IV. *Magnetic Observations made at Stonyhurst College Observatory, from April* 1863 *to March* 1870. *By the Rev.* S. J. Perry. *Communicated by the President.*

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Results of Seven Years' Observations of the Dip and Horizontal Force.

In a paper published in the Philosophical Transactions for 1863, the President of the Royal Society enters into a discussion of a six years' series of the Kew Magnetic Observations, with the view of ascertaining whether the sun's position with reference to the earth really produces a sensible semiannual inequality in the terrestrial magnetic elements. The probability of the existence of such a disturbing cause, founded on a comparison of the monthly determinations of the Dip and Horizontal Force taken at Hobarton and at Toronto, was made much more evident by Sir Edward Sabine's discussion of the Kew observations; and it was from a desire of bringing more data to bear upon this important question that the reduction of the seven years' observations, just completed at this observatory, has been undertaken. With this object in view, it was considered of great importance to adhere closely to the plan laid down by Sir Edward Sabine, and to present the results, for the sake of comparison, in three Tables. The first contains the mean monthly determinations of the elements, with their deduced mean values and secular variation, the second presents a view of the semiannual inequality, and the third gives the residual errors and the consequent most probable errors of any single observation and of the deduced mean values of the elements.

Magnetic observations were first taken at Stonyhurst in 1858, but the continuous series of monthly determinations of the Dip, Declination, and Intensity were only commenced in March 1863. The same instruments, *i. e.* a dip-circle by Barrow and a Jones unifilar, have been used throughout the whole seven years. These instruments were both tested at Kew before being sent to this observatory, and the dip-circle was again examined there last January with most satisfactory results. The constants of the vibration-magnet were determined by Mr. Welsh, and are given in the Proceedings of the Royal Society for February 1865. In calculating the value of the Horizontal Force, it has never been found necessary to apply any correction for the arc of vibration, which has always been small, nor for the Frodsham chronometer, whose rate has never exceeded 2^s per day.

The yearly adopted values of P are the following:—

for 1863	−0·00217	for 1867	−0·00254
1864	−0·00219	1868	−0·00271
1865	−0·00254	1869	−0·00210
1866	−0·00275		

Each of these values is the mean of the monthly determinations obtained by observations of deflections at 1·0 and 1·3 feet.

For the dip three needles have been employed, Nos. 1 and 2 from 1863 to August 1868, and Nos. 1 and 3 since the latter date. A correction has been applied since August 1868 for the change of needle; this correction $= -0'\ 20''$ for the mean value.

The observations have always been taken by the Director of the Observatory, viz. by the Rev. W. SIDGREAVES, from 1863 to September 1868, and since that date by myself.

Unfortunately the station of observation has not been always the same, nor perfectly free from disturbing influences. The first station was a stone pillar erected in 1858 in the botanical garden of the college. In June 1864 the N.W. wall of the garden was replaced by an iron railing, whose nearest distance from the magnetic pillar is 91 feet. In January of the following year a three-quarter inch iron pipe was laid down on the S.E. side of the pillar, at a distance of 38 feet 9 inches; and in September 1867 a second iron pipe, $1\frac{1}{4}$ inch in diameter, was placed parallel to the former at $2\frac{1}{2}$ inches greater distance from the pillar.

At the beginning of 1868 a wooden hut, three of whose sides are in great part glass, was erected in a retired part of the garden, and so placed that the shade of overhanging trees might protect it from the sun in summer, whilst it remained fully exposed to the sun's rays when at low altitudes. No iron was in the vicinity at the time, but a 2-inch iron pipe was laid down in October 1869 at a distance of 51 feet 9 inches from the stone pier on which the observations are taken.

A series of observations of the Dip, Declination, and Horizontal Force have been made on the same days at the old and new stations for the purpose of determining the corrections to be applied for change of locality. The corrections thus found for the first station are $-0{\cdot}0051$ in British units for the Horizontal Force, and $+3'\ 34''$ for the Dip. It is now impossible to determine absolutely what part of these corrections is due to the several masses of iron near the old pillar; but since it seems probable that the two iron pipes would have produced at most but a very slight disturbance, the whole correction has been applied from the time of the placing of the iron railings, *i. e.* from July 1864 to March 1868, both inclusively.

The following Tables contain the corrected values.

The Horizontal Force.

TABLE I.

Monthly mean values of the Horizontal Force.

April to September.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	Mean of seven years.
April	3·5912	3·5950	3·5958	3·5978	3·6094	3·6052	3·6157	3·6014
May	3·5920	3·5995	3·6016	3·5985	3·6088	3·6099	3·6250	3·6050
June	3·5850	3·5999	3·5997	3·6004	3·6090	3·6100	3·6195	3·6034
July	3·5988	3·6004	3·5920	3·6063	3·6070	3·6055	3·6138	3·6034
August	3·5956	3·5924	3·5987	3·5980	3·6104	3·6060	3·6177	3·6027
September	3·5924	3·5876	3·5996	3·5973	3·6067	3·6129	3·6077	3·6006
Means	3·5925	3·5958	3·5979	3·5997	3·6085	3·6083	3·6166	3·6028
October to March.	1863–64.	1864–65.	1865–66.	1866–67.	1867–68.	1868–69.	1869–70.	
October	3·5909	3·5891	3·5912	3·5992	3·6101	3·6173	3·6190	3·6024
November	3·5894	3·5953	3·5966	3·6036	3·6079	3·6173	3·6204	3·6044
December	3·5962	3·5912	3·5978	3·6036	3·6073	3·6194	3·6249	3·6058
January	3·5944	3·5959	3·5986	3·6043	3·5871	3·6194	3·6236	3·6033
February	3·5971	3·6001	3·5990	3·6061	3·6060	3·6223	3·6166	3·6067
March	3·5877	3·5969	3·5958	3·6060	3·6066	3·6100	3·6099	3·6018
Means	3·5926	3·5948	3·5965	3·6038	3·6042	3·6176	3·6191	3·6041
Yearly means	3·5926	3·5953	3·5972	3·6018	3·6064	3·6129	3·6178	3·6034

The values for August and October 1863 are interpolations.

The value in January 1868 is evidently too small; this arose from a sudden change in the time of vibration of the magnet.

The above Table gives for the epoch October 1st, 1866,

The mean Horizontal Force $=3{\cdot}6034$.

With a secular acceleration $=0{\cdot}0042$.

These quantities enable us directly to calculate the probable value of the force at any epoch, and we thus form the next Table.

TABLE II.

Semiannual inequality of the Horizontal Force.

Date.	Correction for secular variation.	Mean ± secular variation.	Observed values.	Observed—Computed.	
				April to September.	October to March.
July 1, 1863	−0·0137	3·5897	3·5925	+0·0028	
Jan. 1, 1864	−0·0116	·5918	·5926	.....	+0·0008
July 1, 1864	−0·0095	·5939	·5958	+0·0019	
Jan. 1, 1865	−0·0074	·5960	·5948	.....	−0·0012
July 1, 1865	−0·0053	·5981	·5979	−0·0002	
Jan. 1, 1866	−0·0032	·6002	·5965	.....	−0·0037
July 1, 1866	−0·0011	·6023	·5997	−0·0026	
Jan. 1, 1867	+0·0011	·6045	·6038	.....	−0·0007
July 1, 1867	+0·0032	·6066	·6085	+0·0019	
Jan. 1, 1868	+0·0053	·6087	·6042	.....	−0·0045
July 1, 1868	+0·0074	·6108	·6083	−0·0025	
Jan. 1, 1869	+0·0095	·6129	·6176	.....	+0·0047
July 1, 1869	+0·0116	·6150	·6166	+0·0016	
Jan. 1, 1870	+0·0137	·6171	·6191	.....	+0·0021
Mean differences in the semiannual periods				+0·00014	−0·00036

Hence we may conclude that there exists an annual variation whose mean value is 0·0005; but the great difference between the figures for the semiannual periods shows that the variation in this particular case is not wholly due to the disturbing action of the sun.

We can now test the accuracy of our assumed values of the secular and semiannual variation, and of the observations themselves, by the formation of the following Table.

TABLE III.

Residual errors in the monthly mean values of the Horizontal Force.

	1863–64.	1864–65.	1865–66.	1866–67.	1867–68.	1868–69.	1869–70.	Mean.	Semiannual mean.
April	+21	+17	−17	−39	+ 35	−49	+ 14	−0·00026	
May	+25	+58	+37	−36	+ 25	− 6	+103	+0·00294	
June	−48	+59	+15	−20	+ 24	− 8	+ 45	+0·00096	+0·00016
July	+86	+60	−66	+35	0	−57	− 16	+0·00060	
August ...	+51	−23	− 2	−51	+ 31	−55	+ 20	−0·00041	
September	+15	−75	+ 3	−62	− 10	+10	− 84	−0·00290	
October ...	+ 2	−58	−79	−41	+ 26	+56	+ 31	−0·00061	
November	−17	0	−29	− 1	0	+52	+ 41	+0·00066	
December	+48	−44	−20	− 4	− 9	+70	+ 83	+0·00177	+0·00014
January ...	+26	− 1	−16	− 1	−215	+66	+ 66	−0·00107	
February	+50	+38	−15	+14	− 29	+92	− 7	+0·00204	
March.....	−48	− 2	−51	+ 9	− 27	−35	− 78	−0·00194	
Means.....	+18	+ 2	−20	−16	− 12	+11	+ 18		

This Table shows that the assumption of a semiannual inequality, whose mean value

is $=0\cdot00025$, has led us into no sensible error, but that the corrections applied for the change of station between July 1864 and March 1868 should be somewhat modified.

Table III. gives as the probable error of a single observation, or monthly mean, $\pm0\cdot00332$, and neglecting January 1868, $\pm0\cdot00292$; and for the error of the mean $\pm0\cdot00036$, or neglecting January 1868, $\pm0\cdot00032$.

The Dip Observations may now be treated in a precisely similar manner as those of the Horizontal Force.

TABLE I.

Monthly mean values of the Dip.

April to September.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	Mean.
April	69° 51′ 13″	46′ 29″	49′ 57″	48′ 52″	45′ 17″	40′ 45″	43′ 57″	69° 46′ 39″
May	48 37	46 40	50 42	47 26	44 16	41 9	37 34	45 12
June	47 50	49 15	49 21	47 33	43 22	39 57	38 45	45 9
July	51 27	47 44	50 29	48 32	47 24	42 11	38 9	46 34
August	49 51	47 29	51 8	46 19	46 15	36 58	40 49	45 33
September	48 15	50 35	50 0	46 11	45 16	40 45	35 15	45 11
Means	69 49 32	48 2	50 16	47 29	45 18	40 18	39 5	69 45 43

October to March.	1863–64.	1864–65.	1865–66.	1866–67.	1867–68.	1868–69.	1869–70.	
October	69 48 23	48 20	51 4	47 15	43 33	43 4	35 16	69 45 16
November	48 30	49 22	48 39	46 33	44 34	42 25	39 52	45 42
December	47 17	49 57	47 5	46 45	43 0	41 52	36 3	44 34
January	47 21	47 15	47 21	46 53	43 40	42 34	33 16	44 3
February	49 13	50 4	49 37	45 19	45 8	40 7	36 16	45 6
March	47 19	49 17	50 3	46 16	43 50	40 43	39 6	45 13
Means	69 48 1	49 3	48 58	46 30	43 58	41 47	36 38	44 59
Yearly means	69 48 47	48 32	49 37	47 0	44 38	41 2	37 52	69 45 21

The values for August and October 1863 are interpolated.

The mean dip for October 1st, 1866, is thus 69° 45′ 21″.

With a secular diminution $=1'\ 49''\cdot2$.

From these quantities we will now calculate the semiannual inequalities.

Table II.

Semiannual inequality of the Dip.

Date.	Correction for secular variation.	Mean ± secular variation.	Observed values.	Observed – Calculated.	
				April to September.	October to March.
July 1, 1863	+5′ 53″	69° 51′ 14″	69° 49′ 32″	−1′ 42″	
Jan. 1, 1864	+4 59	50 20	48 1	.....	−2′ 19″
July 1, 1864	+4 4	49 25	48 2	−1 23	
Jan. 1, 1865	+3 10	48 31	49 3	.....	+0 32
July 1, 1865	+2 15	47 36	50 16	+2 40	
Jan. 1, 1866	+1 21	46 42	48 58	.....	+2 16
July 1, 1866	+0 27	45 48	47 29	+1 41	
Jan. 1, 1867	−0 27	44 54	46 30	.....	+1 36
July 1, 1867	−1 21	44 0	45 18	+1 18	
Jan. 1, 1868	−2 15	43 6	43 58	.....	+0 52
July 1, 1868	−3 10	42 11	40 18	−1 53	
Jan. 1, 1869	−4 4	41 17	41 47	.....	+0 30
July 1, 1869	−4 59	40 22	39 5	−1 17	
Jan. 1, 1870	−5 53	39 28	36 38	.....	−2 50
Mean differences in the semiannual periods				−0 5	+0 5

The resulting difference is small compared with the errors of observation, and therefore it can afford but a slight confirmation of the hypothesis of the dependence of this inequality on the position of the sun in the ecliptic.

Table III.

Residual errors in the monthly mean values of the Dip.

	1863–64.	1864–65.	1865–66.	1866–67.	1867–68.	1868–69.	1869–70.	Mean.	Semiannual mean.
April	−0′ 21″	−3′ 15″	+2′ 2″	+2′ 46″	+1′ 0″	−1′ 43″	+3′ 19″	+0′ 33″	−0′ 1″
May	−2 48	−2 55	+2 56	+1 29	+0 8	−1 10	−2 55	−0 45	
June	−3 26	−0 11	+1 44	+1 45	−0 37	−2 13	−1 35	−0 39	
July	+0 10	−1 33	+3 1	+2 53	+3 34	+0 10	−2 2	+0 53	
August	−1 7	−1 39	+3 49	+0 49	+2 34	−4 54	+0 47	+0 3	
September ...	−2 34	+1 36	+2 50	+0 50	+1 44	−0 58	−4 38	−0 10	
October	−2 26	−0 39	+3 54	+1 54	+0 1	+1 21	−4 37	−0 5	+0 0·5
November ...	−2 10	+0 32	+1 38	+1 21	+1 11	+0 51	+0 8	+0 30	
December ...	−3 14	+1 16	+0 13	+1 42	−0 14	+0 27	−3 32	−0 29	
January	−3 1	−1 17	+0 38	+1 59	+0 35	+1 19	−6 10	−0 51	
February ...	−1 0	+1 41	+3 3	+0 34	+2 12	−1 0	−3 1	+0 21	
March.....	−2 45	+1 3	+3 38	+1 40	+1 3	−0 15	−0 2	+0 37	
Means.....	−2 4	−0 27	+2 27	+1 39	+1 6	−0 40	−2 2		

In this Table the evidence is still stronger than before that the correction applied from July 1864 to March 1868 is in excess.

The probable errors deduced from the above Table are:

for any single monthly value ±1′·45,

and for the deduced means ±0′·16.

The Total Force.

This can be at once deduced from the mean values contained in Tables I.

For Epoch July 1st, 1866, H. F.=3·6028, and Dip=69° 45′ 43″ from April to Sept.

For Epoch Jan. 1st, 1867, H. F.=3·6041, and Dip=69° 44′ 59″ from Oct. to March

Applying the correction for the secular variation to reduce both these to a common epoch, we have for

Jan. 1st, 1867, from April to September, T. F.=3·6049 × sec. 69° 44′ 48″=10·4136.

October to March, T. F.=3·6041 × sec. 69° 44′ 59″=10·4128.

which would make the intensity greater when the sun is further from the earth, the difference being very small, viz. 0·0008.

This last result is opposed to that derived from the reductions of Sir EDWARD SABINE, but will have but little weight, both on account of the smallness of the amount, and still more from the uncertainty attached to the corrections applied for change of station.

The above mean value of the total force, 10·4136, for January 1st, 1867, compared with the observations in October 1858, gives an average annual rate of increase=0·0034, which agrees closely with the amount calculated by General SABINE (*cf.* Proceedings of the Royal Society, February 1865).

Whilst drawing up this paper I was not aware that Dr. BALFOUR STEWART was engaged in a similar reduction of a second six years' series of the Kew observations, which has led to such a satisfactory confirmation of the results obtained by the discussion of the first six years' observations at the same observatory. When another six years have elapsed, we shall be able to determine to what extent the results obtained above are due to local influences.