On the Diurnal Variation of the Magnet at Kew

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were concentrated in the circles where the cord runs. The case discussed above, as analogous to electric currents, occurs when $k^2 < a^2$, a condition that will be satisfied, even without non-rotating attachments, if the cord run near the circumference of the rotating pulleys. The opposite state of things, in which $k^2 > a^2$, would be realized by carrying out masses beyond the groove, and thus increasing the rotatory in comparison with the translatory inertia. In this case the mutual action between A and B is reversed. If when all is at rest A be suddenly started, B moves forward in the *same* direction. Otherwise C and D would have to rotate, and this in their character of fly-wheels they oppose.

Generally, if L, N be the coefficients of self-induction, and M mutual induction, we have (constant factors being omitted)

$$\begin{aligned} L &= N = a^2 + k^2, \\ M &= a^2 - k^2. \end{aligned}$$

In order to imitate the case of two circuits coiled together in close proximity throughout, we must have in the mechanical model $k^2 = 0$; that is, the rotatory inertia of the pendent pulleys must be negligible in comparison with the translatory inertia. Also the energy of the fixed pulleys, not included in the above expressions, must be negligible. If these conditions be satisfied, a sudden rotation imposed upon A generates an *equal* and opposite motion in B.

LVII. *On the Diurnal Variation of the Magnet at Kew.* By W. G. ROBSON and S. W. J. SMITH, of the Normal School of Science and Royal School of Mines*.

THE multiplication of magnetic observatories makes it extremely desirable that the methods of reducing the observations should be as similar as possible. It is, however, practically impossible that all observatories should determine the diurnal variations of the elements by the elaborate method in use at Greenwich, which, in the case of any one element, necessitates the measurement of the hourly ordinates

* Read June 6, 1890.

of the curves at 24 points on all but a very few days of the year under discussion.

Dr. Wild (Rep. Brit. Assoc. 1885, p. 78) advocates the determination of the mean diurnal range from measurements on the comparatively small number of days of very small disturbance, and points out that the inclusion of disturbed days will affect the form of the curve of diurnal range unless the disturbances themselves occur indifferently at all hours of the day and night.

Mr. Whipple, the Superintendent of the Kew Observatory, made a comparison of the methods of Wild and Sabine, and that in use at Greenwich for the years 1870-71-72 (Rep. Brit. Assoc. 1886, p. 71).

His general conclusion was that the difference between the Kew results, as treated by the two methods of Sabine and Wild, was less than the difference between the Greenwich and Kew results in either case.

The range of the differences is given below :—

Mean of three years 1870-72.

	Range of Differences.
Kew (Sabine and Wild)	-0'3 to +0'4
Greenwich and Kew (Sabine)...	-0'6 to +0'6
Greenwich and Kew (Wild) ...	-0'9 to +0'7

It would have been interesting if similar comparisons could have been carried out for more recent years ; but the fact that the Kew magnetic year has not been identical with that used at Greenwich has made such a comparison impossible. The Kew magnetic year has hitherto been from October to October, to admit of the observations being included in the Annual Report made by the Committee to the Royal Society. We understand that in future the civil year will be adopted.

Besides this, some of the Kew results have been obtained not by measuring the hourly ordinates, but by drawing free-hand a mean curve among the superposed traces of "quiet day" curves.

TABLE I.

Year.												Noon.											Midd.		
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.			11.
1883.	-1.42	-1.34	-1.42	-1.58	-1.88	-2.18	-2.68	-3.01	-2.51	-0.68	+1.98	+4.29	+5.52	+5.38	+4.15	+2.57	+1.32	+0.32	-0.29	-0.75	-1.24	-1.39	-1.55	-1.53	Greenwic
	-0.72	-0.77	-0.98	-1.28	-1.80	-2.29	-3.11	-3.77	-3.32	-1.28	+1.50	+3.89	+5.24	+5.06	+3.61	+2.17	+0.90	+0.29	-0.09	-0.35	-0.53	-0.69	-0.92	-0.82	Kew.
1886.	-1.61	-1.46	-1.42	-1.38	-1.57	-1.79	-2.02	-2.07	-1.52	-0.03	+2.17	+4.26	+5.21	+4.92	+3.79	+2.39	+1.14	+0.12	-0.64	-1.18	-1.60	-1.93	-1.99	-1.86	Greenwic
	-1.29	-1.17	-1.24	-1.57	-1.95	-2.23	-2.59	-2.71	-2.18	-0.47	+1.86	+3.84	+4.87	+4.43	+3.20	+1.91	+0.91	+0.23	-0.04	-0.38	-0.68	-0.81	-0.97	-1.13	Kew.
1887.	-1.47	-1.18	-1.05	-1.15	-1.42	-1.62	-1.88	-1.96	-1.85	+0.20	+2.33	+4.08	+4.91	+4.45	+3.17	+1.83	+0.74	-0.05	-0.71	-1.07	-1.47	-1.85	-1.84	-1.74	Greenwi
	-1.00	-0.94	-1.04	-1.25	-1.60	-2.06	-2.47	-2.76	-2.01	-0.25	+1.95	+3.93	+4.66	+4.20	+2.69	+1.39	+0.57	-0.04	-0.34	-0.48	-0.57	-0.80	-0.96	-0.84	Kew.

TABLE II.

Year.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mid.	
1870 ...	-0.9	-0.8	-0.7	-0.2	+0.2	+0.2	+0.5	+0.4	+0.6	+0.6	+0.4	+0.1	+0.5	+0.5	+0.4	+0.6	+0.6	+0.2	0.0	-0.1	-0.4	-0.8	-1.1	-1.0	} Green and K
1871 ...	-0.8	-0.6	-0.6	-0.4	+0.2	+0.7	+0.9	+0.7	+0.7	+0.7	+0.2	+0.5	+0.5	+0.7	+0.8	+0.6	+0.3	+0.1	-0.1	-0.2	-0.9	-0.7	-1.1	-0.9	
1872 ...	-0.9	-0.7	-0.6	-0.5	-0.1	+0.3	+0.5	+0.8	+0.8	+1.0	+0.6	+0.5	+0.7	+0.6	+0.8	+0.5	+0.5	+0.1	-0.1	-0.7	-0.7	-0.9	-1.1	-0.8	} Green and K
1883 ...	-0.7	-0.6	-0.4	-0.3	-0.1	+0.1	+0.4	+0.8	+0.8	+0.6	+0.4	+0.4	+0.3	+0.3	+0.5	+0.4	+0.4	0.0	-0.2	-0.4	-0.7	-0.7	-0.6	-0.7	
1886 ...	-0.3	-0.3	-0.2	+0.2	+0.4	+0.4	+0.6	+0.6	+0.7	+0.4	+0.3	+0.4	+0.3	+0.5	+0.6	+0.5	+0.2	-0.1	-0.6	-0.8	-0.9	-1.1	-1.0	-0.7	}
1887 ...	-0.6	-0.2	0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+0.7	+0.5	+0.4	+0.2	+0.3	+0.3	+0.5	+0.4	+0.2	0.0	-0.4	-0.6	-0.9	-1.1	-0.9	-0.9	
Mean...	-0.7	-0.5	-0.4	-0.2	+0.1	+0.4	+0.6	+0.7	+0.7	+0.6	+0.4	+0.4	+0.4	+0.5	+0.6	+0.5	+0.4	+0.1	-0.2	-0.5	-0.8	-0.9	-1.0	-0.8	

It was therefore determined to make some further comparison of the different methods of reduction, and at the request of Professor Rücker we have determined the diurnal variation of the declination at Kew for three recent civil years.

The years selected were 1883, a year of maximum sun-spots, 1886, and 1887. The mean diurnal range for each year was found by Wild's method—the hourly ordinates for about five quiet days in each month being measured.

The results we obtained have been compared with the corresponding Greenwich results, as published by the Royal Observatory (see Table I.). Thus for the total range for each year at Kew and Greenwich we have the following:—

Total Ranges.

Year.	Kew.	Greenwich.
1883	9'0	8'5
1886	7'6	7'3
1887	7'4	6'9

It is noteworthy that the total range at Kew determined from quiet days is greater than that at Greenwich determined from all days except those of great disturbance. If we may argue from so small a comparison this indicates that storms on the whole diminish instead of increasing the diurnal excursions of the needle. The total range is also apparently decreasing yearly.

The range of differences of the corresponding mean hourly values is:—

	Range of Differences.	Year.
Greenwich and Kew ...	-0'7 to +0'8	1883
" "	-1'1 to +0'7	1886
" "	-1'1 to +0'8	1887

There is thus in 1883 a difference of $1'5$ in a range of $9'$ —the percentage being $16\cdot7$. For 1886 the difference is $1'8$ in a range of $7'6$ —or $23\cdot7$ per cent.; while for 1887 the difference is $1'9$ in a range of $7'4$, or $25\cdot7$ per cent.

Table II. shows the differences of the hourly readings for the three years just determined, together with the differences for the years 1870, 1871, and 1872, as determined by Mr. Whipple (Rep. Brit. Assoc. *loc. cit.*). The mean of these hourly differences for the six years has been taken (see Table II.). It is noticeable that there is considerable uniformity in the nature of the differences between the mean hourly readings for Greenwich and Kew respectively. Thus, for each year, the Greenwich mean curve falls below that obtained from the Kew magnetograph at about 7 P.M., and remains below it until about 4 A.M., from which hour it is above the Kew curve until it crosses it at about 7 P.M. The minimum ordinate for each curve for each year occurs at about 8 A.M., and the maximum at 1 P.M. The declination has its mean value between 10 A.M. and 11 A.M., and again at between 6 P.M. and 7 P.M. Precisely the same features are to be noticed in the tables given by Mr. Whipple for the years 1870, 1871, and 1872 (Rep. Brit. Assoc. 1886, p. 74); so that it may fairly be assumed that the general nature of the difference between the Greenwich and Kew mean curves from 1870 to 1887 is the same.

The general similarity of the differences is shown clearly by the accompanying curves—the abscissæ of which represent hours, while the ordinates give the mean differences between the Greenwich and Kew readings at these hours. The first set are plotted from the data given in Mr. Whipple's paper. The second set are from the data which we have obtained for the years 1883, 1886, and 1887. The lowest represents the mean of the six curves.

The individual readings do not differ from the corresponding mean to an extent greater than $0'4$. It would therefore seem possible, knowing one set of values for any particular year—Greenwich or Kew—to determine the other set, correct to within four tenths of a minute. As the Kew results are published earlier than the Greenwich ones, it would be possible to calculate approximately the latter from the former.

Referring to the reduction of results, Prof. Rücker said that the Stonyhurst observers and Prof. Mascart were willing to adopt Wild's method ; Falmouth, he hoped, would follow suit, and Greenwich had been asked to publish their results in both ways.

Mr. Whipple said that before recording-instruments were available, and the numbers were obtained from separate experiments, the labour involved was considerable, and a single large disturbance or magnetic storm might vitiate the result of a whole year's work. Methods were therefore adopted to eliminate these disturbances ; of these, that used by Sabine may be particularly mentioned. Although declination-records have now been obtained for a considerable number of years, the cause of the variations still remains unknown. They do not seem to be dependent on temperature or on astronomical facts. He considered it valuable to obtain magnetic data from different parts of the earth, but comparisons were only possible when all are published on the same plan. This, he hoped, would result from the efforts of Professors Rücker and Adams. When this is accomplished, the observations on magnetic force will need treatment ; the work will be laborious, and the aid of volunteers like Messrs. Robson and Smith would be of great service.

Prof. W. G. Adams said he was glad to see the satisfactory nature of the work which had just been brought before the Society. Usually the mass of figures to be dealt with was so large that the mere reduction was a great undertaking. If, however, the difference between results obtained by the Greenwich and Wild's method was not more than $0\cdot4$, it may be possible to make out the causes of the variations from observations reduced on Wild's plan. He himself would put more faith in horizontal-force observations, and wished they could be worked out by some ready method. He hoped the one adopted in America, of obtaining mean curves by photography, may prove satisfactory.

Prof. Perry asked if a machine could not be made to do the work.

Mr. Whipple said such machines had been used by the Meteorological Office, but they were so elaborate and expen-

sive that clerical work was just as cheap. The method of photographing mean curves had been tried at Kew, but it was open to the objection that accidental disturbances such as those produced by the movement of iron in the vicinity and the approach of cabs &c. were not eliminated.

Mr. Boys, referring to the use of integrators, said that for a harmonic analyser his disk-cylinder pattern was preferable to the ball disk-cylinder integrators of J. Thomson, for it is much cheaper and has less inertia.

The President said the movement initiated by Prof. Rücker would be of great service if it resulted in the numbers obtained at the various magnetic observatories being published in the same way. It was a great advantage to have such men, who were not permanently attached to an observatory, to take up the subjects and suggest improvements. The heads of such institutions were usually too much employed in making the necessary reductions to have time for devising improved methods. In his opinion greater freedom should be allowed to the chiefs of observatories, for it should be borne in mind that the object of observations is not to produce volumes of figures but to increase our knowledge.

Referring to the reduction of observations, he thought the voluntary services of senior physical students should be more generally accepted, and to this end he suggested that properly recommended persons should be allowed to spend some time in observatories as honorary assistants. This would be of great use to the students themselves and an advantage to the observatories, for the reduction of observations could then be expedited. As regards the accidental disturbances referred to by Mr. Whipple, he contended that regulations should be adopted to render them impossible.