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              SUNSPOT-FORMATION ACTIVITY IN THE GEOMAGNETIC INDICES
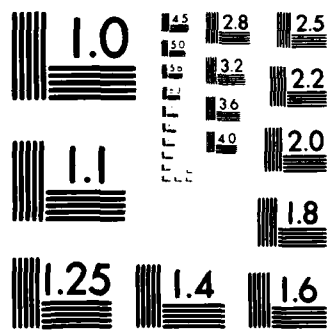   (U) NAVAL OCEAN SYSTEMS CENTER SAN DIEGO CA
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Technical Document 130

MANIFESTATION OF A NORTH-SOUTH ASYMMETRY OF SUNSPOT-FORMATION ACTIVITY IN THE GEOMAGNETIC INDICES

Translated by CM Bigger from an article by NN Petrova
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FIELD	GROUP	SUB-GROUP	sunsport-formation activity
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19 ABSTRACT (Continue on reverse if necessary and identify by block number)

This document presents an investigation of the manifestation of north-south asymmetry of solar activity in geomagnetic effects using a series of M-index values.

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MANIFESTATION OF A NORTH-SOUTH ASYMMETRY OF
SUNSPOT-FORMATION ACTIVITY IN
THE GEOMAGNETIC INDICES

NN Petrova

LA POSTA ASTROGEOPHYSICAL OBSERVATORY

The semiannual variation of geomagnetic activity has been repeatedly investigated in order to ascertain the exact dates of the fall-spring maxima (eg, see the summary in ref 1). However, the results have been substantially different depending on which interval of years was chosen for the statistical analysis. Several authors have come to the conclusion that there exists an additional annual variation of geomagnetic indices with maxima varying according to phase and amplitude (see ref 2). In reference 2, the geomagnetic indices, Ci, were utilized for the period from 1884–1969. The 27-day, semiannual, and 11-year variations were smoothed out through the use of a numerical bandpass filter. A quasistable annual variation with amplitude and phase controlled by the 11-year solar activity cycle was obtained. Larger amplitudes and stable phases of the annual variation were noted during the course of the odd cycles. In reference 2, the existence of the annual variation is linked with the north-south asymmetry of sunspot-formation activity. The probability of the earth intercepting plasma clouds arising in the northern solar hemisphere increases in the autumn, while for those plasma clouds arising in the southern hemisphere the probability increases in the spring. This is due to the difference in the earth's position relative to the solar equator during the course of a year. Therefore, in the event of a predominance of sunspot-formation activity in one hemisphere during the year, it is possible that a reinforcement of geomagnetic activity will be expected in the corresponding half year.

During the present investigation of the manifestation of north-south asymmetry of solar activity in geomagnetic effects, we utilized a series of M-index values for the geomagnetic disturbances which were linked to the well-known planetary k-index by the relation

$$M = 10(\Sigma k_p - 10)$$

A catalogue of monthly M-index values is presented in reference 3. The north-south asymmetry data for sunspot-formation activity during the years 1884–1953 were taken from reference 4 and, during the years 1954–1968, from reference 5.

For the general analysis of the role of activity asymmetry independent of phase and evenness of the cycle, years were chosen during the period from 1884 through 1953 when the difference in the mean yearly latitude of the sunspot area in the northern and southern hemispheres (spots N-S in ref 4) was larger in absolute magnitude than $2°$, ie, when north-south asymmetry of sunspot-formation activity was particularly pronounced.

The normalized mean monthly values $(\overline{M}/M_y)$ (M_y is the mean for the corresponding year) are presented in Ill 1. The continuous lines indicate those years in which the northern hemisphere was more active, while the dashed lines indicate when the activity was predominantly in the southern hemisphere. Let us note that during the calculations the negative M-values in the catalogue were removed by adding some constant number to all monthly values for the corresponding year. During the first half of the year, ie, when the earth is projected on the southern solar hemisphere, there is a noticeable surplus of the dashed line above the continuous and a surplus of the continuous above the dashed during the second half of the year.
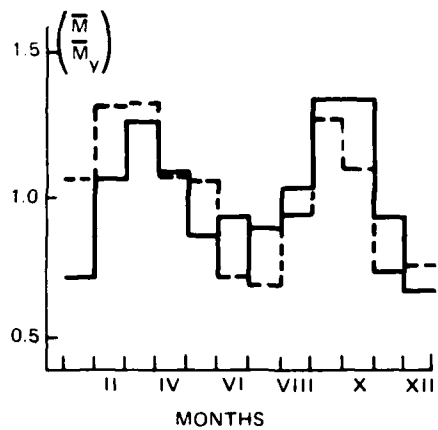
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[1] CT Russell and RL Mc Pherron. J Geoph Res, 78, 92, 1973
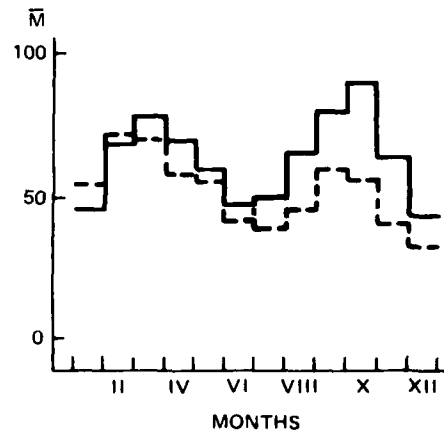[2] GW Münch, Planet Space Sci, 20, 225, 1972
[3] AI Ol', Tr AANII, 289, 5, 1969
[4] Sunspot and Geomagnetic Data Derived from Greenwich Observations 1874-1954. L, 1955
[5] RS Gnevyševa, Tr GAO, 1957-1971

III 1

III 2

The most significant differences in the yearly trend of geomagnetic disturbances
between years with activity predominantly in the northern and in the southern hemispheres
were apparent in the case when intervals from the middle of the even to the middle of the
odd 11-year cycle were taken using the material from 1884–1953. In agreement with
reference 6, some time after the maximum number of sunspots occurred, a change in the
predominant polarity of the interplanetary magnetic field took place, ie, the above indicated
interval between mean cycles corresponds to the solar magnetic cycle. In III 2 also, the
continuous line designates the mean monthly size of the M-index in years with activity pre-
dominantly in the northern hemisphere for intervals from the middle of the even to the
middle of the odd cycles. Years with activity predominantly in the southern hemisphere
are indicated by the dashed line. During the second half of the year (when the earth is pro-
jected on the northern solar hemisphere) an increase in the geomagnetic disturbances is quite
evident for cases when the northern solar hemisphere is more active. The probability of a
chance difference in the means for the October months, according to Fisher's t-test, is 0.003.
For the entire period when the earth is located north of the solar equatorial plane, ie, from
July to November, the probability that a difference in the mean M-values between those cases
with high northern hemisphere activity and those cases with high southern hemisphere activity
occurs by chance is 0.0003.

In order to obtain a clearer isolation of the described singularity, an attempt was
made to free it from the semiannual magnetic disturbance variations. Up until now all pro-
posed hypotheses explaining semiannual variation (ref 1) have in one way or another linked
it with the orbital movement of the earth, ie, they consider only the change in the geometric
parameters. This geometric factor will naturally remain constant for any length of time
examined. Therefore, the yearly geomagnetic disturbance trend in some approximations
may attempt to behave as the sum of a constant component and other components which
depend on the phase, the evenness of the cycle, and the north-south asymmetry of activity,
and therefore, for a large interval of years it is changing its size and sign. When averaging
over a prolonged period of time the constant "geometric" component must manifest itself
in a more distinct form.

[6] JM Wilcox and PH Scherrer. J Geop Res, 77, 5385, 1972

III 3A presents the mean M-Index values according to month for the 85 years from 1884–1968. If the "axial" hypothesis linking the semiannual variation with a change in the
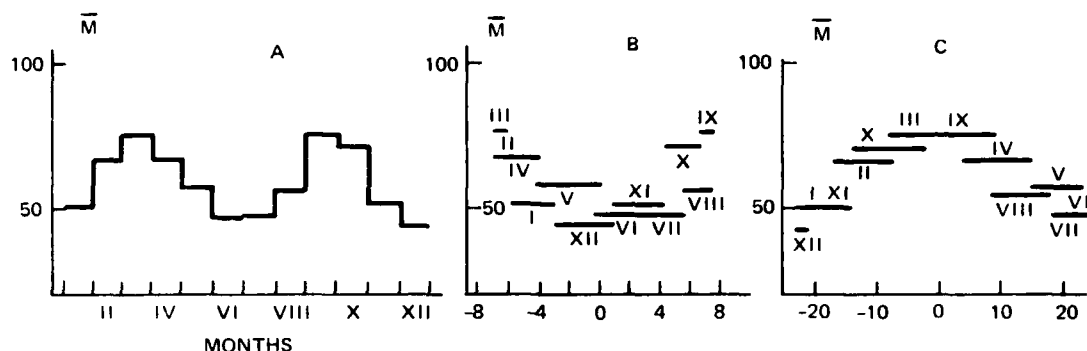
III 3

earth's heliographic latitude is valid, then the mean monthly values obtained must be distributed along some smooth curve which depends on the correspondence of the heliographic latitude value of the apparent solar disk for each month. In the event that the "equinox" hypothesis is true, the monthly means must show a systematic trend with a change in solar declination. In III 3B and 3C, the mean monthly values obtained were distributed according to intervals of the earth's heliographic latitude and the declination of the sun. Roman numerals mark the corresponding months. In the second case, the data show a somewhat more ordered trend. This result may serve as additional evidence in favor of the "equinox" hypothesis (ref 7). At the present time, there are in the literature sufficient data confirming the "equinox" hypothesis (see ref 8). In conjunction with these data it is necessary to examine the possibility that, in planetary phenomena which may have been stimulated by solar plasma flux, there can be found an analogous semiannual variation (appearing as half the sidereal rotation period). For the existence of semiannual variation, in accordance with reference 7, it is essential that the planet have both a magnetosphere and a significant angle of equatorial inclination towards the plane of the ecliptic. Thus, for example, there are surges in Jupiter's decameter radio emission connected with solar activity[9] which are not required to have semiannual variation, since in spite of the presence of a powerful magnetosphere the angle between the equatorial plane and the orbital plane of Jupiter is too small ($3°^-$). In the event that Jupiter describes a similar variation, then evidently the equinox hypothesis requires further reexamination.

The mean monthly values obtained were then normalized to the mean for 85 years (M_y^*) and then subtracted in this manner from the mean values and normalized to the corresponding mean value M for the even and odd cycles, their various phases, and for intervals between the means of the even and odd cycles. It was assumed that the singularities inherent in the given phase of the cycle, thus successfully separated from the constant "geometric" component, will be much more clearly expressed. As above, the data were divided into years having activity predominantly in the northern solar hemisphere and years with activity predominantly in the southern.

[7] G Bartels. Handbuch der experimentalphysik. XXV. I Teil. 1928
[8] GM Wilcox. Space Sci Rev. 8, 258, 1968
[9] NN Petrov. Soln Dannye. No 3, 1973

In this manner Ill 4 shows the differences obtained for the even (A) and odd (B) 11-year cycles. As earlier, the continuous line corresponds to years having a prevalence of activity in the northern hemisphere and the dashed line to years having a prevalence of activity in the southern hemisphere. It is clearly seen that the effect of the north-south asymmetry of activity is displayed only in the odd cycles. This result agrees well with the
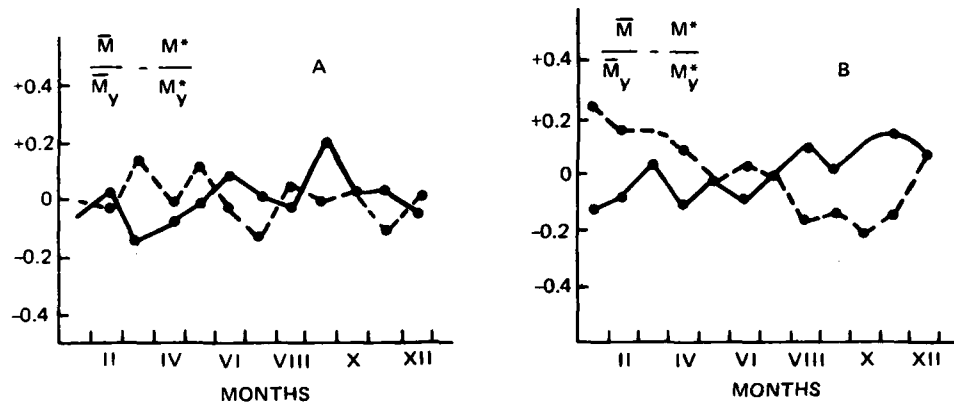
Ill 4

conclusion in reference 2 where the existence of a stable annual variation in cycles 13, 15, 17, and 19 was established, while in the even cycles such a stability is not shown. Such a similarity of results to some extent indicates the acceptability of applying the described method of liberation from the semiannual variation. The difference between the even and odd cycles may be connected with a different characteristic of the interplanetary magnetic field, depending on cycle evenness. The polarity and intensity of the interplanetary magnetic field to a large extent determine the magnitude of the geomagnetic disturbance (ref 8).

Grouping data by the interval between the middle of the cycles, ie, between the moments close to the epoch of solar magnetic polarity change, also showed a difference according to the cycle succession. As described above, Ill 5 presents the differences in the


Ill 5

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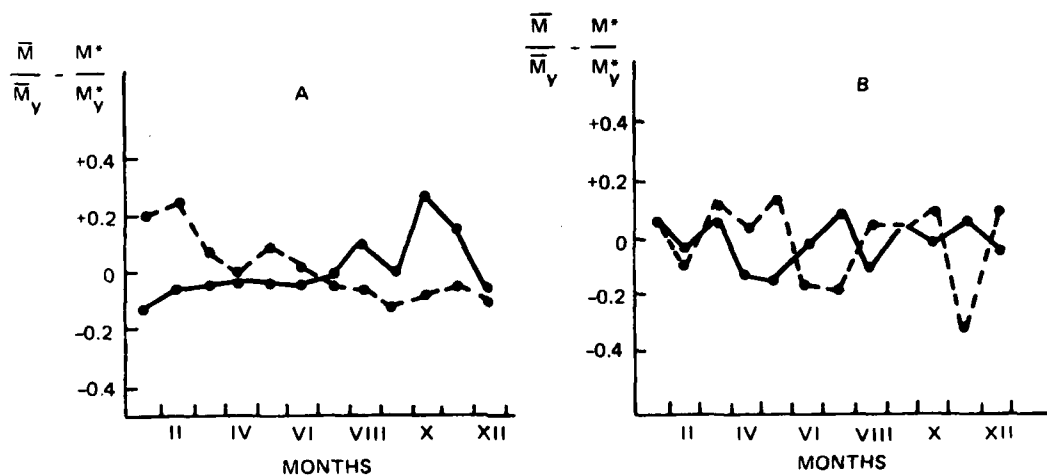
intervals (A) from the middle of the even to the middle of the odd cycles and (B) from the middle of the odd to the middle of the even cycles. In the first case, the differences between the effects of the more active northern and more active southern hemispheres were expressed sufficiently clearly; however, the second case was missing any kind of systematic trend. On this basis, it may be assumed that the geomagnetic disturbances may also serve as one of the indices of the 20-year solar magnetic cycle described in reference 6.

The probability that the differences

$$\frac{\bar{M}}{M_y} - \frac{M^*}{M_y^*}$$

belong to the same statistical aggregate in all of the alternatives was verified with the help of the Mann-Whitney U* test (ref 10).

Since this test relates to the distribution of data from both samples in their increasing order, and since the present work is investigating the case of the sign change for the effect during the transition of the earth's heliographic latitude from negative to positive, the data were divided into groups consisting of January through May and July through November. This was done according to five criteria. June and December were excluded from the examination because during these months the heliographic latitude of the earth is changing sign.

III 6*

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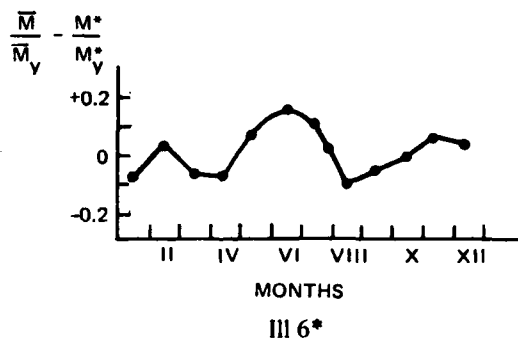
*Translator's note: No reference to III 6 -- this was not referred to in the original document.

[10]D Ximmel'blau. Analiz processov statisticeskimi metodami. "Mir," M. 1973, str 159

The results of the analysis are presented in the table.

Alternative No	Data Grouping Alternatives	The Probability of Belonging to One Statistical Class	
		January–May	July–November
1	Odd cycles	0.008	0.004
2	Even cycles	0.028	0.274
3	Middle even cycles to middle odd cycles	0.004	0.004
4	Middle odd cycles to middle even cycles	0.111	0.345

Alternatives 1 and 3 can, evidently, be investigated in relation to various statistical associations, then as with cases 2 and 4 they will have a large probability of relating to one aggregate.

For the maximum epoch (we took the first year before the maximum, the year of the maximum, and the first year after the maximum) the differences obtained clearly show the reinforcement of activity in the summer months that was noted by AI Ol' as early as 1948 (ref 11).

The results obtained lead to the following conclusions:

1. The trend for the mean monthly M-index value of the geometric disturbance during the 85 years (ref 3) evidently agrees better with the equinox hypothesis (ref 7) as an explanation for the existence of semiannual variation.

2. For an analysis of the link between geomagnetic disturbances and solar activity, it is necessary to calculate the north-south activity asymmetry.

3. The role of north-south asymmetry differs as a function of phase and evenness of the 11-year solar activity cycle; evidently the solar magnetic cycle described in reference 6 appears also in the north-south asymmetry.

In conclusion, I convey my thanks to BM Rubašev and AL Ol' for their interest in the work and their valuable advice.

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[11] AI Ol'. Priroda. No 7, 1948

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8. GM Wilcox, Space Sci Rev, _8_, 258, 1968

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