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A Comparison of Values of the Magnetic Elements, deduced from the British Magnetic Survey of 1891, *with Recent Observation.*

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In the preparation of maps showing lines of equal magnetic declination for commercial use from the data given in the last great Magnetic Survey of the British Isles* it has of late years become apparent, by comparison with the observations made at the several British Magnetic Observatories of Greenwich, Kew, Stonyhurst, Falmouth, and Valentia, that, owing to decrease in value of the annual variation, the lines, as brought forward from the survey, are now carried too far to the west, that is to say, they give a value of declination that is too small, the discordance being apparently greater towards the west than on the eastern side. I have thus thought that it would be desirable to examine this question further, not only for declination, but also for horizontal force and dip, comparing the survey values as brought forward to the epoch 1906·0 by use of the annual rates of change which obtained when it was made with the results of recent observation at the places mentioned.

It will be interesting, in the first instance, to ascertain in what degree the annual variation of the several elements may have changed in recent times. This is shown in Table I, which gives the mean annual variation of each

Table I.—Annual Variation of Magnetic Elements in Three Successive Periods.

Period.	Declination.			Horizontal force.			Dip.		
	Greenwich.	Kew.	Stonyhurst.	Greenwich.	Kew.	Stonyhurst.	Greenwich.	Kew.	Stonyhurst.
1871—1891	−6′·9	−7′·4	−7′·8	+20	+19	+18	−1′·4	−1′·2	−1′·2
1891—1901	−5·7	−5·3	−5·1	+23	+26	+26	−1·7	−2·4	−2·0
1901—1905	−4·0	−4·0	−4·0	+10	+15	+16	−2·5	−1·4	−1·1
Magnetic survey	−6·2	−6·3	−6·9	+20	+20	+20	−1·3	−1·3	−1·2

The unit in horizontal force is 0·0001 of the value in metrical measure = 1·82 approximately.

* "A Magnetic Survey of the British Isles for the Epoch January 1, 1891," by A. W. Rücker, M.A., F.R.S., and T. E. Thorpe, D.Sc., LL.D., F.R.S., 'Phil. Trans.,' vol. 188.

element at Greenwich, Kew, and Stonyhurst in three successive periods, the values in the last period being those appearing in Table II, adding thereto corresponding information from Table XIV of the magnetic survey.

Remarking that the survey values appear to have been deduced mainly from a consideration of the period 1886 to 1891, the epochs of the first and second survey, without knowledge of what might happen after 1891, the survey values appear to be generally well in accord with other observations. We see, however, what has followed in declination: a rapid continuous numerical decrease in magnitude of the annual variation at all three stations. But in horizontal force there is definite increase of value in the second period at all stations, with drop of value in the third period to something less than the values of the first period. In dip there is marked numerical increase of value in the second period at Kew and Stonyhurst, with reversion in the third period to values more in accord with those of the first period. At Greenwich there is only a small increase in the second period, with a considerable increase in the third period, an increase that would appear to be real, although opposed to what occurred at Kew and Stonyhurst, since the yearly value at Greenwich depends on five or six observations each of two needles in every month, the difference between the resulting means of the two needles in 1901, 1902, 1903, and 1904 being only 0′·1, 0′·0, 0′·3, and 0′·2 respectively. Of that in 1905 I have no information.

Extracting now from the various official publications* the mean yearly values of declination, horizontal force, and dip for the years 1901 to 1905, values which apply to the middle of each year, the mean of these five values is taken for each element at each place, thus giving values that apply to the epoch 1903·5 as appearing in Column (2) of Table II. The difference between the first and last of the yearly values (1901 and 1905), divided in each case by four, is taken as the annual variation,† excepting for horizontal force at Stonyhurst and Falmouth, and dip at Stonyhurst, which, on account of some little irregularity in the progression of the yearly values, were treated graphically, extending the series a little backward, so producing values for the period 1901 to 1905 that were sufficiently satisfactory. The resulting annual variations are given in Column (3). In Column (4) the observed values

* 'Results of the Magnetical and Meteorological Observations made at the Royal Observatory, Greenwich'; 'Report of the Observatory Department of the National Physical Laboratory'; 'Results of Meteorological and Magnetical Observations at Stonyhurst College Observatory.'

† The determination of annual variation from observations made at a particular hour of the day (instead of from mean values), as at Stonyhurst and Valentia, is not strictly accurate, but is abundantly so for the purposes of this paper.

of Column (2) are reduced to the epoch 1906·0 by the annual variations of Column (3). The values are mean values. To secure this, however, as the observations of declination, horizontal force, and dip at Stonyhurst were made at 16 h., 10 h., and 12 h. respectively (civil time counting from midnight), and at Valentia at 10 h., 12 h., and 13 h. respectively, small corrections* to reduce to mean values became necessary, as shown in Table II. The Greenwich values of dip also were made on the average from 13 h. to 14 h., and the Falmouth observations in 1901, 1902, and 1903 at 15 h., but no corrections for diurnal range were in these cases necessary.

It becomes of interest here to note that the Greenwich values of declination include all days, excepting those of great magnetic disturbance, whilst the Kew and Falmouth declinations include only the five selected quiet days in each month, and further to inquire whether the declinations found by these two methods show any difference. The declinations at Greenwich were therefore calculated for the years 1903 and 1904, including only the five quiet days in each month, with the following result:—

Greenwich Magnetic Declination.

	Including all days.	Including quiet days only.	Excess of latter.
1903	16° 19′·1	16° 19′·2	+0·1
1904	16° 15′·0	16° 14′·9	−0·1

As regards the difference between the separate monthly values in the 24 months of the two years, on three occasions there was no difference, on five occasions a difference of 0′·1, on eleven occasions 0′·2, on two occasions 0′·3, and 0′·4, 0′·5, and 0′·6 on one occasion each only. In horizontal force the result would be presumably similar.

Coming now to the survey values, Column (5) of Table II contains the value of each element, at each place, for 1891·0 from Table XXIV of the Magnetic Survey, reduced to the epoch 1906·0 by means of the annual variations of Table XIV. But as survey values for Greenwich for 1891·0 do not appear in Table XXIV, they have been calculated from Tables XX, XXI, and XXII, and similarly brought forward to 1906·0 by the survey variations. To these values, by application of the local deviation (difference between the observed and survey values for 1891·0 in Table XXIV), the concluded survey values for 1896·0 are found, the difference between which and the observed values for the same epoch (Column (4)) showing the discordance of the survey value. The survey values for Greenwich not having

* From a consideration of the records at Greenwich, Kew, and Falmouth, 1901 to 1905.

been inserted in Table XXIV, the difference between those specially calculated for 1891·0, as above mentioned (declination 17° 18′·8, horizontal force 1·8241, dip 67° 24′·7), and the observed Greenwich values for 1891·0 (declination 17° 26′·0, horizontal force 1·8242, dip 67° 23′·9) have been for this purpose taken as the local deviation. The resulting comparison is shown in Table II.

Table II.—Comparison of Magnetic Survey Values of Declination, Horizontal Force, and Dip, reduced to the Epoch 1906·0, with Results derived from Direct Observation.

(1) Place of observation.	(2) Observed value 1903·5.	(3) Annual variation.	(4) Reduced to 1906·0.	(5) Survey value reduced to 1906·0.	(6) Local deviation.	(7) Concluded survey value 1906·0.	(8) Discordance of the survey value.
Greenwich	16° 18′·6	−4′·0	16° 8′·6	15° 45′·8	+ 7′·2	15° 53′·0	−15′·6
Kew	16 41·0	−4·0	16 31·0	15 53·3	+15·9	16 9·2	−21·8
Stonyhurst	18 1·5	−4·0	17 50·0[1]	17 28·3	− 8·4	17 19·9	−30·1
Falmouth	18 17·1	−4·3	18 6·4	17 30·7	+ 3·6	17 34·3	−32·1
Valentia	21 19·2	−4·3	21 9·5[2]	20 31·4	+ 0·3	20 31·7	−37·8
Greenwich	1·8507	+0·0010	1·8532	1·8538	+0·0001	1·8539	+0·0007
Kew	1·8486	+0·0015	1·8523	1·8526	−0·0019	1·8507	−0·0016
Stonyhurst	1·7367	+0·0016	1·7422[3]	1·7423	+0·0007	1·7430	+0·0008
Falmouth	1·8745	+0·0015	1·8783	1·8836	−0·0041	1·8795	+0·0012
Valentia	1·7831	+0·0012	1·7876[4]	1·7813	+0·0068	1·7881	+0·0005
Greenwich	67° 0′·7	−2′·5	66° 54′·4	67° 5′·8	−0′·8	67° 5′·0	+1′·0·6
Kew	67 6·6	−1·4	67 3·1	67 7·6	+4·9	67 12·5	+ 9·4
Stonyhurst	68 47·2	−1·1	68 43·9[5]	68 53·2	−1·3	68 51·9	+ 8·0
Falmouth	66 39·1	−1·7	66 34·9	66 47·0	−2·0	66 45·0	+10·1
Valentia	68 22·6	−1·8	68 17·9[6]	68 30·5	−5·5	68 25·0	+ 7·1

Corrections for diurnal range are included—in (1), −1′·5; in (2), +1′·0; in (3) and (4), +0·0015; in (5), −0′·5; in (6), −0′·2.

The horizontal force is in metrical measure.

The survey values for declination, brought up to the present time, thus give a westerly declination that is too small as compared with observation, the difference being greatest on the western side, and the dip, similarly brought up, gives a value that is too great, with little difference in amount at the various places. The survey values of horizontal force are in much closer agreement with observation.

The discordance in horizontal force is expressed in metrical measure, but in order to show the relative magnitude of the discordances in the other elements of declination and dip, these have been converted also into metrical

measure at each station by means of the data contained in Table II, the factor for declination expressed in minutes being, horizontal force metric $\times \sin 1'$, and that for dip, total force metric $\times \sin 1'$, the values of horizontal force at the different stations ranging from 1·7422 at Stonyhurst to 1·8783 at Falmouth, and that of total force ranging from 4·7235 at Greenwich to 4·8347 at Valentia. These results are given in Table III:—

Table III.—Discordances of Survey Values in Metrical Measure (unit = 0·0001 of the metrical values of horizontal force and total force respectively).

Station.	Latitude North.	Longitude West.	Declination.	Horizontal force.	Dip.
	° ′	° ′			
Greenwich	51 29	0 0	− 84	+ 7	+146
Kew	51 28	0 19	−117	−16	+130
Stonyhurst	53 51	2 28	−153	+ 8	+112
Falmouth	50 9	5 5	−175	+12	+139
Valentia	51 56	10 15	−197	+ 5	+100
Approximate value in metrical measure			1·82 Horizontal force.		4·77 Total force.

The discordances thus pointed out have no concern with the important deductions and conclusions regarding the magnetic condition of the British Isles, so fully discussed in the survey volume, but simply indicate that the secular variations of Table XIV of the survey have undergone change since the time when the survey was made, especially in the case of magnetic declination and dip. The secular changes there tabulated were primarily put together for the necessary purpose of reducing the observations on which the survey was based to a mean epoch, and were not intended for application to future years without being checked. As the authors of the survey pointed out, the continuous records available at the various magnetic observatories, combined with further magnetic observations, taken from time to time, at a limited number of selected stations distributed over the area covered by the survey, may give sufficient information, the local deviations being thus known, for rectification of the mean lines of equal values of the several magnetic elements.