit the evidence for those suppositions and suggest that the long-lived recurrences of the sector structure deserves further study.