# III. *The Absolute Direction and Intensity of the Earth's Magnetic Force at Bombay, and its Secular and Annual Variations.* *By* Charles Chambers, *F.R.S.*, *Superintendent of the Colaba Observatory.*

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The observations discussed in this paper were taken at the Colaba Observatory during the years 1867 to 1874, and consist of observations of Dip, Declination, and Horizontal Intensity. The instruments with which they were taken were a Dip-circle by Barrow, with $3\frac{1}{2}$-inch needles, and a Unifilar Magnetometer by Elliott Brothers, and both were examined and approved at the Kew Observatory before being sent out to India in the year 1867. Complete observations were taken regularly of the Dip and Horizontal Force twice a week, and of the Declination once a week.

*Data for Investigation.*—These consist of the monthly means of the determinations of Absolute Dip from April 1867 to March 1874, and the monthly means of the determinations of Absolute Declination and Absolute Horizontal Intensity from July 1867 to December 1873.

## I. *Dip.*

2. For some unexplained reason, but which is suspected to be owing to a sudden deterioration in the axles of the dip-needles, the quality of the observations began in March 1870 to be of a decidedly inferior order to that of the earlier observations; and the efforts made to obtain new needles, of the high-class character of those first supplied with the dip-instrument, have hitherto been unsuccessful, possibly because some secret process in their production has died with the maker. For this reason the first three years' observations will alone be treated in some detail, and the monthly and annual means of the last four years will be simply recorded.

*Monthly Mean Values.*—The following Table shows the monthly mean values of the Dip from April 1867 to March 1870:—

Table I.

| Year. | April. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 19°+ | 19°+ | 19°+ | 19°+ | 19°+ | 19°+ | 19°+ | 19°+ | 19°+ | 19°+ | 19°+ | 19°+ |
| 1867–68 ...... | 1′·1 | 1′·9 | 1′·5 | 0′·8 | 2′·2 | 2′·5 | 2′·5 | 2′·8 | 2′·7 | 2′·7 | 3′·4 | 3′·8 |
| 1868–69 ...... | 4·1 | 4·1 | 4·3 | 4·3 | 4·2 | 4·3 | 4·2 | 3·6 | 3·5 | 3·7 | 4·8 | 5·2 |
| 1869–70 ...... | 6·0 | 6·2 | 6·3 | 6·8 | 6·4 | 5·7 | 6·2 | 6·5 | 5·6 | 5·6 | 5·8 | 6·0 |

* I have taken the opportunity, which the lapse of time affords, of extending the number of years of observations treated in the paper from $3\frac{1}{2}$ to $6\frac{1}{2}$.—*July*, 1876.

3. *Annual Mean Values and Secular Change.*—The annual mean values and yearly increments are as follows:—

TABLE II.

| Year. | Mean Dip. | Annual Increase of Dip. |
|---|---|---|
| 1867–88 ........... | 19° 2'·3 | |
| 1868–69 ........... | 19 4·2 | +1'·9 |
| 1869–70 ........... | 19 6·1 | +1·9 |
| Mean Dip for three years... | 19 4·2 | |

The two yearly differences agree in making the annual secular change of dip a steady increase of 1'·9; hence the mean dip for the three years, 19° 4'·2, will properly correspond to the mean epoch, which is the 1st October, 1868.

4. *Annual Variation.*—The average monthly values of dip for the period of three years, shown below, are affected by secular change; this is eliminated, on the assumption that the change is uniform from month to month, by subtracting from the values for the months May to March respectively once, twice, thrice, &c. the monthly secular increase (0'·16).

TABLE III.

| Month .................. | | April. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Monthly Dip for period of three years... | 19°+ | 3'·7 | 4'·1 | 4'·0 | 4'·0 | 4'·3 | 4'·2 | 4'·3 | 4'·3 | 3'·9 | 4'·0 | 4'·7 | 5'·0 |
| Correction for secular change, to April 15, 1868 | ...... | 0 | −0·2 | −0·3 | −0·5 | −0·6 | −0·8 | −1·0 | −1·1 | −1·3 | −1·4 | −1·6 | −1·8 |
| Monthly values cleared of secular change............ | 19+ | 3·7 | 3·9 | 3·7 | 3·5 | 3·7 | 3·4 | 3·3 | 3·2 | 2·6 | 2·6 | 3·1 | 3·2 |

The means of different groups of the monthly values thus cleared of secular change, but affected by the annual variation of dip, are:—

| | | |
|---|---|---|
| For April to September . . . . . . . . . | 19° 3'·6 | Corrected for secular change to epoch April 15, 1868. |
| ,, October to March . . . . . . . . | 19 3·0 | |
| ,, May to August . . . . . . . . . . | 19 3·7 | |
| ,, March, April, September, and October . | 19 3·4 | |
| ,, November to February . . . . . . . | 19 2·9 | |

which all agree in indicating an annual variation, in which the dip is a maximum when the sun is about its most northerly position in declination, a minimum when the sun is about its most southerly position, and having intermediate values when the sun is near the equator. The semiannual excess of dip when the sun has north declination above the mean value for the year is 0'·3.

5. *Diurnal Inequality at Observation-hours.*—The difference between the morning and afternoon observations is almost inappreciable, as will be seen by the following statement, which embraces every observation in 1867 and 1868, finished before 15 hours or commenced after 15 hours, for every month in which observations of both kinds are recorded; the general result is a slight excess of dip in the afternoon:—

TABLE IV.

| Period. | Needle No. | Number of Observations. | Mean Time of Observation. First half. Commencement. | First half. Conclusion. | Last half. Commencement. | Last half. Conclusion. | Mean Dip. | Excess of Afternoon over Morning. |
|---|---|---|---|---|---|---|---|---|
| | | | h m | h m | h m | h m | ° ′ | ′ |
| 1867, June to December ........ | 1 | 17 | 10 22 | 10 56 | 11 4 | 11 47 | 19 1·0 | +0·3 |
| " " " ........ | 1 | 13 | 15 20 | 15 50 | 16 5 | 16 38 | 19 1·3 | |
| " " " ........ | 2 | 15 | 10 23 | 10 58 | 11 19 | 11 50 | 19 3·3 | 0·0 |
| " " " ........ | 2 | 15 | 15 26 | 15 55 | 16 11 | 16 41 | 19 3·3 | |
| 1868, January to December ... | 1 | 26 | 10 25 | 10 49 | 10 59 | 11 25 | 19 3·2 | +0·1 |
| " " " ... | 1 | 26 | 15 24 | 15 51 | 16 0 | 16 25 | 19 3·3 | |
| " " " ... | 2 | 27 | 10 18 | 10 44 | 10 54 | 11 21 | 19 4·4 | +0·1 |
| " " " ... | 2 | 25 | 15 24 | 15 49 | 15 59 | 16 24 | 19 4·5 | |

From this it may be inferred that the annual variation of the diurnal inequality of dip for the mean observation hour (or rather the mean variation for the morning and afternoon hours) is also probably small, and may scarcely affect sensibly the annual variation of dip found above; this latter variation must, however, be accepted subject to correction, if necessary, when the annual variation of the diurnal inequality of dip has been well determined.

6. *Probable Error.*—It will suffice to give an idea of the quality of the observations of dip if an account be here given of the results of determinations, made early in 1869, of the probable error of a single weekly determination (being the mean of a pair of observations) in three distinct periods in 1867 and 1868. The semiannual inequality found, by a similar process to that described above, from this more limited body of observations was the same as that found above from three years' observations, viz. an excess of 0′·3 in the dip from April to September above the mean of the year, and an equal defect during the opposite half-year. The annual secular increase of dip was found to be 1′·3. These values were embodied in formulæ for correcting the observed weekly values of dip to a common epoch as follows:—

From April 29 to August 16, 1867,

$$\theta=\theta'-0'\cdot1\, m,$$

$m$ being the excess (in months) of the date over June 15, 1867;

From August 23 to September 27, 1867,

$$\theta=\theta'-0'\cdot1\, m-0'\cdot3;$$

From October 1 to December 31, 1867,

$$\theta=\theta'-0'\cdot1\, m+0'\cdot3,$$

} $m$ being the excess of the date (in months) over October 15, 1867;

From January 1 to March 31, and from October 1 to December 31, 1868,

$\theta = \theta' - 0'{\cdot}1\, m + 0'{\cdot}3$,

And from April 1 to Sept. 30, 1868,

$\theta = \theta' - 0'{\cdot}1\, m - 0'{\cdot}3$,

($m$ being the excess of the date (in months) over July 15, 1868,—)

$\theta$ in every case representing the dip at the common epoch of the period, and $\theta'$ the observed dip.

The weekly values of dip being thus corrected, the differences were taken between them and the mean of all the corrected values in each period, and to these differences the method of least squares was applied to find the probable errors for the several periods; these are:—

For April 29 to August 16, 1867, the probable error $= \pm 0'{\cdot}67$,
,, August 23 to December 31, 1867 ,, ,, $= \pm 0{\cdot}26$,
,, January 1 to December 31, 1868 ,, ,, $= \pm 0{\cdot}24$.

The remaining observations, of 1869 and 1870, being of about the same quality as those of 1868 will have about the same probable error.

The unusual smallness of the probable error of a weekly determination since August 17, 1867, is attributable mainly, I think, to the comparative infrequency and moderate amount of disturbance at a low latitude station, but partly also to the extreme care that has been given to secure the perfect preservation of the axles of the needles; the needles themselves also appear to be of excellent character.

7. *Differences with different needles.*—The mean dip observed with needle No. 2 has, at different periods, exceeded that observed with needle No. 1, as shown below:—

TABLE V.

| Period. | Excess of Dip with Needle No. 2 over that with Needle No. 1. | |
|---|---|---|
| | Morning observations. | Afternoon observations. |
| 1867, June to August | +5'·0 | +5'·0 |
| ,, September to December | +0·3 | −0·2 |
| 1868, January to December | +1·2 | +1·2 |

It is noticeable that the great change between the two first periods is contemporaneous with the introduction of the practice of remagnetizing the needle before commencing an observation.

8. *Monthly Mean Values of the Dip from April* 1870 *to March* 1874.—

TABLE VI.

| Year. | April. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 19°+ | 19°+ | 19°+ | 19°+ | 19°+ | 19°+ | 19°+ | 19°+ | 19°+ | 19°+ | 19°+ | 19°+ |
| 1870–71 | 10'·6 | 12'·4 | 8'·0 | 7'·0 | 2'·5 | 1'·3 | 7'·4 | 6'·4 | 8'·8 | 1'·9 | 12'·8 | 12'·7 |
| 1871–72 | 14·1 | 7·0 | 0·9 | 5·7 | 9·3 | 11·5 | 9·7 | 9·2 | 11·2 | 11·5 | 11·9 | 11·7 |
| 1872–73 | 12·8 | 14·3 | 14·4 | 15·0 | 14·9 | 14·9 | 15·3 | 14·7 | 15·6 | 14·4 | 14·4 | 16·7 |
| 1873–74 | 16·7 | 16·4 | 15·6 | 14·6 | 12·8 | 12·9 | 14·2 | 13·7 | 13·7 | 14·2 | 14·9 | 13·8 |

On and after September 21, 1871, the place of observation was changed from the basement of the Electrometer Tower to the top room of the same building, the former height above the ground having been 6 feet and the present height being 38 feet.

9. *Annual Mean Values of the Dip and Annual Increase of Dip for seven years.*—

TABLE VII.

| Year. | Mean Dip. | Annual Increase of Dip. |
|---|---|---|
| 1867–68 ............ | 19° 2′·3 | |
| 1868–69 ............ | 19 4·2 | +1′·9 |
| 1869–70 ............ | 19 6·1 | +1·9 |
| 1870–71 ............ | 19 7·6 | +1·5 |
| 1871–72 ............ | 19 9·5 | +1·9 |
| 1872–73 ............ | 19 14·8 | +5·3 |
| 1873–74 ............ | 19 14·5 | −0·3 |
| Mean Dip for seven years. | 19 8·4 | Corresponding to epoch October 1, 1870. |

## II. *Declination.*

10. *Monthly Mean Values.*—In Table VIII. are collected the monthly means of the values of absolute declination, as observed from July 1867 to December 1873, and the corresponding mean readings of the large declination magnetometer; and in Table IX. are shown the same mean values of declination, corrected for the difference between the corresponding mean readings of the large declination magnetometer and the mean readings of that instrument (also given with the same Table) for the respective months, the corrected values thus obtained showing the mean declination of the several months. The adopted value of a unit of the scale of the large declination magnetometer is 6′ 49″·5, increasing readings denoting increasing easterly declination.

TABLE VIII.

| Month. | Mean Observed Declination. | | | | | | | Corresponding Mean Scale-reading of large Declination Magnetometer. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1867. | 1868. | 1869. | 1870. | 1871. | 1872. | 1873. | 1867. | 1868. | 1869. | 1870. | 1871. | 1872. | 1873. |
| January............ | ′ ″ ...... | 44′ 16″ | 46′ 15″ | 47′ 9″ | 49′ 7″ | 53′ 11″ | 53′ 6″ | ...... | 35·25 | 35·55 | 35·70 | 36·13 | 36·59 | 36·50 |
| February ......... | ...... | 44 2 | 46 56 | 47 4 | 50 18 | 52 43 | 53 2 | ...... | 35·30 | 35·54 | 35·73 | 36·26 | 36·53 | 36·50 |
| March ............ | ...... | 44 56 | 46 22 | 48 4 | 49 32 | 50 57 | 52 35 | ...... | 35·32 | 35·46 | 35·88 | 36·13 | 36·23 | 36·47 |
| April............... | ...... | 43 19 | 45 7 | 46 36 | 48 31 | 50 45 | 53 14 | ...... | 35·12 | 35·28 | 35·64 | 35·94 | 36·20 | 36·53 |
| May ............... | ...... | 42 27 | 45 26 | 47 0 | 49 11 | 50 29 | 52 00 | ...... | 35·12 | 35·38 | 35·67 | 36·01 | 36·17 | 36·30 |
| June ............... | ...... | 42 24 | 45 38 | 46 54 | 48 37 | 51 6 | 52 20 | ...... | 35·07 | 35·38 | 35·63 | 35·92 | 36·24 | 36·36 |
| July ............... | 41 34 | 43 24 | 45 57 | 47 17 | 48 48 | 50 6 | 52 52 | 34·86 | 35·25 | 35·47 | 35·66 | 35·95 | 36·09 | 36·41 |
| August ............ | 41 15 | 43 39 | 45 16 | 46 43 | 49 10 | 51 6 | 51 15 | 34·80 | 35·21 | 35·38 | 35·62 | 35·97 | 36·21 | 36·16 |
| September......... | 41 20 | 42 31 | 45 15 | 47 23 | 48 50 | 50 8 | 51 49 | 34·78 | 35·14 | 35·46 | 35·70 | 35·97 | 36·06 | 36·30 |
| October ........... | 42 18 | 44 51 | 46 29 | 49 15 | 50 6 | 52 46 | 52 46 | 34·92 | 35·47 | 35·62 | 36·02 | 36·10 | 36·47 | 36·47 |
| November......... | 43 38 | 46 4 | 47 13 | 49 47 | 51 31 | 52 35 | 52 59 | 35·08 | 35·59 | 35·73 | 36·17 | 36·31 | 36·44 | 36·51 |
| December ......... | 43 58 | 45 34 | 47 43 | 50 7 | 51 52 | 52 58 | 53 36 | 35·19 | 35·44 | 35·74 | 36·22 | 36·37 | 36·48 | 36·64 |

## Table IX.

| Month. | Mean Monthly Declination reduced to Mean Monthly Reading of the large Declination Magnetometer. | | | | | | | Mean Monthly Reading of large Declination Magnetometer. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1867. | 1868. | 1869. | 1870. | 1871. | 1872. | 1873. | 1867. | 1868. | 1869. | 1870. | 1871. | 1872. | 1873. |
| | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | | | | | | | |
| January | ...... | 44 8 | 45 55 | 48 27 | 49 52 | 52 26 | 53 51 | ...... | 35·23 | 35·50 | 35·89 | 36·24 | 36·48 | 36·61 |
| February | ...... | 43 54 | 47 0 | 48 14 | 50 26 | 52 43 | 53 43 | ...... | 35·28 | 35·55 | 35·90 | 36·28 | 36·53 | 36·60 |
| March | ...... | 44 52 | 47 15 | 48 33 | 50 46 | 52 52 | 53 49 | ...... | 35·31 | 35·59 | 35·95 | 36·31 | 36·51 | 36·65 |
| April | ...... | 45 14 | 47 30 | 48 55 | 51 3 | 52 52 | 53 55 | ...... | 35·40 | 35·63 | 35·98 | 36·31 | 36·51 | 36·63 |
| May | ...... | 44 26 | 47 37 | 48 51 | 50 53 | 52 40 | 53 51 | ...... | 35·41 | 35·70 | 35·94 | 36·26 | 36·49 | 36·57 |
| June | ...... | 44 43 | 47 49 | 48 57 | 50 44 | 52 48 | 54 2 | ...... | 35·41 | 35·70 | 35·93 | 36·23 | 36·49 | 36·61 |
| July | 43 16 | 44 38 | 47 23 | 49 16 | 51 3 | 52 38 | 54 14 | 35·11 | 35·43 | 35·68 | 35·95 | 36·28 | 36·46 | 36·61 |
| August | 43 6 | 45 38 | 47 47 | 49 39 | 51 37 | 53 13 | 54 36 | 35·07 | 35·50 | 35·75 | 36·05 | 36·33 | 36·52 | 36·65 |
| September | 43 35 | 45 31 | 47 38 | 50 35 | 51 22 | 53 12 | 54 12 | 35·11 | 35·58 | 35·81 | 36·17 | 36·34 | 36·51 | 36·65 |
| October | 43 56 | 46 1 | 47 47 | 50 37 | 52 1 | 53 43 | 54 0 | 35·16 | 35·64 | 35·81 | 36·22 | 36·38 | 36·61 | 36·65 |
| November | 44 19 | 45 56 | 47 50 | 50 7 | 52 28 | 53 45 | 53 56 | 35·18 | 35·57 | 35·82 | 36·22 | 36·45 | 36·61 | 36·65 |
| December | 43 58 | 45 42 | 48 20 | 50 8 | 52 21 | 53 47 | 53 48 | 35·19 | 35·46 | 35·83 | 36·21 | 36·44 | 36·60 | 36·67 |

11. *Annual Mean Values and Secular Change.*—Table X. shows the Absolute Declination, both as observed and corrected as in Table IX., for each year from 1867 to 1873, and also the respective annual increments of declination and the mean annual increment for the period of six and a half years.

## Table X.

| Year. | Absolute Declination and Annual Increments. | | | |
|---|---|---|---|---|
| | As observed. | | Corrected to Mean Reading of large Declination Magnetometer. | |
| | Declination. | Annual Increment. | Declination. | Annual Increment. |
| 1867, July to December | 42′ 20″ | | 43′ 42″ | |
| 1868, July to December | 44 20 | [+2′ 0″] | 45 34 | [+1′ 52″] |
| 1868, January to December | 43 57 | | 45 4 | |
| 1869, January to December | 46 8 | +2 11 | 47 29 | +2 25 |
| 1870, January to December | 47 47 | +1 39 | 49 21 | +1 52 |
| 1871, January to December | 49 38 | +1 51 | 51 13 | +1 52 |
| 1872, January to December | 51 34 | +1 56 | 53 3 | +1 50 |
| 1873, January to December | 52 38 | +1 4 | 54 0 | +0 57 |
| Mean for 6½ years | 48 8 | +1 46 | 49 32 | +1 48 |

The values 48′ 8″ and 49′ 32″ of absolute easterly declination, as observed and as corrected, correspond to the mean epoch October 1, 1870; the annual increase of declination (1′ 46″ or 1′ 48″) differs by a scarcely appreciable amount, whether it is derived directly from the observations or from the observations corrected. In calculating the means only half weight has been given to the values in brackets, which are derived from only half as many observations as the other values.

12. *Annual Variation.*—The means for the period of six and a half years of easterly declination in each month are shown below, both as observed and corrected; the cor-

rections for secular change to reduce the values for each month to the same epoch (October 1, 1870), being at the rate of 9″ per month, are also shown, as are likewise the mean monthly values cleared of secular change and the monthly excesses above the mean of the year.

TABLE XI.—Monthly Mean Values of Absolute Declination, as observed.

| Month......... | Jan. | Feb. | March. | April. | May. | June. | July. | August. | Sept. | Oct. | Nov. | Dec. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Declination... | 48′ 51″ | 49′ 1″ | 48′ 44″ | 47′ 55″ | 47′ 45″ | 47′ 50″ | 47′ 8″ | 46′ 55″ | 46′ 45″ | 48′ 22″ | 49′ 7″ | 49′ 24″ | |
| Correction for secular change ... | + 22 | + 13 | + 4 | − 4 | − 13 | − 22 | + 22 | + 13 | + 4 | − 4 | − 13 | − 22 | |
| Corrected to epoch October 1, 1870 | 49 13 | 49 14 | 48 48 | 47 51 | 47 32 | 47 28 | 47 30 | 47 8 | 46 49 | 48 18 | 48 54 | 49 2 | 48′ 9″ |
| Annual Variation... | +1 4 | +1 5 | +0 39 | −0 18 | −0 37 | −0 41 | −0 39 | −1 1 | −1 20 | +0 9 | +0 45 | +0 53 | |

TABLE XII.—Monthly Mean Values of Absolute Declination, reduced to Mean Monthly Reading of the large Declination Magnetometer.

| Month......... | Jan. | Feb. | March. | April. | May. | June. | July. | August. | Sept. | Oct. | Nov. | Dec. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Declination... | 49′ 6″ | 49′ 20″ | 49′ 41″ | 49′ 55″ | 49′ 43″ | 49′ 50″ | 48′ 55″ | 49′ 22″ | 49′ 26″ | 49′ 44″ | 49′ 46″ | 49′ 43″ | |
| Correction for secular change ... | + 22 | + 13 | + 4 | − 4 | − 13 | − 22 | + 22 | + 13 | + 4 | − 4 | − 13 | − 22 | |
| Corrected to epoch October 1, 1870 | 49 28 | 49 33 | 49 45 | 49 51 | 49 30 | 49 28 | 49 17 | 49 35 | 49 30 | 49 40 | 49 33 | 49 21 | 49′ 33″ |
| Annual Variation... | −0 5 | 0 0 | +0 12 | +0 18 | −0 3 | −0 5 | −0 16 | +0 2 | −0 3 | +0 7 | 0 0 | −0 12 | |

The two sets of monthly differences represent the annual variation of declination, first, as affected by the annual variation of the diurnal inequality at the usual observation hour, and, secondly, after the elimination of that affection; it is seen at a glance that the effect of the diurnal inequality is to alter both the character and range of the apparent annual variation, raising the range from 0′ 34″ to 2′ 25″, and impressing upon the variation high values during the winter and low values during the summer months—effects quite consistent with the known character of the annual variation of diurnal inequality. The true (corrected) annual variation has a systematic character, with a double oscillation in the period, showing maxima near the times of the equinoxes, and minima about the times of the solstices.

13. That the Declination is greater near the equinoxes than near the solstices may also be shown without assuming a value for the annual secular change; for if this change be uniform the means for the months January and December, February and November, &c. . . . . June and July, will all correspond to the same epoch and be directly comparable; these means are as follows:—

| | ′ | ″ |
|---|---|---|
| January and December . . . . . | 49 | 24 |
| February and November . . . . . | 49 | 33 |
| March and October . . . . . . | 49 | 42 |
| April and September . . . . . . | 49 | 40 |
| May and August . . . . . . . | 49 | 32 |
| June and July . . . . . . . . . | 49 | 22 |

the large values occurring in the middle of the column near the time of the equinoxes. The mean for the months April to September is 49′ 31″, and that for the months January to March and October to December 49′ 33″, showing a scarcely appreciable amount of semiannual inequality.

14. *Probable Error.*—The probable error of a single determination of Absolute Declination has been calculated separately for each of the years 1868 to 1870. The numbers of observations made in those years are 53, 53, and 57 respectively, and each one was reduced to the constant reading 35·00 of the large Declination Magnetometer. If there was no error of observation, and if the large Declination Magnetometer was perfect, these reduced values ought all to be alike, and the degree of accordance existing amongst them will indicate the extent to which these conditions are fulfilled. The differences being taken for each year between each individual reduced value of the Declination and the means of all the values for that year, the probable error of a single determination was found from these differences by the usual method (of least squares) to be ±22″·5, ±22″·0, and ±15″·4 for the years 1868, 1869, and 1870 respectively; and the probable error of the annual means to be ±3″·1, ±3″·0, and ±2″·0 respectively.

## III. *Horizontal Force.*

15. *Monthly Mean Values.*—In Table XIII. are collected the mean monthly values, as observed, of the Horizontal Force for the period from July 1867 to December 1873, and the corresponding monthly mean readings of the large Horizontal-force Magnetometer, corrected to the constant temperature 82° FAHR. In correcting the magnetometer readings 0·15 has been adopted as the decrease of reading produced by an increase of 1° of temperature.

TABLE XIII.

| Month. | Mean observed Absolute Horizontal Force. | | | | | | | Corresponding Mean Scale-reading of large Horizontal-force Magnetometer, corrected to Temperature 82°·0. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1867. | 1868. | 1869. | 1870. | 1871. | 1872. | 1873. | 1867. | 1868. | 1869. | 1870. | 1871. | 1872. | 1873. |
| January ........... | ...... | 8·0608 | 8·0616 | 8·0655 | 8·0768 | 8·0727 | 8·0750 | ...... | 24·60 | 24·30 | 24·77 | 25·57 | 25·89 | |
| February ......... | ...... | 8·0556 | 8·0688 | 8·0670 | 8·0791 | 8·0743 | 8·0811 | ...... | 24·61 | 24·07 | 24·72 | 25·61 | 25·95 | 10·47 |
| March ........... | ...... | 8·0597 | 8·0655 | 8·0758 | 8·0774 | 8·0818 | 8 0830 | ...... | 24·48 | 24·29 | 25·26 | 25·64 | 25·96 | 10·50 |
| April ............. | ...... | 8·0595 | 8·0616 | 8·0697 | 8·0743 | 8·0873 | 8·0856 | ...... | 23·79 | 24·34 | 24·90 | 25·35 | 26·15 | 10·64 |
| May ............. | ...... | 8·0614 | 8·0547 | 8·0706 | 8·0742 | 8·0876 | 8·0859 | ...... | 24·32 | 24·09 | 25·49 | 25·80 | 26·32 | 10·76 |
| June ............. | ...... | 8·0668 | 8·0683 | 8·0818 | 8·0790 | 8·0844 | 8·0874 | ...... | 24·54 | 24·84 | 25·62 | 25·78 | 25·79 | 10·88 |
| July ............. | 8·0494 | 8·0651 | 8·0695 | 8·0756 | 8·0819 | 8·0811 | 8·0889 | 23·53 | 24·07 | 24·84 | 25·21 | 25·54 | 25·67 | 10·93 |
| August ........... | 8·0612 | 8·0490 | 8·0633 | 8·0768 | 8·0808 | 8·0813 | 8·0847 | 23·41 | 24·15 | 24·25 | 25·15 | 25·42 | 25·64 | 10.72 |
| September ......... | 8·0508 | 8·0546 | 8·0710 | 8·0700 | 8·0824 | 8·0808 | 8·0828 | 23·37 | 23·29 | 24·31 | 24·35 | 25·56 | 25·39 | 10·83 |
| October ........... | 8·0569 | 8·0637 | 8·0646 | 8·0687 | 8·0799 | 8·0753 | 8·0853 | 23·32 | 24·10 | 24·45 | 24·56 | 25·11 | 25·18 | 10·99 |
| November ......... | 8·0523 | 8·0659 | 8·0690 | 8·0680 | 8·0757 | 8·0769 | 8·0841 | 24·09 | 24·51 | 24·48 | 24·73 | 25·37 | 25·65 | 11·35 |
| December ......... | 8·0593 | 8·0588 | 8·0625 | 8·0787 | 8·0710 | 8 0795 | 8·0849 | 24·27 | 24·42 | 24·74 | 25·59 | 25·59 | 25·38 | 11·61 |

Table XIV. corresponds with Table XIII., except that the mean monthly readings deduced from all the hourly observations of the large Horizontal-force Magnetometer are given instead of those which correspond to the times of the absolute observations only; and the values of Horizontal Force are corrected for the difference between the two sets of mean monthly readings, so as to represent the values of the *mean* Horizontal Force for the several months. The scale-coefficient adopted for the large Horizontal-force Magnetometer is $\frac{dX}{X} = \cdot 001488$, or $dX = +\cdot 012$ for an increase of unity in the scale-reading.

TABLE XIV.

| Month. | Monthly Mean Absolute Horizontal Force reduced to Monthly Mean Readings of large Horizontal-force Magnetometer. | | | | | | | Monthly Mean Reading of large Horizontal-force Magnetometer, corrected to Temperature 82°·0. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1867. | 1868. | 1869. | 1870. | 1871. | 1872. | 1873. | 1867. | 1868. | 1869. | 1870. | 1871. | 1872. | 1873. |
| January | ...... | 8·0556 | 8·0584 | 8·0581 | 8·0674 | 8·0668 | 8·0725 | ...... | 24·17 | 24·03 | 24·15 | 24·79 | 25·40 | |
| February | ...... | 8·0491 | 8·0680 | 8·0610 | 8·0681 | 8·0643 | 8·0727 | ...... | 24·07 | 24·00 | 24·22 | 24·69 | 25·12 | 9·77 |
| March | ...... | 8·0551 | 8·0629 | 8·0654 | 8·0673 | 8·0718 | 8·0757 | ...... | 24·10 | 24·07 | 24·39 | 24·80 | 25·13 | 9·89 |
| April | ...... | 8·0606 | 8·0552 | 8·0627 | 8·0628 | 8·0770 | 8·0802 | ...... | 23·88 | 23·81 | 24·32 | 24·39 | 25·29 | 10·19 |
| May | ...... | 8·0578 | 8·0524 | 8·0611 | 8·0658 | 8·0793 | 8·0816 | ...... | 24·02 | 23·90 | 24·70 | 25·10 | 25·63 | 10·40 |
| June | ...... | 8·0602 | 8·0592 | 8·0708 | 8·0705 | 8·0791 | 8·0809 | ...... | 23·99 | 24·08 | 24·70 | 25·07 | 25·35 | 10·34 |
| July | 8·0480 | 8·0617 | 8·0613 | 8·0702 | 8·0735 | 8·0746 | 8·0833 | 23·41 | 23·79 | 24·16 | 24·76 | 24·84 | 25·13 | 10·46 |
| August | 8·0593 | 8·0444 | 8·0580 | 8·0672 | 8·0713 | 8·0715 | 8·0822 | 23·25 | 23·77 | 23·81 | 24·35 | 24·63 | 24·82 | 10·51 |
| September | 8·0473 | 8·0568 | 8·0619 | 8·0642 | 8·0718 | 8·0744 | 8·0791 | 23·08 | 23·47 | 23·55 | 23·87 | 24·68 | 24·86 | 10·52 |
| October | 8·0547 | 8·0573 | 8·0576 | 8·0604 | 8·0752 | 8·0691 | 8·0809 | 23·14 | 23·57 | 23·87 | 23·87 | 24·72 | 24·66 | 10·62 |
| November | 8·0487 | 8·0612 | 8·0671 | 8·0630 | 8·0657 | 8·0707 | 8·0793 | 23·79 | 24·12 | 24·32 | 24·31 | 24·54 | 25·13 | 10·95 |
| December | 8·0564 | 8·0554 | 8·0582 | 8·0685 | 8·0662 | 8·0752 | 8·0814 | 24·03 | 24·14 | 24·38 | 24·74 | 25·19 | 25·02 | 11·32 |

During part of the month of January 1873 the large Horizontal-force Magnetometer was under readjustment, and the correction had to be deduced partly from its readings before readjustment, and partly from readings of the Horizontal-force Magnetograph taken at the time of the absolute observations. From and after February 1873 the monthly mean readings of the large Horizontal-force Magnetometer were obtained by subtracting from the monthly mean for the five civil hours 6, 10, 14, 16, and 22, the excess, expressed in scale-readings, of the mean force at those hours in the years 1846 to 1872 above the mean force for the twenty-four hours in the same years.

16. *Annual Mean Values and Secular Change.*—The mean value of the Horizontal Force for the epoch October 1, 1870, is 8·0718 or 8·0658, according as the observations are uncorrected or corrected to the mean of the several months.

The following Table shows the mean values, uncorrected and corrected, of the Horizontal Force in each year or half-year from 1867 to 1873, and the corresponding annual increments of Horizontal Force:—

TABLE XV.

| Year or Half-year. | As observed. | | Corrected to Mean Reading of large Horizontal-force Magnetometer. | |
|---|---|---|---|---|
| | Horizontal Force. | Annual Increment. | Horizontal Force. | Annual Increment. |
| 1867, July to December ............ | 8·0550 | [+·0045] | 8·0524 | [+·0037] |
| 1868, ,, ,, ............ | 8·0595 | | 8·0561 | |
| 1868, January to December......... | 8·0601 | | 8·0563 | |
| 1869, ,, ,, ......... | 8·0650 | +·0049 | 8·0600 | +·0037 |
| 1870, ,, ,, ......... | 8·0723 | +·0073 | 8·0644 | +·0044 |
| 1871. ,, ,, ......... | 8·0777 | +·0054 | 8·0688 | +·0044 |
| 1872, ,, ,, ......... | 8·0802 | +·0025 | 8·0728 | +·0040 |
| 1873, ,, ,, ......... | 8·0841 | +·0039 | 8·0791 | +·0063 |
| Mean ................................ | ......... | +·0048 | ......... | +·0045 |

The annual increments within brackets, being derived from *half-yearly* means, are allowed only half the weight of the others. The mean secular change of Horizontal Force is thus found to be a yearly increase of ·0048 from the uncorrected observations, or ·0045 from the corrected observations.

17. *Diurnal Inequality at different heights above the ground.*—In Table XVI. a comparison is drawn between the diurnal inequalities of Horizontal Force at corresponding hours, shown by the absolute observations and by the large Horizontal-force Magnetometer.

The temperature- and scale-coefficients used in calculating the numbers in the last column from those in columns 6 to 9 have been already given.

The general result (with which twenty-one half-yearly differences are in agreement, and four of contrary import) is that the diurnal variation of Horizontal Force is, between the hours in question, less in the top room of the Electrometer Tower, at a height of 38 feet above the ground, where the absolute observations were taken, than it is at a height of 6 feet, where the large Horizontal-force Magnetometer is placed; and on the average it is about one fifth less. The average time of the first observation is $12^{h}\ 22^{m}$, and that of the second observation $14^{h}\ 39^{m}$; and during this interval, which is generally about the same in extent and has nearly the same limits, the mean for the whole year of the regular daily diminution of force is 0·37 of the mean range for the year of the diurnal variation of force, so that we are dealing with a large fraction (more than a third) of the whole diurnal movement. The maximum Horizontal Force of the day occurs about half an hour before the middle of the first observation.

The supposition that most readily suggests itself in explanation of a result of this nature is, that, being derived from observations with instruments of different construction, it is due to error of observation in the one case, or to error in the scale-coefficient or temperature-coefficient employed in the other.

Against the supposition that it is due to error of observation with the Unifilar Magnetometer, it may be urged, first, that it recurs in twenty-one out of twenty-five half-

TABLE XVI.

| Half-yearly Period. | Civil Time of First Observation. | Civil Time of Second Observation. | Horizontal Force deduced from First Observation. | Horizontal Force deduced from Second Observation. | Large Horizontal-force Magnetometer at First Observation: Scale-reading. | Large Horizontal-force Magnetometer at First Observation: Thermo-meter. | Large Horizontal-force Magnetometer at Second Observation: Scale-reading. | Large Horizontal-force Magnetometer at Second Observation: Thermo-meter. | Excess of First over Second Result: By Absolute Determinations. | Excess of First over Second Result: By large Horizontal-force Magnetometer. |
|---|---|---|---|---|---|---|---|---|---|---|
| | h m | h m | English Units. | English Units. | | | | | | |
| 1867, July to December | 12 16 | 14 44 | 8·0573 | 8·0552 | 23·62 | 83·4 | 23·23 | 84·0 | +·0021 | +·0036 |
| 1868, ,, ,, | 12 48 | 14 49 | 8·0613 | 8·0578 | 23·95 | 83·7 | 23·63 | 84·2 | +·0035 | +·0030 |
| 1869, ,, ,, | 12 30 | 14 38 | 8·0683 | 8·0652 | 24·36 | 84·2 | 23·92 | 84·7 | +·0031 | +·0043 |
| 1870, ,, ,, | 12 20 | 14 40 | 8·0762 | 8·0697 | 25·08 | 83·1 | 24·38 | 83·6 | +·0065 | +·0074 |
| 1871, ,, ,, | 12 10 | 14 29 | 8·0808 | 8·0764 | 25·42 | 83·7 | 24·83 | 84·4 | +·0044 | +·0059 |
| 1872, ,, ,, | 12 16 | 14 37 | 8·0811 | 8·0771 | 25·68 | 83·3 | 25·20 | 84·0 | +·0040 | +·0046 |
| 1873, ,, ,, | 12 22 | 14 55 | 8·0868 | 8·0837 | 11·18 | 82·6 | 10·69 | 83·3 | +·0031 | +·0046 |
| Mean, ,, ,, | 12 23 | 14 42 | ...... | ...... | ...... | ...... | ...... | ...... | +·0038 | +·0048 |
| 1868, January to June | 12 18 | 14 24 | 8·0652 | 8·0632 | 24·42 | 83·1 | 24·09 | 83·7 | +·0020 | +·0028 |
| 1869, ,, ,, | 12 37 | 14 49 | 8·0661 | 8·0611 | 24·24 | 84·0 | 23·74 | 84·7 | +·0050 | −·0047 |
| 1870, ,, ,, | 12 12 | 14 27 | 8·0743 | 8·0703 | 25·19 | 83·4 | 24·55 | 84·3 | +·0040 | +·0060 |
| 1871. ,, ,, | 12 23 | 14 29 | 8·0794 | 8·0741 | 25·42 | 85·1 | 24·83 | 85·7 | +·0053 | +·0059 |
| 1872, ,, ,, | 12 12 | 14 36 | 8·0836 | 8·0790 | 25·57 | 82·9 | 25·01 | 83·6 | +·0046 | +·0055 |
| 1873, ,, ,, | 12 27 | 14 56 | 8·0861 | 8·0825 | 11·11 | 83·6 | 10·49 | 84·2 | +·0036 | +·0064 |
| Mean, ,, ,, | 12 21 | 14 37 | ...... | ...... | ...... | ...... | ...... | ...... | +·0041 | +·0052 |
| 1868, Jan. to March and Oct. to Dec. | 12 39 | 14 46 | 8·0626 | 8·0592 | 24·62 | 81·6 | 24·29 | 82·5 | +·0034 | +·0023 |
| 1869, ,, ,, ,, | 12 43 | 14 54 | 8·0678 | 8·0627 | 24·56 | 82·4 | 24·00 | 83·2 | +·0051 | +·0053 |
| 1870, ,, ,, ,, | 12 20 | 14 31 | 8·0736 | 8·0679 | 25·21 | 81·9 | 24·59 | 82·8 | +·0057 | +·0061 |
| 1871, ,, ,, ,, | 12 18 | 14 27 | 8·0790 | 8·0743 | 25·55 | 83·0 | 24·99 | 83·9 | +·0047 | +·0050 |
| 1872, ,, ,, ,, | 12 13 | 14 34 | 8·0789 | 8·0742 | 25·63 | 81·1 | 25·11 | 82·1 | +·0047 | +·0044 |
| 1873, ,, ,, ,, | 12 20 | 14 53 | 8·0850 | 8·0819 | 11·67 | 81·7 | 11·09 | 82·7 | +·0031 | +·0050 |
| Mean, ,, ,, ,, | 12 25 | 14 41 | ...... | ...... | ...... | ...... | ...... | ...... | +·0044 | +·0047 |
| 1868, April to September | 12 28 | 14 28 | 8·0638 | 8·0617 | 23·75 | 85·1 | 23·44 | 85·4 | +·0021 | +·0031 |
| 1869, ,, ,, | 12 24 | 14 33 | 8·0666 | 8·0636 | 24·02 | 85·9 | 23·65 | 86·4 | +·0030 | +·0036 |
| 1870, ,, ,, | 12 12 | 14 32 | 8·0769 | 8·0721 | 25·07 | 84·6 | 24·35 | 85·1 | +·0048 | +·0078 |
| 1871, ,, ,, | 12 14 | 14 31 | 8·0811 | 8·0762 | 25·28 | 85·8 | 24·67 | 86·3 | +·0049 | +·0064 |
| 1872, ,, ,, | 12 15 | 14 39 | 8·0857 | 8·0819 | 25·61 | 85·1 | 25·08 | 85·5 | +·0038 | +·0055 |
| 1873, ,, ,, | 12 28 | 14 58 | 8·0878 | 8·0842 | 10·69 | 84·2 | 10·17 | 84·7 | +·0036 | +·0053 |
| Mean, ,, ,, | 12 20 | 14 37 | ...... | ...... | ...... | ...... | ...... | ...... | +·0037 | +·0053 |

yearly comparisons; and secondly, that the probable error of a single weekly determination (that is, of the mean of the first and second observation) being $\pm{\cdot}0043$ (see paragraph 19), that of the mean difference, for six and a half years, between the first and second observations will be less than $\pm{\cdot}0005$ (or $=\pm{\cdot}0043\div\sqrt{\frac{338}{2}}\times\sqrt{2}$), a quantity which is less than half the magnitude of the difference that the error is supposed to explain. And if it were due to erroneous allowance for temperature of the large Horizontal-force Magnetometer, it ought to be small when the diurnal range of temperature is small, and large when the range is large; whilst, in fact, the difference in question is only ·0003 in the half-year October to March, when the range of temperature is large, and is ·0016 in the half-year April to September, when the range of temperature is small. At the same time the range of the diurnal variation of Horizontal Force is nearly the same throughout the year, its value for the half-year October to March being a fourteenth greater than for the half-year April to September, and its mean value for the year, as shown by the large Horizontal-force Magnetometer, is ·00166 of the whole force. It remains, therefore, if the result be an instrumental one, that the scale-coefficient adopted for the large Horizontal-force Magnetometer must be supposed to be one fourth of itself in excess of the truth: this the writer cannot think possible, and he hopes soon to have the opportunity of submitting to the judgment of the Royal Society evidence (in connexion with a general discussion of the observations with this instrument) which will completely set aside such a supposition.

If the result be admitted as a true magnetic phenomenon, it suggests the attribution of a very considerable magnetic influence to the state of the medium intervening between the upper and lower places of observation, in such a way that when the air is of equable temperature and almost uniformly moist throughout, the variations of force are nearly alike above and below, whilst in the dry months of the year there is a very considerable diminution of daily change of force with increase of height. The writer readily admits that such attribution should not rest upon a result of observations taken at a single station only.

18. *Annual Variation.*—In Table XVII. are shown the means for each month, in the period of six and a half years, of the values of Horizontal Force, corrected to the mean monthly reading of the large Horizontal-force Magnetometer; also the corrections for secular change, at the rate of $+{\cdot}0045$ per year, to reduce those means to the common epoch, October 1, 1870, and the same means cleared of secular variation; and, further, the excess of each of the corrected monthly values above the mean value for the year, the last series of numbers representing the annual variation of Horizontal Force.

TABLE XVII.

| Months ......... | Jan. | Feb. | March. | April. | May. | June. | July. | August. | Sept. | Oct. | Nov. | Dec. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean horizontal force ............ | 8·0631 | 8·0639 | 8·0664 | 8·0664 | 8·0663 | 8·0701 | 8·0675 | 8·0648 | 8·0651 | 8·0650 | 8·0651 | 8·0659 | ... |
| Correction for secular change... | +9 | +6 | +2 | −2 | −6 | −9 | +9 | +6 | +2 | −2 | −6 | −9 | ... |
| Corrected to epoch Oct. 1, 1870 ... | 8·0640 | 8·0645 | 8·0666 | 8·0662 | 8·0657 | 8·0692 | 8·0684 | 8·0654 | 8·0653 | 8·0648 | 8·0645 | 8·0650 | 8·0658 |
| Annual variation ... | −·0018 | −·0013 | +·0008 | +·0004 | −·0001 | +·0034 | +·0026 | −·0004 | −·0005 | −·0010 | −·0013 | −·0008 | ... |

The annual variation exhibits a semiannual inequality in which the horizontal force is, during the months March to August, ·0011 greater than the mean of the year, and during the months September to February ·0011 less. The quarterly means that give the greatest difference are as follows:—

| | |
|---|---|
| February to April . . . . . | ·0000 |
| May to July . . . . . . . . | +·0020 |
| August to October . . . . . | −·0006 |
| November to January . . . . | −·0013 |

Without applying any corrections for secular change, the means of the values of Horizontal Force in Table XVII., for January and December, February and November, &c., will all correspond to the same epoch, October 1, 1870. Such means are compared below both for the uncorrected observations and for the observations corrected to the mean of each month.

TABLE XVIII.

| Months. | Uncorrected. | | Corrected. | |
|---|---|---|---|---|
| January and December ............... | 8·0697 | 8·0701 | 8·0645 | 8·0645 |
| February and November............... | 8·0706 | | 8·0645 | |
| March and October..................... | 8·0722 | 8·0719 | 8·0657 | 8·0657 |
| April and September .................. | 8·0716 | | 8·0657 | |
| May and August ........................ | 8·0717 | 8·0736 | 8·0655 | 8·0671 |
| June and July ........................... | 8·0755 | | 8·0688 | |
| April to September ..................... | ...... | 8·0729 | ...... | 8·0667 |
| October to March ...................... | ...... | 8·0708 | ...... | 8·0649 |

Both sets of numbers indicate a small semiannual inequality, in which the force is about a four-thousandth of itself greater in the half-year April to September than in the half-year October to March; and the four-monthly means show that the force passes through its mean value in the months March, April, September, and October nearest to the equinoxes; and thence, of necessity, the maximum occurs in the months May to August, about the summer solstice, and the minimum in the months November to

February, about the winter solstice. The difference of range of the four-monthly means, uncorrected and corrected, is doubtless a consequence of the uncorrected values having reference to the mean interval from $12^h\ 22^m$ to $14^h\ 39^m$, whilst the corrected values have reference to the mean of the twenty-four hours.

Whilst, however, recording this result as that which the absolute observations are capable of yielding, the writer does not claim for it any great confidence; for the probable error of an observation is considerably greater than the monthly differences which have been obtained as representing the annual variation; and consequently it is only by combining together the observations of a number of years that the influence of errors of observation can be expected to be practically eliminated, and half the period of six and a half years seems not to be sufficient for this purpose; for when the observations are separated into two groups (of three and a half years and three years) the annual variations yielded are of totally different character.

19. *Probable Error.*—The probable error of a single weekly determination of Absolute Horizontal Force has been computed separately for July to December 1867 and for the year 1868. This has been done independently from all the complete observations except those of July 2 to 27, 1867, and for all, with the further exception of those of August 21, 1867, and April 8 and 15 and August 19, 1868, which give results that are evidently erroneous, far beyond the range of observational error. The observations were all reduced to the constant reading 24·27, at temperature 82°, of the large Horizontal-force Magnetometer, allowance being further made for the loss of strength of the magnet of that instrument; and the differences being then taken between each corrected determination and the mean of all, the probable errors were calculated from these differences by the method of least squares. The rate at which allowance was made for the loss of strength of the magnet was ·00015 of the whole per annum (see 'Introduction to Bombay Observations,' 1864, page xvi). The probable errors found are as follows:—

TABLE XIX.

| Period. | Including abnormal values. | | Excluding abnormal values. | |
|---|---|---|---|---|
| | English Units of Force. | | | |
| | Of a single weekly determination. | Of the mean of all the determinations. | Of a single weekly determination. | Of the mean of all the determinations. |
| July to December 1867 ............... | ±·0053 | ±·0011 | ±·0043 | ±·0009 |
| January to December 1868 ......... | ±·0067 | ±·0009 | ±·0043 | ±·0006 |

The remaining observations of 1869 to 1873 being of about the same quality as those of 1868, will have about the same probable error.

The maximum probable error (that of the moment of inertia of the vibration-magnet)

of the constants used in reductions of the Horizontal-force observations has about the same effect ($\pm$·0006) as the smallest of the above determinations, which have reference to observational errors only.

## IV. *Total Force.*

20. With the following data:—

| | |
|---|---|
| Dip for epoch 1st October, 1868 . . . . . . . . . | $=19° 4'·2$ |
| Secular change of Dip per annum . . . . . . . . | $=+1'·9$ |
| Semiannual inequality of Dip:—excess from April to September above the mean of the year . . . | $=+0'·3$ |
| Horizontal Force for epoch 1st October, 1870 . . . | $=$ 8·0658 |
| Secular change of Horizontal Force per annum . . | $=+$ ·0045 |
| Semiannual inequality of Horizontal Force: excess from April to September above the mean of the year . . . . . . . . . . . . . . . . | $=+$ ·0009 |

We find

| | |
|---|---|
| Dip for epoch 1st January, 1871 . . . . . . . . . | $=19° 4'·2$ $+2·25\times 1'·9=19° 8'·5$ |
| Horizontal Force for epoch 1st January, 1871 . . . | $=8·0658+\frac{·0045}{4}$ $=8·0669$ |

And by the formula $R=\frac{X}{\cos\theta}$, where R represents the Total Force, X the Horizontal Force, and $\theta$ the Dip:—

| | |
|---|---|
| Total Force for epoch 1st January, 1871 . . . . . | $=$ 8·5391 |

And by the formula $dR=\frac{dX}{\cos\theta}+R\tan\theta\, d\theta$:—

| | |
|---|---|
| Secular change of Total Force per annum . . . . . | $=+$ ·0064 |
| Semiannual inequality of Total Force: excess from April to September over mean of the year . . | $=+$ ·0012 |

21. *Annual Variation.*—In the annual variation of Total Force, derived by the formula last given from those of Dip and Horizontal Force in Tables III. and XVII., the monthly excesses above the yearly mean are, for January to December respectively, as follows:— −·0025, −·0015, +·0008, +·0008, +·0004, +·0039, +·0029, −·0001, −·0004, −·0011, −·0015, and −·0015; and the quarterly means which give the greatest differences are:—February to April, ·0000; May to July, +·0024; August to October, −·0005; and November to January, −·0018.

## V. *Absolute Magnetical Results.*

### Collected together.

### Table XX.

| Magnetic Element. | Epoch. | Value at epoch. | Value at common epoch, 1st January, 1871. | Secular change per annum. | Semiannual inequality: excess of April to September over mean of year. | |
|---|---|---|---|---|---|---|
| Declination ......... | 1st October, 1870 ... | 0° 49′ 32″ | 0° 50′ 8″ | +1′ 48″ | −0′ 1″ | |
| Dip..................... | 1st October, 1868 ... | 19 4·2 | 19 8·5 | +1·9 | +0·3 | |
| Horizontal force ... | 1st October, 1870 ... | 8·0658 | 8·0669 | + ·0045 | + ·0009 | Foot-grain-second units. |
| Do. .. | ...... | ...... | 3·7195 | + ·0021 | + ·0004 | Metre-gramme-second units. |
| Total force............ | ...... | ...... | 8·5391 | + ·0063 | + ·0012 | Foot-grain-second units. |
| Do. ............ | ...... | ...... | 3·9372 | + ·0029 | + ·0006 | Metre-gramme-second units. |