Kodaikanal Observatory.

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AN APPARENT INFLUENCE OF THE EARTH ON SOLAR PROMINENCES

By J. EVERSHED, F.R.S., and P. R. CHIDAMBARA AYYAR, B.A.[1]

In her well-known paper on "An Apparent Influence of the Earth on the number and area of Sunspots in the Cycle 1889--1901," Mrs. Maunder gives evidence which "seems to show that spots tend to diminish in area rather than to increase as they pass under the Earth, and that there is a decided tendency to check the generation of spots on the hemisphere presented to the Earth."[2]

In Kodaikanal Bulletin No. XXVIII "On the Relative Numbers of Prominences observed on the Eastern and Western Limbs," the evidence given seems to support the conclusion that in the case of prominences also there is a tendency to a diminution in numbers as they cross the visible disc.

On the other hand, Dr. Royds and S. Sitarama Ayyar have shown by the periodogram method of Schuster that any effect due to planetary action, including the Earth, is improbable, although "the observed systematic excess on the one limb or any periodicities in its variations must be associated with the Earth's direction."[3]

If it is assumed that the Earth tends to extinguish a prominence during its passage across the Sun's disc, this action might be expected to vary between the northern and southern hemispheres having some relation to the direction of the Earth or to the relative areas presented to the Earth. For instance, between February and March of each year the centre of the Sun's disc is in 7° south latitude and the total visible area of the southern hemisphere is greater than that of the northern by about 28 per cent. In August and September the northern hemisphere predominates over the southern by the same amount. If therefore the Earth really exerts an influence on the prominences, this difference in area or the change in the direction should give rise to a semi-annual periodicity in the eastern excess for each hemisphere. The Sun's synodic rotation period being roughly 28 days, we can find the amount of extinction supposed to be produced by the Earth by comparing the prominences on any day on the east limb with those on the west limb fourteen days later. Thus, if x be the prominences reckoned in numbers or areas observed on the east limb on the first day, y those observed on the west limb on the 15th day, the extinction is $x - y = E$, where E may be expressed as a percentage of x, and is positive when prominences are reduced in number or area, negative when new prominences are added or areas increased.

Let us suppose that the inclination of the Sun's axis, which we call D, is a maximum in the north, or $D = +7°$. Then $x_n - y_n = E_n$ will represent the extinction in the northern hemisphere, where x_n represents the prominences observed on the north-east limb on any day, and y_n those observed on the north-west limb on the fifteenth day. Similarly $x_s - y_s = E_s$ will represent the extinction in the southern hemisphere. But since the northern hemisphere is presented towards Earth, E_n should be greater than E_s, $E_n - E_s$ being positive.

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1 Mr. Chidambara Ayyar who recently joined the staff at Kodaikanal has by great industry in dealing with the mass of material contained in our prominence records discovered a new relation between prominence frequencies east and west of the sun's axis and the heliographic latitude of the Earth. This, while adding weight to the case for an influence of the Earth on solar phenomena, is apparently opposed to the suggestion that the Earth tends to extinguish a prominence in its passage across the visible disc. Mr. Chidambara Ayyar is entirely responsible for the method of treating the records and for the facts given in this paper, and is to be congratulated on the interesting and suggestive results of his research.--J.E.

2 Monthly Notices of the Royal Astronomical Society, LXVII, 474.

3 Kodaikanal Observatory Bulletin No. XXXV.

In the same way, when D is $-7°$, E_s should be greater than E_n, $E_n - E_s$ being negative. If therefore our assumption is correct, the value of $E_n - E_s$ should every year be positive when $D = +7°$ and negative when $D = -7°$, or at any rate the values should rise and fall consistently with the changes in D.

If on the other hand $E_n - E_s$ is systematically negative when $D = +7°$, and positive when $D = -7°$, or the value falls for $+7°$ and rises for $-7°$, it would seem that the Earth instead of extinguishing prominences tends to sustain or generate them.

This principle has been employed in examining the large amount of material supplied by the prominence records of the Kodaikanal Observatory for the years 1904—1920. Precautions have been taken to ensure trustworthy comparisons of the east and west limbs on pairs of days a fortnight apart. For example, if prominences were recorded on a fine day and the record for the fifteenth day was imperfect in any way, the comparison would show an exaggerated extinction, but the extinction would be lessened if the conditions existed in the reverse order. It was therefore necessary to reject all pairs of days on which complete records did not exist, or the photographs were not obtained under as far as possible ideal conditions.

The comparisons have been made in the first instance at epochs when the value of D reaches 7° or over, north and south, which limits the number of days in each year to 30 pairs between February and March and 30 pairs between August and September, and since a proportion of these has to be rejected, the material for each individual year becomes too slender to indicate any very trustworthy result. It is indeed surprising that the annual results come out as consistently as they do.

Table I gives the results of examining in this way the prominence numbers for the entire period of 16 years 1904—1920. Owing to the much more favourable conditions in February and March compared with August and September, when cloudy monsoon weather prevails, the annual numbers for $D = -7°$ are much larger and therefore give more trustworthy mean values than those for $D = +7°$.

It will be seen that the percentage of extinction on the west limb varies very irregularly, as is to be expected in dealing with such relatively small numbers for each year. Yet there is seen to be more often a gain than a loss of prominences on the west limb in that hemisphere which is turned towards Earth, and when we compare the values $E_n - E_s$ for $D = +7°$ with those for $D = -7°$ there results a systematic difference, which is readily appreciated when the values are plotted as we have done in diagram No. I. Here it is evident that whilst the values rise and fall with respect to the zero line of no difference in extinction, yet the higher points are consistently at $-7°$ and the lower at $+7°$ for every year until 1916 or 1917, when a change occurs, and from 1917 onwards the reverse is the case, the + values of D corresponding with the greater extinction in the north. It is to be noted that this change occurs at a time when the general distribution of prominences between east and west underwent a marked change. Thus from the beginning of our records in 1905 until the end of 1916 each year has shown a numerical excess of eastern prominences, excepting 1914, when there was a very slight western excess. The proportion of eastern prominences averaged 52·7 per cent of the whole number from 1905 to 1911 inclusive, and in the five years 1912—1916 it was 50·5 per cent only. Between 1916 and 1917 it fell from 50·5 to 49·5 per cent, and in the four years 1917—1920 the mean is 48·2 per cent.

If we take areas instead of numbers the same change is exhibited, both in the general distribution between east and west and in the periodical relation between the northern and southern hemispheres corresponding to the extreme values of D plus and minus. But the figures for prominence areas show smaller departures from equality between east and west than do numbers. The mean eastern proportion for the five years 1912—1916 for areas is 50·2 per cent instead of 50·5 per cent for numbers, and for the four years 1917—1920 it is 49·0 per cent instead of 48·2 per cent.

We have tabulated in the same way as for numbers the areas of prominences for the epochs when D has the extreme values of $+7°$ and $-7°$, but in this case we start with 1910, since estimates of areas are not available before that date. The results are shown in Table II, the unit in this case is a tenth of a square minute of arc. The same apparently unsystematic irregularities are even more marked than in the case of

numbers, yet the comparison of the values $E_n - E_s$ for $D = +7°$ and $D = -7°$ shows the same periodical fluctuations, in which plus values (representing a greater extinction in the northern hemisphere) or the higher points in the curve occur when $D = -7°$. There is also the same change of sign between the years 1916 and 1917, after which the higher points correspond to $D = +7°$. The results are plotted in diagram No. II.

So far we have taken no account of the intermediate values of D. In order to determine whether the value $E_n - E_s$ rose and fell in the negative direction concurrently with the increase and decrease in D, and vice versa, it was necessary to examine the prominences of every day from the first week in June 1904 to the first week in June 1920, throughout each of the years, and tabulate the numbers east and west by the method already described. This was a most laborious undertaking, but the results obtained have, we think, justified the labour spent upon it.

The change in D was divided into a series of stages as follows :—0° to 2°, 2° to 4°, 4° to 6°, 6° to 7°, 7° to 6° and so on in the reverse order. The extinction was then calculated on those prominences that started from the east limb during the period that D was changing from 0° to 2°, from 2° to 4°, and so on. The values of $E_n - E_s$ for each such stage and for all the years is given in Table III. The mean values for the 16 years have been plotted in diagram No. III. This result is most striking, the curve being a fair approximation to the ideal sine curve that we might expect to get were the conditions perfect. There is a slight difference in phase in that the transition from positive to negative direction, and negative to positive, does not take place exactly at the point where $D = 0°$, and the maximum of the curve for the negative values of D does not occur exactly at $D = -7°$. This is possibly due to the inherent irregularities in the materials we are dealing with. It appears to us that the general trend of the curve shows that there is a close correlation between the variations in the proportion of eastern and western prominences and the heliographic latitude of the Earth.

The relation does not, however, appear to be a permanent one and applies only to the period 1904—1916 inclusive. If we take the years before and after the change which took place in 1916–1917 and plot the results in the same way we get the curves I and II in diagram No. IV. Here curve I is for the years 1904—1916 inclusive and curve II for the four years 1917—1920. It will be seen that whilst curve I approximates to the sine curve given in broken lines, curve II shows no relation at all to the values of D.

Finally we have investigated the relative frequencies between the northern and southern hemispheres to see whether any relation can be made out between the total activity of the hemisphere turned towards Earth compared with that turned away from Earth. Taking as before the epochs when D has the maximum values $+7°$ and $-7°$ we find that there is no such relation as is shown by the figures for the relative extinction between north and south.

On the whole during the period 1904—1920 there is shown a general preponderance of south over north the northern prominences being 48·1 per cent of the whole number when $D = +7°$ and 48·9 per cent when $D = -7°$. If we limit the period to 1904—1916 the figures are 48·1 and 48·2 per cent respectively. We can scarcely attach any significance to so small a difference as is here indicated.

THE OBSERVATORY, KODAIKANAL,
19th June 1921.

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TABLE I.

$D = +7°$.										$D = -7°$.									
Years.	North.				South.				$E_n - E_s$.	Years.	North.				South.				$E_n - E_s$.
	Number of prominences on N.E. limb.	Number of prominences on N.W. limb.	Number of prominences extinguished.	Percentage of extinction or E_n.	Number of prominences on S.E. limb.	Number of prominences on S.W. limb.	Number of prominences extinguished.	Percentage of extinction or E_s.			Number of prominences on N.E. limb.	Number of prominences on N.W. limb.	Number of prominences extinguished.	Percentage of extinction or E_n.	Number of prominences on S.E. limb.	Number of prominences on S.W. limb.	Number of prominences extinguished.	Percentage of extinction or E_s.	
1904	18	34	− 16	− 88·9	40	23	+ 17	+ 42·5	− 131·4	1905	193	99	+ 94	+ 48·7	143	189	− 46	− 32·2	+ 80·9
1905	31	40	− 9	− 29·0	76	40	+ 36	+ 47·4	− 76·4	1906	147	150	− 3	− 2·0	132	142	− 10	− 7·6	+ 5·6
1906	46	54	− 8	− 17·4	68	43	+ 25	+ 36·8	− 54·2	1907	240	126	+ 114	+ 47·5	213	219	− 6	− 2·8	+ 50·3
1907	57	108	− 51	− 89·5	126	96	+ 30	+ 23·8	− 113·3	1908	163	91	+ 72	+ 44·2	114	160	− 46	− 40·4	+ 84·6
1908	58	63	− 5	− 8·6	100	74	+ 26	+ 26·0	− 34·6	1909	125	119	+ 6	+ 4·8	149	149	0	0	+ 4·8
1909	56	56	0	0	62	34	+ 28	+ 45·2	− 45·2	1910	149	130	+ 19	+ 12·8	127	129	− 2	− 1·6	+ 14·4
1910	52	66	− 14	− 26·9	60	58	+ 2	+ 3·3	− 30·2	1911	146	133	+ 13	+ 8·9	158	148	+ 10	+ 6·3	+ 2·6
1911	66	65	+ 1	+ 1·5	77	68	+ 9	+ 11·7	− 10·2	1912	113	101	+ 12	+ 10·6	128	122	+ 6	+ 4·7	+ 5·9
1912	61	60	+ 1	+ 1·6	78	71	+ 7	+ 9·0	− 7·4	1913	133	132	+ 1	+ 0·8	134	127	+ 7	+ 5·2	− 4·4
1913	41	67	− 26	− 63·4	60	48	+ 12	+ 20·0	− 83·4	1914	150	114	+ 36	+ 24·0	117	125	− 8	− 6·8	+ 30·8
1914	66	46	+ 20	+ 30·3	74	50	+ 24	+ 32·4	− 2·1	1915	160	192	− 32	− 20·0	162	194	− 32	− 19·8	− 0·2
1915	30	28	+ 2	+ 6·7	36	32	+ 4	+ 11·1	− 4·4	1916	139	150	− 11	− 7·9	172	174	− 2	− 1·2	− 6·7
1916	49	55	− 6	− 12·2	59	42	+ 17	+ 28·8	− 41·0	1917	222	182	+ 40	+ 18·0	171	191	− 20	− 11·7	+ 29·7
1917	73	68	+ 5	+ 6·8	61	58	+ 3	+ 4·9	+ 1·9	1918	161	146	+ 15	+ 9·3	151	150	+ 1	+ 0·7	+ 8·6
1918	44	26	+ 18	+ 40·9	59	52	+ 7	+ 11·9	+ 29·0	1919	114	100	+ 14	+ 12·3	113	113	0	0	+ 12·3
1919	22	31	− 9	− 40·9	15	27	− 12	− 80·0	+ 39·1	1920	84	87	− 3	− 3·6	73	78	− 5	− 6·4	+ 2·8
Total and mean percentage.	770	867	− 97	− 12·6	1,051	816	+ 235	+ 22·4	− 35·0		2,439	2,052	+ 387	+ 15·9	2,257	2,410	−153	− 6·8	+ 22·7

TABLE II.

Year.	$D = -7°$. North. Prominences N.E.	Prominences N.W.	Prominences extinguished.	Percentage of extinction or E_n.	$D = -7°$. South. Prominences S.E.	Prominences S.W.	Prominences extinguished.	Percentage of extinction or E_s.	$E_n - E_s$.	$D = +7°$. North. Prominences N.E.	Prominences N.W.	Prominences extinguished.	Percentage of extinction or E_n.	$D = +7°$. South. Prominences S.E.	Prominences S.W.	Prominences extinguished.	Percentage of extinction or E_s	$E_n - E_s$.
1910	313·5	219·0	+ 94·5	+ 30·1	213·0	253·0	− 40·0	− 18·8	+ 48·9	38·0	56·5	− 18·5	− 48·7	63·5	62·0	+ 1·5	+ 2·4	− 51·1
1911	172·0	164·5	+ 7·5	+ 4·4	210·5	200·0	+ 10·5	+ 5·0	− 0·6	70·0	78·5	− 8·5	− 12·1	136·0	98·5	+ 37·5	+ 27·6	− 39·7
1912	102·0	121·0	− 19·0	− 18·6	197·5	137·0	+ 60·5	+ 30·6	− 49·2	50·0	66·5	− 16·5	− 33·0	136·0	99·5	+ 36·5	+ 26·8	− 59·8
1913	152·0	169·5	− 17·5	− 11·5	125·5	117·5	+ 8·0	+ 6·4	− 17·9	45·0	50·0	− 5·0	− 11·1	116·5	75·0	+ 41·5	+ 35·6	− 46·7
1914	187·0	105·5	+ 81·5	+ 43·6	83·0	101·0	− 18·0	− 21·7	+ 65·3	107·0	24·0	+ 83·0	+ 77·6	104·0	56·0	+ 48·0	+ 46·2	+ 31·4
1915	206·5	340·0	− 133·5	− 64·6	172·0	368·0	− 196·0	− 114·0	+ 49·4	50·0	44·0	+ 6·0	+ 12·0	98·5	127·0	− 28·5	− 28·9	+ 40·9
1916	349·0	152·5	+ 196·5	+ 56·3	232·5	200·0	+ 32·5	+ 14·0	+ 42·3	112·0	59·0	+ 53·0	+ 47·3	93·0	72·0	+ 21·0	+ 22·6	+ 24·7
1917	445·0	401·0	+ 44·0	+ 9·9	471·0	447·5	+ 23·5	+ 5·0	+ 4·9	54·0	54·5	− 0·5	− 0·9	93·5	107·0	− 13·5	− 14·4	+ 13·5
1918	280·0	407·0	− 127·0	− 45·4	322·5	386·5	− 64·0	− 19·8	− 25·6	98·5	65·0	+ 33·5	+ 34·0	204·0	94·5	+ 109·5	+ 53·7	− 19·7
1919	245·0	249·5	− 4·5	− 1·8	375·5	239·5	+ 136·0	+ 36·2	− 38·0	59·5	68·5	− 9·0	− 15·1	19·0	18·5	+ 0·5	+ 2·6	− 17·7
1920	205·0	344·5	− 139·5	− 68·0	270·5	280·5	− 10·0	− 3·7	− 64·3	159·0	185·0	− 26·0	− 16·4	136·5	189·5	− 53·0	− 38·8	+ 22·4

TABLE III.

The value of $E_n - E_s$ as the value of D changes from 0° through +7° to 0° and from 0° through −7° to 0° for the years 1904–1905 to 1919–1920.

Years.	0° to 2°	2° to 4°	4° to 6°	6° to 7°	+7°	7° to 6°	6° to 4°	4° to 2°	2° to 0°	0° to −2°	−2° to −4°	−4° to −6°	−6° to −7°	−7°	−7° to −6°	−6° to −4°	−4° to −2°	−2° to 0°
1904–05	− 50·0	+ 10·1	− 13·4	− 88·7	−131·4	− 40·9	−170·1	− 85·0	− 86·8	− 53·1	− 25·9	− 16·7	+ 76·4	+80·9	+ 55·9	+ 57·8	+ 40·0	− 17·5
1905–06	+ 34·3	− 7·3	− 47·8	− 97·1	− 76·4	− 15·0	− 36·8	−133·3	− 22·2	− 34·0	− 10·3	− 15·7	− 9·9	+ 5·6	+ 93·4	+ 9·7	+ 13·6	+ 1·7
1906–07	− 23·9	+ 28·9	− 48·4	+ 7·6	− 54·2	− 27·8	− 96·9	− 39·6	− 18·4	− 39·5	+ 24·8	+ 20·1	+ 59·0	+50·3	+ 3·6	+ 10·3	+ 32·7	+ 49·7
1907–08	+ 69·8	+ 50·0	+ 28·5	− 58·6	−113·3	− 89·2	−103·1	− 50·2	− 62·4	− 21·0	− 2·3	+ 35·8	+ 51·4	+84·6	+ 80·3	+ 66·2	+ 40·0	− 18·4
1908–09	+ 31·0	− 1·1	− 33·1	+ 33·1	− 34·6	·0	− 10·8	− 6·8	− 6·5	− 2·7	− 10·8	+ 3·7	+ 53·1	+ 4·8	+ 2·6	+ 42·0	+22·7	+ 2·7
1909–10	+ 26·2	− 52·4	− 32·6	+ 42·4	− 45·2	+ 0·9	− 19·1	− 6·6	− 6·3	− 10·3	+ 38·8	− 0·9	− 18·5	+14·4	+ 29·7	+ 22·6	+ 4·2	− 9·6
1910–11	− 13·2	− 46·3	+ 0·2	+ 3·8	− 30·2	+ 9·7	− 13·6	− 26·1	+ 1·9	+ 28·2	+ 34·3	+ 15·6	+ 16·4	+ 2·6	+ 28·1	+ 35·0	+ 33·2	− 23·4
1911–12	+ 20·9	+135·0	+ 8·3	+ 12·3	− 10·2	+ 3·4	− 23·3	+ 1·5	+ 35·7	− 34·7	+ 5·5	+ 29·8	+ 32·5	+ 5·9	+ 25·0	+ 33·5	+ 6·8	+ 12·5
1912–13	− 3·2	− 6·8	+ 5·3	+ 37·3	− 7·4	− 19·1	+ 8·7	− 80·1	+ 32·1	+ 8·7	− 27·1	+ 21·9	+ 20·3	+ 4·4	+ 8·9	+ 35·2	+ 11·3	+ 1·0
1913–14	+ 32·3	− 47·1	+ 7·0	− 49·1	− 83·4	− 53·5	− 59·6	+ 40·4	− 12·6	+ 1·8	+ 1·7	+ 29·0	+ 38·0	+30·8	+ 42·1	+ 24·2	+ 42·3	+ 64·0
1914–15	+ 29·6	− 44·9	− 33·4	− 43·0	− 2·1	+ 27·4	+ 33·9	+ 1·1	− 47·3	− 7·1	+ 53·3	+ 50·4	+ 22·5	− 0·2	+ 12·7	+ 10·8	+ 35·0	+ 26·4
1915–16	− 26·9	+131·0	− 37·5	− 79·0	− 4·4	− 9·1	+ 4·9	− 19·0	+ 36·5	+ 12·0	− 2·5	− 2·8	+ 18·5	− 6·7	+ 20·6	+ 11·8	− 10·5	− 10·3
1916–17	+ 96·9	− 20·0	− 11·7	− 17·5	− 41·0	+ 4·1	+ 28·5	+ 43·4	+ 29·4	+ 47·9	+ 25·4	− 29·1	+ 24·1	+29·7	+ 21·6	+ 1·1	+ 19·3	+ 53·7
1917–18	− 28·6	− 15·2	+ 38·2	+ 29·4	+ 1·9	+ 43·2	− 3·9	− 27·1	+ 18·6	+ 17·5	+ 45·0	+ 10·4	+ 21·1	+ 8·6	+ 30·3	+ 16·7	+ 56·2	− 31·6
1918–19	+ 32·8	+ 1·1	+ 36·5	− 4·1	+ 29·0	− 99·0	− 24·4	+ 69·3	+ 85·7	+ 29·8	+ 24·6	+ 26·9	+ 4·7	+12·3	+ 14·2	− 28·8	+ 9·0	− 2·3
1919–20	+ 72·2	− 27·6	+ 2·0	− 3·8	+ 39·1	− 7·2	+ 34·1	+ 90·9	+ 27·4	− 55·0	− 40·0	+ 36·6	− 18·2	+ 2·8	+ 29·4	+ 24·0	+ 29·0	+ 60·7
Average.	+ 18·8	+ 5·5	− 8·2	− 17·2	− 35·2	− 17·0	− 28·8	− 14·2	+ 0·3	− 7·0	+ 8·4	+ 13·4	+ 24·5	+20·7	+ 33·4	+ 23·3	+ 22·4	+ 10·0
Average for 1st 12 years.	+ 10·6	+ 12·6	− 16·4	− 23·3	− 49·4	− 17·8	− 40·5	− 33·6	− 13·0	− 12·6	+ 6·6	+ 14·2	+ 30·0	+23·1	+ 36·6	+ 29·9	+ 20·3	+ 6·6
Average for the last 4 years.	+ 43·3	− 15·4	+ 16·3	+ 1·0	+ 7·3	− 14·7	+ 8·6	+ 44·1	+ 40·3	+ 10·1	+ 4·6	+ 11·2	+ 7·9	+13·4	+ 23·9	+ 3·3	+ 28·4	+ 20·1

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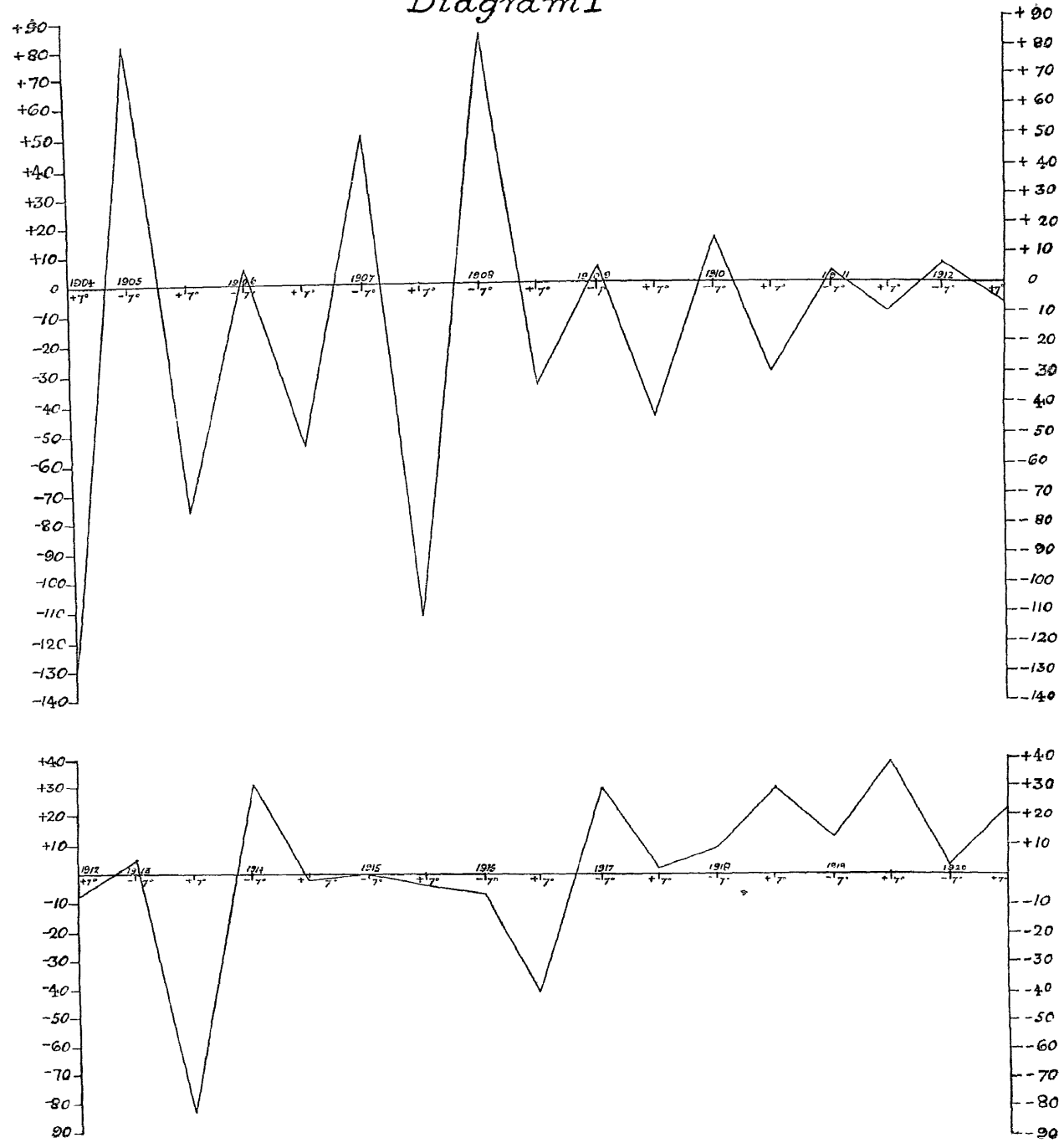
Diagram I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1904 1905 1907 1908 1910 1912
+7° -7° +7°
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Diagram II

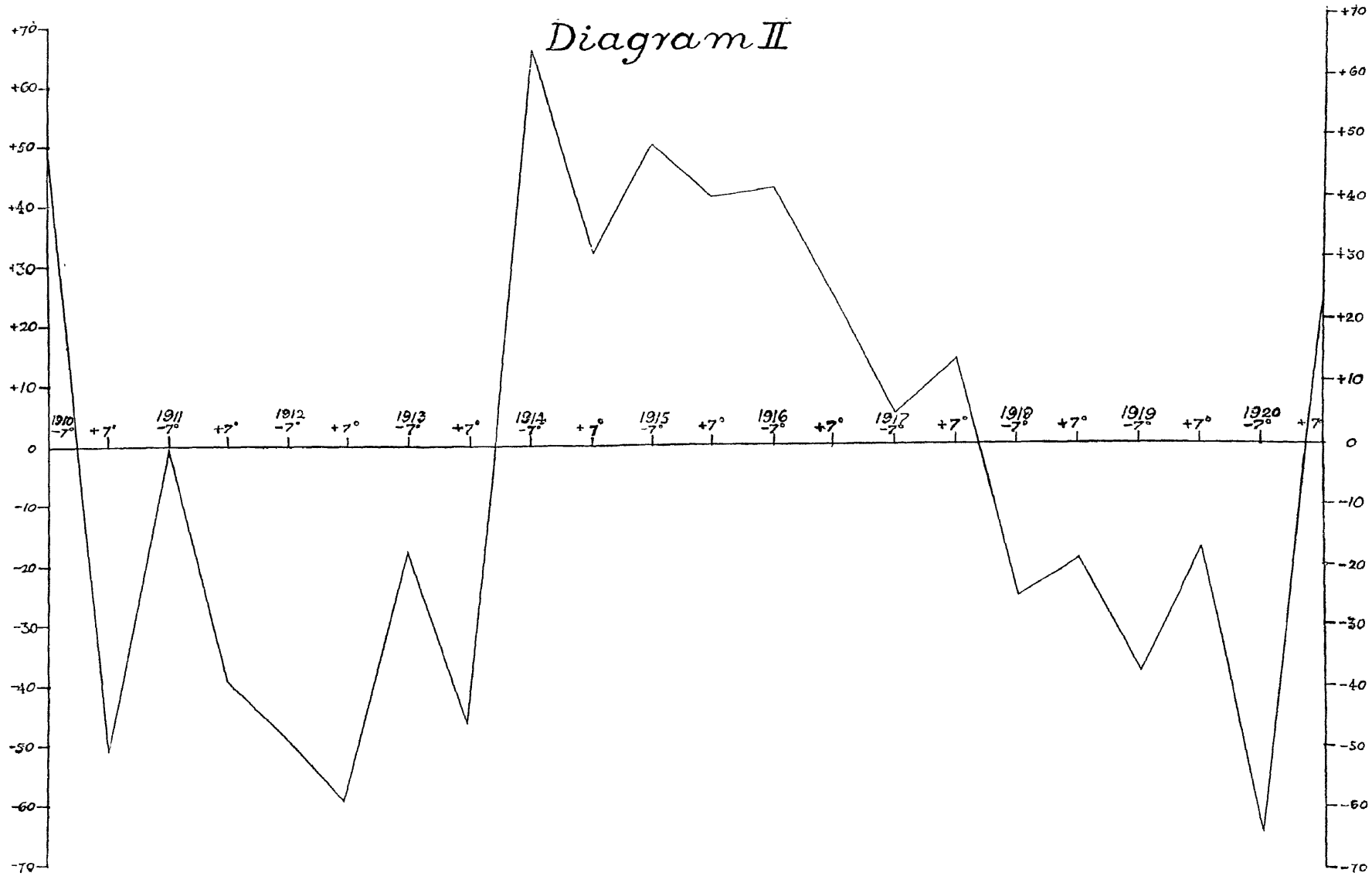
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Diagram III

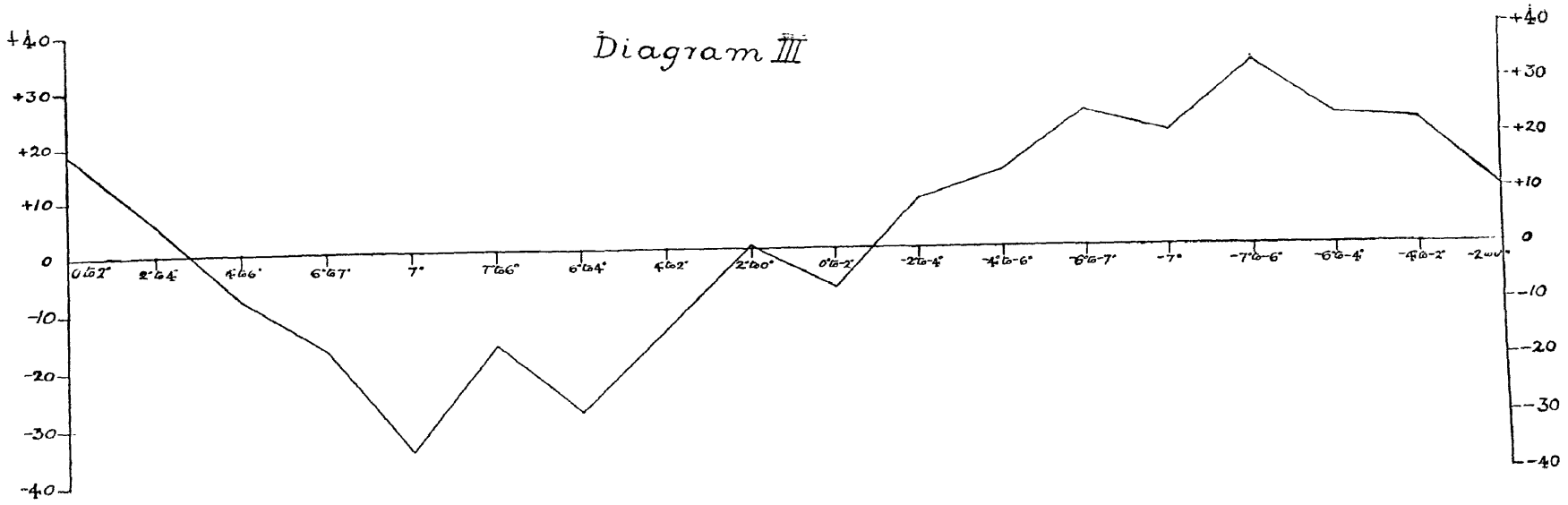

Diagram IV