REPORT

OF

THE ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1893 *June* 3.

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The Report here presented refers to the year from 1892 May 11 to 1893 May 10, and exhibits the state of the Observatory on the last-named day.

I. Buildings and Grounds, Moveable Property, and Library :—

The building of the South wing of the proposed Physical Observatory, in order to provide additional accommodation for chronometers and deck watches, was commenced on November 24 last, but was interrupted on March 4, on arriving at the first floor, by a failure in the supply of terra cotta. Building operations are now about to be re-commenced. The need for further accommodation is being more urgently felt every day, in all departments of the Observatory. A number of the staff are at present housed in the Octagon room, which is part of my official residence ; and the inconvenience of this arrangement was strikingly demonstrated during the last winter. In view of this the Admiralty have now authorized the building of the North wing of the Physical Observatory and the completion of the central octagon by the addition of a storey and the erection of the Lassell Dome over it, a much needed extension, the postponement of which, since it was first brought forward in 1891, has caused serious difficulty in carrying on the work of the Observatory, both as regards observations and computations.

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The new Museum building, forming the central portion of the Physical Observatory, has at length been fitted with the necessary glass cases, which are now nearly ready for the reception of portable instruments and apparatus.

In the New Library four cases of shelves have been fitted on the west side of the gallery for the storage of forms, of which a large stock is required for entry and reduction of the observations and for other purposes. Two large cases are also being fitted, one to hold 10-inch solar photographs, the stock of which has already filled one case, and the other the 16-centimetre stellar photographs for the Astrographic chart, which are rapidly accumulating.

In preparation for the erection of the new 36-foot dome on the South-East tower, the old cylindrical dome was dismounted in November last, and the mounting of the new dome was commenced on December 16 and completed on April 25. The work of construction and erection of this large dome has been completed most satisfactorily by Messrs. T. Cooke & Sons, who have skilfully overcome various difficulties encountered in carrying out a novel design.

The usual external painting of the Observatory buildings and domes was done last autumn, with the exception of the South-East dome and building, which are now being painted.

An inventory of moveable property has been completed as far as circumstances would allow, a portion of the old instruments and apparatus being stored in sheds, where they are not at present accessible for examination. This inventory will require thorough revision when the completion of the new Physical Observatory allows of a rearrangement on a more permanent basis, and, in the meanwhile, considerable changes in the storage of the moveable property will result from the utilization of the new glass cases in the Museum building.

The principal moveable instruments are thus distributed :—

At Greenwich—

Transits B, D and E, and the transit with axis view.

Altazimuth D.

Equatorials (6-inch).—Cooke, No. 2 ; Hodgson ; and the tube and object glass of the Corbett.

Photoheliographs.—One complete (the tube No. 4, mounted in the South Ground on the stand No. 3); two tubes (one without the object glass), a driving clock (used for the Personal Equation Instrument).

Detached Telescopes (on tripod stands).—Two 4-inch (Simms, Nos. 1 and 2), two 4-inch (R.O., Nos. 1 and 2), two $3\frac{1}{2}$-inch (R.O., Nos. 3 and 4), and one $2\frac{3}{4}$-inch (R.O., No. 5).

On loan—

Transits.—A, at the Cape Observatory; C, at Montreal, for completion of the determination of personal equation in the Montreal longitude work.

Altazimuths.—A, at Bethnal Green Museum; B, at the Cape Observatory; E, at the Royal Naval College, Greenwich.

Equatorials (6-inch).—Lee at the Hong Kong Observatory; Simms, No. 2, lent to the Science and Art Department; Simms, No. 1, and the declination and polar axes, circles, and clock of the Corbett Equatorial, lent to the Joint Eclipse Committee for use in the Total Solar Eclipse Expeditions of April last.

Photoheliographs.—One complete at the Cape Observatory; one complete which had been lent to the Science and Art Department, and was transferred under Admiralty sanction to the Joint Eclipse Committee for observations of the Total Solar Eclipse in April last; and the mounting and driving clock of No. 4, previously in use here, together with object glass No. 3, lent to the same Committee for the same purpose; and the mounting of another (without driving clock) lent to the Science and Art Department.

Clocks.—Dent, No. 1916, and Dent, No. 2013, at the Cape Observatory; Dent, No. 2011, at the Kew Observatory; and Dent, No. 2010, at Devonport.

Anemometer.—Whewell's Anemometer, formerly (1843–1862) mounted above the roof of the Octagon Room of the Royal Observatory, has been lent to the Science and Art Department for exhibition at South Kensington Museum.

The instruments used in the longitude operations of last year have all been safely returned from Montreal, Canso, and Waterville, with the exception of Transit C, which is still at Montreal for a determination of personal equation between Prof. McLeod and Mr. Klotz.

A prismatic compass, two spectroscope slits, a $1\frac{1}{2}$-inch collimator object glass, and a $2\frac{3}{4}$-inch prism of 62° have also been lent for the Eclipse expeditions.

A Rowland diffraction grating, $3\frac{1}{4}$-in. by $1\frac{3}{4}$-in., on a 4-in. plate, for use with the new 28-in. equatorial, was obtained from Mr. Brashear in June last.

The electric light installation for the principal instruments proposed last year has been sanctioned, and the necessary generating plant, consisting of gas engine, dynamo, accumulators, and main leads, has been supplied by Messrs. Johnson & Phillips. It is proposed to set up the gas engine, dynamo, and accumulators in the ground floor of the new South wing of the Physical Observatory, but the delay in the completion of that building has stopped further progress.

The annual comparison of the books and manuscripts with the catalogue has been made, and two books and four pamphlets are at present missing. The book reported missing last year has been found.

II.—Astronomical Observations :—

Transit-Circle.—The Sun, Moon, planets, and fundamental stars have been regularly observed on the meridian as usual. The extraordinarily fine weather in the months of March and April has made the number of observations, as shewn in the following statement, much larger than ever before :—

Transits, the separate limbs being counted as separate observations	8217
Determinations of collimation error	304
Determinations of level error	512
Circle observations	7179
Determinations of nadir point (included in the number of circle observations)	461
Reflexion observations of stars (similarly included)	527

The annual catalogue of stars observed in 1892 contains 1710 stars.

As an illustration of the continuity of fine weather in March and April, it may be mentioned that 2600 transits and 2300 circle observations were made in these two months, the average corresponding numbers for the seven previous years being 945 and 877 respectively ; that 70 observations of Polaris or Polaris S.P. were

obtained (exclusive of isolated observations which are only used for azimuth error and not for place of the star), the average for these months in 10 years preceding being 22·2 and the greatest in any of these years 38, (in 1885) ; and that 24 groups of clock stars extending over more than 12 hours were obtained, the mean for 10 years preceding in March and April being 2·6. In this last case something must be attributed to the special interest shewn by the observers recently in obtaining long groups of clock stars.

As regards the computations :—

The transits are completely reduced (so as to exhibit Mean R.A. 1893·0) to April 9, and Observed R.A. corrected for instrumental errors and clock errors to April 22, collimation and level errors being applied to May 3, and means of transits being taken to May 9. The copy for press for 1892 is in the printer's hands.

The investigation of personal equations is completed for 1892, a provisional investigation having been made in August last, owing to the numerous recent changes in the staff.

The circle observations are completely reduced to April 9, circle readings, &c., being complete to May 2. The copy for press for 1892 is in the printer's hands.

The apparent correction for discordance between the nadir observations and stars observed by reflexion for 1892 is $-0''\cdot25$, and has been persistently negative for some months. Past experience suggests that this discordance may be due to wear in the microscope screws, which have now been in use 8 years, though the probability of this cause is diminished by the following considerations :—

(1.) That the screws are now made of steel, which is less liable to wear.

(2.) That three of them are reversed, so that the effect of wear on the mean is of opposite sign.

Observations were undertaken in February to test the uniformity of the screws, and it was found that although several of them shewed signs of wear, the mean of the six microscope readings was not sensibly in error over the available range ($0^r - 5^r$), the actual errors found by observation being—

at $9^r\cdot0$	at $0^r\cdot0$	at $1^r\cdot0$	at $2^r\cdot0$	at $3^r\cdot0$	at $4^r\cdot0$	at $5^r\cdot0$	at $6^r\cdot0$
$-''\cdot29$	$-''\cdot11$	$-''\cdot15$	$+''\cdot03$	$-''\cdot03$	$''\cdot00$	$-''\cdot09$	$-''\cdot28$

The corresponding quantities found in 1886, soon after the screws were mounted, were—

$-''\cdot13$ $-''\cdot07$ $+''\cdot03$ $-''\cdot06$ $+''\cdot06$ $''\cdot00$ $-''\cdot06$ $+''\cdot10$.

If three of the screws had not been reversed these errors would have been at the present time—

$-''\cdot56$ $-''\cdot21$ $-''\cdot12$ $+''\cdot03$ $-''\cdot03$ $+''\cdot02$ $-''\cdot22$ $-''\cdot42$.

The correction for R—D, the error of assumed colatitude, and the position of the ecliptic have been investigated for 1892; and the whole of the planetary reductions for 1892 are complete.

The correction for R—D, $+0''\cdot062+0''\cdot576$ sin Z.D., agrees well with the results of recent years. Several points connected with this peculiarity of the instrument are under investigation by Mr. Turner and Mr. Thackeray.

The colatitude of the transit-circle as found by the observations of 1892 is 38° 31′ 22″·10, differing by + 0″·20 from the adopted value. Recent investigations have made it probable that the colatitude undergoes fluctuations of short period: and in comparing the observations in the individual years 1877–1886 with the final results in the Ten Year Catalogue, confirmatory evidence of these fluctuations was found. Mr. Thackeray was thus led to undertake an examination of all the observations of N.P.D. of the four close circumpolar stars since 1851. The results were found to accord well with Mr. S. C. Chandler's hypothesis (Astronomical Journal, No. 277), and have been communicated to the Royal Astronomical Society (Vide *Monthly Notices*, liii., p. 3).

The correction to tabular obliquity of the ecliptic from solar observations in 1892 is + 0″·44, rather a large quantity. The discordance between the results from the summer and winter solstices is + 0″·40, indicating that the mean of the observed distances from the pole to the ecliptic is too small by + 0″·20, and thus confirming the stellar observations for colatitude. The readings of the Standard Meteorological thermometer have been used for reducing observations of the Sun. The mean monthly excess of the adopted readings over those of the ordinary exterior thermometer (corrected for index error) was least in January (+ 0°·2) and December (+ 0°·3), and greatest in April (+ 3°·3) and August (+ 2°·9). The mean for the year is + 2°·2.

The mean error of the Moon's tabular place (computed from Hansen's lunar tables with Newcomb's corrections) is + 0ˢ·083 in R.A. and + 1″·29 in longitude, as deduced from 95 observations in 1892, agreeing well with the results for 1891. The mean values of these quantities for the ten years 1883–1892 are + 0ˢ·044 and + 0″·61; and the differences from these means are as follows: R.A. $-^{s}013$, $-^{s}026$, $-^{s}020$, $-^{s}015$, $+^{s}015$, $+^{s}046$, $-^{s}034$, $-^{s}024$, $+^{s}033$, $+^{s}039$: longitude $-''\cdot19$, $-''\cdot32$, $-''\cdot25$, $-''\cdot27$, $+''\cdot05$, $+''\cdot60$, $-''\cdot49$, $-''\cdot38$, $+''\cdot61$, $+''\cdot68$.

The mean error of the Moon in N.P.D. for 1892 is $-0''\cdot27$.

Further discussion of the readings of the six thermometers at various points of the transit-circle room indicates that these readings depend sensibly upon the deviation of external temperature from the average, whatever the season. The discussion is given in the Monthly Notices for May 1893.

Altazimuth.—At the beginning of April it was noticed that the bubble of one of the upper levels was longer than the scale, and on examination it was found that there was a small crack in the glass, through which the liquid had been gradually evaporating, as the readings shewed, indicating a date for the crack toward the end of February. On unscrewing the level for repair, it broke. A new level is ordered but has not yet been supplied.

The total number of observations made in the year ending 1892 May 10 is as follows :—

Azimuths of the Moon and Stars	167
Azimuths of Mark I.	62
Azimuths of Mark II.	64
Zenith distances of the Moon	62
Zenith distances of Mark I.	60
Zenith distances of Mark II.	62

These numbers are considerably less than in recent years owing to the fact that observations with the altazimuth were suspended from 1892 May to October 18, during great pressure of longitude and other work.

The observations are completely reduced to February 20.

The following table shews the number of days on which complete observations of the Moon were obtained with the transit-circle and altazimuth respectively :—

Moon's Time of Meridian Passage.	Transit-circle.	Altazimuth.
13^h to 14^h civil time	0	2
14^h to 15^h ,,	0	5
15^h to 16^h ,,	5	5
16^h to 17^h ,,	5	3
17^h to 18^h ,,	6	3
18^h to 21^h ,,	21	2
21^h to 0^h ,,	28	—
0^h to 3^h ,,	25	—
3^h to 6^h ,,	21	—
6^h to 7^h ,,	7	5
7^h to 8^h ,,	5	3
8^h to 9^h ,,	0	3
9^h to 10^h ,,	0	1
10^h to 11^h ,,	0	1

The whole number of places of the Moon observed with the transit-circle is 123 or 10·0 per lunation, and with the altazimuth 33 or 4·7 per lunation (excluding the 5 lunations during which observations with the altazimuth were suspended).

The Moon's diameter has been measured with the transit-circle 4 times in R.A. and 15 times in N.P.D.

The proposal for a universal transit-circle to replace the existing altazimuth and to serve as a duplicate meridian instrument for fundamental determinations was brought forward in my last Report page 25, and was recommended at a special meeting of the Board of Visitors on October 26. The provision of this new instrument with suitable building and dome has been sanctioned by the Government, and its construction has been entrusted to Messrs. Troughton and Simms, who are now preparing the working-drawings. It is proposed to erect this instrument on the site indicated in my last Report, to the north of the Magnetic Observatory.

Clocks and Chronographs.—The Sidereal Standard has required more attention than usual during the past year. On 1892 June 26 it was found stopped, though wound up sufficiently for another 2 days ; on September 3, after going very erratically, it was examined and repaired by Messrs. E. Dent & Co., who reported that the oil had thickened on the escape pivots ; the clock was again examined on 1893 February 13, suspicion having been entertained that it stopped during winding ; the maintaining power was found defective and strengthened ; and on 1893 May 4 it was noticed that the barometric inequality was (and apparently had been for some time) considerably under-corrected, and an alteration was made with a view to its more complete compensation.

The Mean Solar Clock was cleaned by Mr. Kullberg on 1892 May 27, the signals at 10^h and 13^h not being interfered with. The clock Hardy was repaired on May 30 ; and the clock Mudge and Dutton was cleaned on January 10.

With a view to the improvement of the hourly time signals the clock Dent 2012 with zinc and steel pendulum had been fitted with hourly contact springs and mounted in the Ball Lobby to replace the electrical Mean Solar Clock, but it was not brought into use pending arrangements for working the sympathetic dials by reverse currents at the alternate seconds. Mr. Kullberg is now fitting seconds contact springs which will it is hoped effect this, and the new clock, which has a very steady rate, will be brought into use for the hourly time-signals as soon as possible.

Reflex Zenith Tube.—Since the date of the last Report, 7 double observations of γ Draconis have been made.

Equatorials.—The tube of the new 28-inch refractor together with the declination-axis cones, declination circle, and clamping circle, which had been sent to Sir H. Grubb for fitting, were delivered here on April 21 and the erection of the instrument which has been awaiting the completion of the new dome is being proceeded with as rapidly as possible. The object-glass which has been at the Observatory since March 1892 is ready for mounting.

The Rowland diffraction grating for use with the 28-inch telescope has been received from Mr. Brashear as mentioned above.

The 12¾-inch Merz refractor of the South-east equatorial was mounted last May in place of the Lassell 2-foot reflector, the Thompson 9-inch photographic-telescope being carried on the same mounting. It has been used assiduously by Mr. Lewis since February last for observations of double stars. In all he has made 545 measures of position angle and 609 of distance of 85 pairs ; 32 pairs being less than 1″ apart, 26 between 1″ and 2″, 8 between 2″ and 3″, and 19 over 3″. This work has a special value at the present time, as giving information as to the performance of the instrument and as to the modifications in the mounting which may be advisable before erecting it in its proposed position on the Physical Observatory. In its present site much of the sky is cut off by the adjacent building, and important observations such as those of the conjunction of Saturn and γ Virginis, are thus often lost.

Since the date of the last Report, 26 disappearances and 7 reappearances of stars occulted by the Moon have been observed, including 7 disappearances and 3 reappearances observed during the lunar eclipse of 1892 May 11, and 10 disappearances of stars below the Nautical Almanac limit of brightness (6·5) approximately predicted by Mr. Crommelin. Also the disappearance of Uranus behind the Moon on July 3, the occultation of 73 Piscium by Jupiter on May 23, and 62 phenomena of Jupiter's satellites. These observations are completely reduced to 1893 February 26.

Comet *a* 1892 has been observed with the Sheepshanks equatorial on 8 nights, Comet *c* 1892 on 1 night, Comet *d* 1892 on 9 nights, Comet *f* 1892 on 21 nights.

and Comet g 1892 on 11 nights. Particular care has been taken about the orientation of the cross wires, and with a view to determining personal equation in such observations, the nebula N.G.C. 1931 has been observed on 3 nights, and the Crab nebula on 5 nights. This investigation will be continued.

To investigate the breadth of the diffraction border in images of the Sun and Moon, observations of the limbs have been made on 4 days and 4 nights with diaphragms of different apertures placed on the Sheepshanks equatorial. Further observations are required to elucidate this point completely.

On the occasion of the conjunction of Saturn and γ Virginis, differences of R.A. and N.P.D. were measured with the $12\frac{3}{4}$-inch Merz refractor on April 10 and 12; and near the time of conjunction of Mars and Ceres, differences of R.A. and N.P.D. between the planets, and between them and neighbouring stars were observed with the Sheepshanks equatorial on 5 nights.

With the Astrographic equatorial 722 plates, with a total of 1812 exposures, have been taken on 161 nights in the year ending May 10, and of these 116 have been rejected, viz.:—57 from photographic defects, 6 from mechanical injury, 12 from mistakes in setting, 6 from the plate being wrongly placed in the carrier, 7 from failure in clock driving, and 28 from interference by cloud. The following statement shows the progress made with the photographic mapping of the heavens in the year 1892 May 11 to 1893 May 10:—

	No. of Photos taken.	Successful Plates.
Astrographic Chart (exposure 40^m)	200	183
Plates for Catalogue (exposures 6^m, 3^m and 20^s) .	367	288
Number of Fields photographed for the Chart . .		172
,, ,, ,, ,, Catalogue .		271
Total Number of Fields photographed since the commencement of the work for the Chart . . .		176
Total Number of Fields photographed since the commencement of the work for the Catalogue . .		299

It has been made a practice to take a trail on each night on a catalogue plate as a check on the orientation, and during the past year 127 plates with trails have been thus secured.

The following miscellaneous photographs (included in the total number of 722 given above) have also been taken :—

	No. of Photos.
Nova Aurigæ	49
For zero of scales and orientation. . . .	36
North Pole (for adjustments of Equatorial) .	11
Pleiades with various exposures . . .	19
Victoria Comparison Stars (for determination of scale value)	12
Lunar Eclipse, 1892 May 11	4
Comet Holmes	2
Moon	3
Saturn	5
Conjunction of Saturn and γ Virginis . . .	16
Trails of Equatorial stars.	3

Four of the plates of the Pleiades have been taken with the group in four different positions on the plate for determination of the optical distortion of the telescope.

Some experimental plates of Jupiter, Saturn, double stars and lunar craters, have also been taken with the image enlarged about 14 times by a secondary magnifier, consisting of a triple cemented concave lens of $1\frac{3}{8}$ in. diameter and 3 in. focus, supplied by Mr. T. R. Dallmeyer. The results are very promising.

One of the *réseaux* supplied by M. Gautier has been in use since 1892 May 23, but though the collodion coating has undoubtedly protected the film, pin holes have developed as before though in a lesser degree. A *réseau* is occasionally developed alone on a plate for the detection of spurious images on the Chart plates.

The examination of the plates taken specially for testing zero of scales and orientation of plate shows that great care is required in printing the *réseau* on the plate, as well as in placing the plate in the camera of the photo-telescope, in order to secure the setting of the *réseau* within 5″ of the tabular place, and the exact orientation of the *réseau* lines relatively to a star trail.

The photograph-micrometer as modified to adapt it to the measurement of the Astographic plates has been brought into use, and appears to answer its purpose well, though systematic work with it has not yet been commenced. A description of this measuring apparatus, which dispenses with the necessity for measurement of the lines of the *réseau*, is given in the Monthly Notices for last March. To test the straightness of the perpendicular slide, on which the determination of relative positions of stars in

different parts of the plate largely depends, three plates of the trails of three equatorial stars (1 and ζ Aquarii and δ Ceti) taken across the meridian, which (when corrected for the very slight curvature of path) give a mathematical straight line, have been measured, with the result that the errors of the slide are insensible. The *réseau* lines which have also been compared with the trails appear likewise to be sensibly straight.

Some experimental measures of stars on several plates have been made to test the accuracy with which positions can be determined. The comparison of three plates of the same field gives very satisfactory results for positions determined without reference to the *réseau* lines.

Since the date of the last Report, 33 of the plates of Nova Aurigæ have been measured for determination of the magnitude of that interesting star. The results up to September 6 are given in the Monthly Notices for last November. Since August 30, when the star, after having fallen below the 14th magnitude, had brightened considerably, the photographic magnitude appears to have remained nearly constant up to April 4, the date of the last photograph measured.

III.—Spectroscopic and Photographic Observations :—

No spectroscopic observations have been made during the past year, the regular observations for stellar motion in the line of sight having been interrupted by the dismounting of the South-East Equatorial, and there being great pressure in the Solar photographic work.

The telescope and camera of the Dallmeyer photoheliograph were again removed on 1892 September 9 from the wooden dome, where the new buildings obscured the horizon, to the first floor of the new museum, where they were re-mounted on stand No. 3, which was simply placed on the floor and found sufficiently steady. From this position it was possible to photograph the Sun during about 2 hours each day. The instrument and stand No. 3 (the proper stand No. 4 having been lent for use in the Eclipse Expeditions) were taken back to the wooden dome on 1893 April 7, the Sun being then visible over the roof of the intervening building.

In the year ending 1893 May 10, photographs of the Sun have been taken with this instrument on 180 days, and of these 410 have been selected for preservation, besides 22 photographs with double images of the Sun for determination of zero of position.

The photographic telescope presented by Sir Henry Thompson, which has been mounted on the Lassell equatorial, has been in regular use as a photoheliograph since January 1893, and photographs of the Sun have been obtained with it on 89 days, or

which 158 have been selected for preservation. In all with one photoheliograph or the other a record of the state of the solar surface has been secured on 220 days during the year. A new enlarging lens by Messrs. Ross & Co., which appears to be very free from distortion, was fitted to the Thompson photoheliograph on December 13, and has been used regularly since for the eight-inch photographs of the Sun.

For the year 1892 Greenwich photographs have been selected for measurement on 197 days, and photographs from India and Mauritius (filling up the gaps in the series) on 165 days, making a total of 362 days out of 366 on which photographs are available.

The solar activity has been fully maintained throughout the past year, though no single spot has appeared equal to that of 1892 February. The mean daily spotted area for 1890 was 100, for 1891, 566, and for 1892, about 1230.

This great development of activity seriously increases the work of the department; as an example it may be mentioned that 35 books of the form used in reducing the spot positions were required for the years 1891 and 1892, while in the whole 17 years preceding, for which photographs have been measured, only 85 books had been used, 39 of these having been used in the *three* years 1882–4 of the last maximum. Notwithstanding this increase in the work, the measures and reductions are in a more forward state than at the date of the last Report. The measures of Positions and Areas for 1891 are now passing through the press, and the Spot Ledgers for that year are prepared for press. The photographs have been measured and reduced up to 1893 January 13, the reductions examined up to 1892 October 27, and the copy for press written up to 1892 September 10. But to cope with this unexpectedly severe Sun spot maximum it has been necessary to largely increase the number of Computers employed on this work, and a further addition will probably be required if, as seems likely, the solar activity continues to increase.

IV.—Magnetic Observations :—

The photographic registration of the variations of magnetic declination, horizontal force and vertical force, and of earth currents, with the accompanying eye observations of absolute declination, horizontal force and dip, are maintained as in former years. The period has been one of great magnetic activity, and at such times we can appreciate the advantage of the newer photographic processes, as compared with those of earlier days, in the clearness and delicacy of the registration of the many rapid magnetic movements that occur during magnetic storms. There is also greater general certainty in the photographic work, the loss of register due to photographic failure being now a

very rare circumstance. The magnet basement is kept at a temperature of about 67°; it seldom rises much above this in summer, and in winter, thanks to the improved gas service, the same temperature is usually easily maintained.

During the winter the circle of the declination theodolite was redivided. The divisions had become very indistinct in places, the instrument having been continuously in use since the establishment of the Magnetic Observatory. The pivots were also reground, and it was found that the previously existing slight inequality had been increased. The bubble of the striding level was shortened, and the value of $1^{div.}$ of the scale is now found to be $1''{\cdot}5$, the value previously in use being $1''{\cdot}05$.

It is proposed to apply to the clocks of the automatic apparatus for registering the magnetic elements a gearing similar to that recently applied to the Osler anemometer clock, for giving a more open time scale when desired.

The disturbance of the earth current registers due to the trains running on the City and South London Electric Railway still continues and is of about the same magnitude as before. The substitution of a non-magnetic silver pointer for the upper magnetic-needle in the galvanometers for the earth current apparatus, as mentioned in the last Report, has proved very successful, the scale values, which used to vary considerably, having since remained remarkably constant.

In view of the approaching introduction of a dynamo into the Observatory grounds for electric lighting, experiments have been made to determine the possible effect on the magnetographs of the dynamo unshielded and with triple iron shield. These experiments were carried out at Messrs. Johnson & Phillips' factory, Charlton, the deflection of the declination magnet of the portable unifilar magnetometer being observed at distances of 20 and 40 feet respectively due west (magnetic) of the dynamo, the poles of which were in the east and west direction (magnetic), thus giving the maximum deflecting effect. At the Royal Observatory the poles of the dynamo will be north and south (astronomical), and it will be placed at a distance of about 170 feet from the magnets and nearly due south (magnetic). Making due allowance for this, the experiments at Charlton would give the following results :

Effect on	Declination Magnet	or	Horizontal Force Magnet.
Dynamo unshielded . .	4″		·00008
Dynamo with triple shield .	0″·5		·00001

the effect on the horizontal force magnet being expressed in parts of the whole horizontal force. The corresponding displacements of the magnetograph registers would be only $\frac{1}{2000}$th of an inch for declination and $\frac{1}{400}$th of an inch for horizontal force, in each case with triple shield to the dynamo. As the separate portions of the

triple iron shield were only loosely put together, it is proposed to repeat these experiments with the completed shield which is now ready. In any case it seems clear that the shield will so greatly reduce the disturbing effect as to make it quite insensible.

The magnetic reductions are completed to the following stages :—

The eye observations of the upper declination magnet, and of the horizontal and vertical force magnets, are completely reduced to the end of 1892. The time-scales for declination, horizontal force, and vertical force are complete to the end of 1892, and the base line values, deduced from eye-observations, are entered on the photographic sheets for declination, and for horizontal and vertical force.

The hourly ordinates of the photographic curves are read out to the end of 1892 for horizontal force and vertical force ; and for declination to the end of March ; and the daily and hourly means of vertical force are taken for a few months ; the time scales for earth currents are complete to the end of August. The dip observations are completely reduced to the present time, and the deflexion observations for absolute measure of horizontal force to the end of 1892. The temperature of the magnet basement at every hour has been read off from the sheets of the Richard thermograph to the end of 1892, and the daily and hourly means have been taken.

The following are the principal results for the magnetic elements for 1892 :—

Mean declination (approximate) . .	17° 18′ West.
Mean horizontal force . .	3·9613 (in British units). 1·8265 (in Metric units).
Mean dip	67° 18′ 42″ (by 9-inch needles). 67° 19′ 45″ (by 6-inch needles). 67° 21′ 7″ (by 3-inch needles).

In the year 1892 there were 22 days of great magnetic disturbance, and also 25 other days of lesser disturbance, for all of which tracings of the photographic curves will be published according to the arrangement made with M. Mascart. The calculation of diurnal inequalities from 5 typical quiet days in each month has been continued.

The new Kew unifilar magnetometer has been used for the determination of absolute horizontal force near the times at which observations were made with the regular instrument. The mean of the monthly values for horizontal force made with the instrument in 1892 is 1·8288, which is ·0023 greater than the mean given by the old instrument. From June to December 1891 there was a similar excess of ·0030 in amount.

The reduction of the magnetic results for 1865–1867, and the correction of those for 1868–1882 is complete; and the whole series for 1865–1882 will be published with the 50 years' Meteorological Reductions in a separate volume.

It may be mentioned that portable electric lamps have been found very useful in reading the circle of the declination magnet, the barometer, and other instruments.

Applications for information on the magnetic declination in different parts of the country become more and more numerous, and the accurate map of Profs. Rücker and Thorpe is found very valuable.

V. Meteorological Observations :—

The meteorological instruments are all in good order, the registration of atmospheric pressure, temperature of the air, and of evaporation, pressure and velocity of the wind, rainfall, sunshine, and atmospheric electricity having been continuously maintained, except that during the severe frost of last winter the register of atmospheric electricity was interrupted on several days by freezing of the water in the exit pipe.

I have long considered it desirable to have a largely increased time-scale for the register of wind-pressure during gales, the high pressures being usually confined to gusts of very brief duration, and I have recently arranged with Mr. Kullberg to apply a special gearing to the clock of the Osler anemometer for this purpose; so that the table carrying the record can either be driven at the usual rate, or twelve times as fast, the ordinary sheet thus giving a register for two hours instead of twenty-four. This arrangement was brought into use on April 22, and works very satisfactorily.

The meteorological reductions are in the following state :—The observations of barometer, thermometers, anemometers, rain-gauges, and sunshine-recorder (corrected, where necessary, for instrumental error) are reduced up to the present time. On the photographic sheets all the time-scales are laid down, and the hourly ordinates are read out for the dry and wet bulb thermometers to the end of the year 1892, and for electrometer to the end of July 1892. The table of principal changes in the direction of the wind for 1892 is complete.

The mean temperature of the year 1892 was 48°·1, being 1°·4 below the average of the 50 years, 1841-1890. The highest air temperature in the shade was 85°·9 on June 10, and the lowest 17°·6 on December 27. The mean monthly temperature

in 1892 was below the average in all months excepting May, August, and November. In March it was below the average by 4°·4, in October by 4°·6, and in December by 3°·0.

The mean daily motion of the air in 1892 was 265 miles, being 17 miles below the average of the preceding 25 years. The greatest daily motion was 687 miles on January 29, and the least 48 miles on December 28. The greatest pressure registered was 11·8 lbs. on the square foot on October 9.

During the year 1892 Osler's anemometer showed an excess of about 20 revolutions of the vane in the positive direction N., E., S., W., N., excluding the turnings which are evidently accidental.

The number of hours of bright sunshine recorded during 1892 by the Campbell-Stokes sunshine instrument was 1277, which is about 7 hours below the average of the preceding 15 years, after making allowance for the small difference of the indications with the Campbell and Campbell-Stokes instruments. The aggregate number of hours during which the Sun was above the horizon was 4465, so that the mean proportion of sunshine for the year was 0·286, constant sunshine being represented by 1.

The rainfall in 1892 was 22·3 inches, being 2·2 inches below the average of the 50 years 1841–1890.

With regard to the recent drought, the following particulars may be of interest:—

The sunshine registered in the months of March and April has been phenomenal. For March it was 155·1 hours, and for April 231·0 hours; the greatest numbers for these months in the 16 years 1877–1892 being $141^{h}·0$ (1880 March) and $196^{h}·3$ (1892 April). The greatest values for *any* month in the 16 years preceding are $277^{h}·1$ (1887 July), $267^{h}·1$ (1877 June), and $237^{h}·8$ (1882 May); and if we consider the *ratios* of sunshine to the total time the Sun was above horizon, or to the total time, less $1\frac{1}{2}$ hours each day, during which the Sun is too low to give a record on the paper, we find that April 1893 was the sunniest month yet recorded.

	Ratio to	
	Total No. of Hours.	Total, less $1\frac{1}{2}$ hours daily.
1877 June	0·540	0·594
1882 May	0·493	0·546
1887 July	0·558	0·615
1893 April	0·557	0·624

The mean amount of cloud registered in March 1893 was 4·0, and in April 3·1, on the usual scale. According to the table for Greenwich for 70 years (given by Mr. Ellis in the Quarterly Journal of the Royal Meteorological Society, Vol. XIV., p. 187) the least previous value for March since 1818 was 5·0 (in 1841) and for April 3·7 (in 1840). The least mean value in any month since 1818 is 3·0 (in 1848 May) and the next is 3·2 (in 1865 September). The least pair of mean values for any two consecutive months is 3·3 and 4·7 (1835 July and August), and for March and April is 6·2 and 3·7 (in 1840). It will thus be seen that the amount of cloud recorded for last March and April is considerably less than that for any two consecutive months previously.

For the 72 days from 1893 March 5 to May 15, the total amount of rain measured was only 0·246 inches, the average for the corresponding period being about 4 inches. There was a period of 30 days from March 18 to April 16 without rain. There is no similar dry period of 72 days since the commencement of the register in 1841. It is worthy of note that immediately preceding the drought there was heavy rain ; between 1893 February 1 and March 4, rain fell on 25 days to the total amount of 3·03 inches, the average rainfall for the corresponding period being about 1·67 inches.

During the period of 9 days, 1893 April 18 to 26, the maximum temperature on 8 days was above 70°, including April 20, when the maximum was 80°·0. For the 50 years 1841–1890 the earliest recorded occasion in any year on which the thermometer rose to 80° was April 27, in 1865, when it rose to 81°·5. The mean maximum temperature of the 9 days was 74°·1, being 15°·0 above the average for the corresponding days for 50 years. The mean temperature of the 9 days was 58°·5, or 10°·1 above the 50 years' average. From April 21 to 26 the total sunshine registered was $71^{h}\cdot0$, a daily average of $11^{h}\cdot8$; the least daily value being $11^{h}\cdot5$, and the greatest $12^{h}\cdot6$, a run of exceptional uniformity. The daily number of hours the Sun was above the horizon at a sufficient altitude to register was $12^{h}\cdot8$.

The tabulation of the daily maximum and minimum temperatures, and mean daily temperature for every day during the 50 years 1841–1890, with daily means for the whole period, and for each half period of 25 years, is complete ; and the reductions will be printed together with certain other abstracts and tables, and the magnetic reductions mentioned above, as a separate publication.

Many applications for meteorological information have been answered, including one for special information on wind velocity from Lord Spencer.

VI.—Printing and Distribution of Greenwich Publications :—

The volume of Greenwich Observations for 1889, and the separate copies of Results, were distributed in July and August last, the distribution having been greatly delayed under unfortunate circumstances as mentioned in the last Report.

The copies of the volume of Greenwich Observations for 1890, and of the separate Results, were received last February and have been distributed, together with Vol. I. Parts 2, 3 and 4 of the Annals of the Cape Observatory.

Owing to various causes the printing of the volume of Greenwich Observations for 1891 has fallen into arrear, but arrangements have lately been made with H.M. Stationery Office and with the Printers which will, it is hoped, expedite the work, and lost ground is now being made up. The Altazimuth and Magnetic and Meteorological Sections (with the exception of the Introduction) are printed, as well as the Meridian Zenith Distances and Chronometer Rates, and the printing of the Transits is nearly complete. The Photographic Results, which have been exceptionally heavy, are printed to June. The whole of the manuscript of the volume for 1891 is in the Printer's hands with the exception of the Introductions.

The whole of the manuscript of the Transits, Meridian Zenith Distances, and Altazimuth Results for 1892, as well as the Chronometer and Deck-watch Rates 1892–93, has been sent to the Printers, and the manuscript of the Photographic Results for 1892, which has involved considerable labour in preparation owing to the great solar activity, is practically complete.

VII.—Chronometers, Time Signals, and Longitude Operations :—

The number of chronometers and deck-watches now being tested at the Observatory is 206 (137 box chronometers, 26 pocket chronometers, and 43 deck-watches). In addition to these there are 8 chronometers on trial for purchase by the Indian Government ; and 4 box chronometers and 2 pocket chronometers have been tested after repair for the same Government. The next annual competitive trial of chronometers commences on July 1, and the trial of deck-watches on October 21.

In the year ending 1893 May 10 the average daily number of chronometers and deck-watches being regularly rated was 274 ; the total number received was 759, the total number issued was 761, and the number sent for repair was 422.

For the annual trial of chronometers (which lasted for 29 weeks) with a range of temperature of from 37° to 103°, 48 chronometers were sent in, and of these, 25 have

been purchased for the Navy. Considering the exceptionally severe nature of the trial, owing to the low temperature in January, the chronometers purchased compare favourably with those holding corresponding positions in last year's trial ; the average trial number of the first six being 20·0, as compared with 21·4 last year.

For the annual trial of deck watches, the watches were separated into two classes, A and B, 38 being entered (by their makers) as A and 10 as B, the trial in positions for the latter (which are intended for ordinary use on board ship) being limited to "dial up" and "pendant up." Of these, 43 have been purchased for the Navy, 35 being classed as A, and 8 as B. The performance of the watches in both classes, however, compares somewhat unfavourably with last year's, but the conditions were more severe owing to the low temperature in January. Many of the watches in Class A were not satisfactorily adjusted for temperature compensation, and were returned to the makers for adjustment before final purchase, necessitating a further trial of nine weeks (1893 August 26 to October 28) on their return to the Observatory.

On 1892 July 20, August 30, and 1893 February 10, the Greenwich time-ball was not raised on account of the violence of the wind ; on 1892 December 25, and 1893 March 23, the ball failed to drop correctly at 13^h and was raised again and dropped at 14^h ; and on 1892 May 31, the ball was accidentally dropped $1^{min.}$ before 13^h. On all other days it was dropped correctly. On 1892 June 26, July 10 (Sunday), and 1893 March 23, the Greenwich signal at 13^h did not reach the General Post Office through failure in the electric connexions. The signal was considerably in error on the following dates through accidental circumstances :—1892 September 21, $0^s{\cdot}7$ late ; 1892 October 2, $1^s{\cdot}3$ late ; 1892 December 12, $1^s{\cdot}0$ late ; and 1892 December 18, $2^s{\cdot}3$ early.

The automatic drop of the Deal time-ball failed on 9 days owing to interruption of the telegraph connexions, and on three days when no signal left Greenwich ; on one day (February 10) the ball was not raised owing to high wind. Some difficulty having been experienced with the automatic return signal, the Post Office Authorities arranged to revert to the hand signal, which has been in use from September 6. The automatic return signal was reintroduced on May 9, after I had inspected the arrangements at Deal.

Signals from the Devonport clock have been received regularly since the date of the last Report, except on 55 days when the signal totally failed, or was interrupted by telegraph signals. The apparent error of the clock signal (after daily correction of the clock by the help of a time-signal from Greenwich) was under $0^s{\cdot}2$ on 71 per cent. of the 304 days of observation, under $0^s{\cdot}5$ on 90 per cent., and exceeded 1^s on one occasion only.

A similar clock corrected daily by help of a time-signal from Greenwich, automatically starting an auxiliary seconds' pendulum, has been established at Portsmouth for dropping the time-ball, and return signals from it have been received here regularly at $13^h\ 0^m\ 20^s$ since November 18 last, except on 28 days when the signal totally failed or was interrupted by telegraph signals. Information is sent to the Commander-in-Chief at Portsmouth whenever this signal is sensibly in error. The error was under $0^s.2$ on 61 per cent. of the 140 days of observation; under $0^s.5$ on 96 per cent., and between $0^s.5$ and $1^s.0$ on 4 per cent., never exceeding $1^s.0$.

The automatic signals from the Westminster clock have been received regularly throughout the year ending 1893 May 10, except on 25 days when the signal failed. The error of the clock was insensible on 42 per cent. of the days of observation; it amounted to 1^s on 29 per cent., to 2^s on 21 per cent., to 3^s on 7 per cent., and to 4^s on 1 per cent.

During the past year a Sidereal Clock and a Mean Time Clock made by Mr. Kullberg, and intended for use with the Singapore time-ball, and a clock by the same maker intended for the Natal Observatory, have been tested at this Observatory. The transit instrument made for Singapore by Messrs Troughton and Simms was also examined.

Longitude Operations: Immediately after Visitation Day last year, operations were commenced for the re-determination of the longitude of Paris. Four observers, two French and two English, took part in the work, as in 1888; three of them were the same as before (Colonel Bassot, Commandant Defforges, and Mr. Turner), but Mr. Hollis replaced Mr. Lewis, whose special attention was required in the Time department. The plan of operations adopted in 1888 was only modified in the following particulars: two clocks were used instead of one, at each end of the line, and all the clocks were placed in rooms kept at nearly constant temperature. The Sidereal Standard was used by the English observer at Greenwich throughout. The English observers used the small chronographs procured for the Montreal longitude, with one pen only, thus avoiding the troublesome correction for parallax of pens.

In the first part of the operations, Commandant Defforges and Mr. Turner were at Greenwich, Colonel Bassot and Mr. Hollis at Paris. Signals were exchanged on 7 nights, on 4 of which clock error was determined at Greenwich and on 6 at Paris.

In the second and third parts the observers were interchanged; signals were exchanged on 11 nights, observations of stars for clock error being obtained on 8 of these, both at Greenwich and at Paris.

In the fourth part, the observers returned to their original stations. Signals were exchanged on 11 nights, clock errors being determined on 5 nights at Greenwich and on 9 nights at Paris.

The preliminary discussion of the English results for the difference of longitude between the Greenwich transit circle and Cassini's meridian is now complete, the mean of 25 practically independent determinations, after correcting for personal equation, being $9^m\ 20^s{\cdot}82$. The value found in 1888 by the English observers was $9^m\ 20^s{\cdot}85$.

In July Prof. McLeod came to Greenwich to discuss the first stage of the operations for the longitudes Montreal—Canso—Waterville—Greenwich. It appeared that the cable signals were for practical purposes as accurate as those over the land lines; and thus the chief difficulties of the work are, as in other cases, simply those of absolute time determination.

The second stage of the operations was commenced on August 16, and completed on September 16. It consisted of two parts, in the first of which the observers at Montreal, Canso, Waterville, and Greenwich were Mr. Turner, Mr. Klotz, Mr. Hollis, and Prof. McLeod respectively; signals being exchanged on every night (except in one or two cases of accidental interruption) from August 16 to August 30, and clock errors being obtained at the several stations on 8, 6, 6, and 11 nights respectively.

The observers were then interchanged to the following order:—Mr. Klotz, Mr. Turner, Prof. McLeod, Mr Hollis. Signals were exchanged each night from September 3 to September 16, and clock errors were obtained on 6, 12, 6, and 10 nights respectively.

The total number of nights on which there was complete connexion by signal between Greenwich and Montreal was 20.

The sidereal observations made by the Greenwich observers, and the signals, are completely reduced; but we have not yet received from Montreal the results of the time determinations by Prof. McLeod and Mr. Klotz.

In 1892 July, Commandant Defforges mounted his "relative" pendulum apparatus in the Record Room and made determinations of the force of gravity. He subsequently took the same apparatus to Leith Fort, Edinburgh, where Sabine had made observations; and during his work there time signals were sent him from this Observatory.

Early in April last, Col. Von Sterneck, of Vienna, mounted his pendulum apparatus on the same spot, and made a complete series of observations. He repeated the observations at the Kew Observatory.

VIII. Personal Establishment :—

The staff at the present time is thus constituted, the names being arranged in alphabetical order in each class :—

Chief Assistant—Mr. Turner.

First-class Assistants—Mr. Criswick, Mr. Ellis (Superintendent of the Magnetic and Meteorological Branch), Mr. Lewis, Mr. Maunder, Mr. Thackeray.

Second-class Assistants—Mr. Bryant, Mr. Crommelin, Mr. Hollis, Mr. Hudson, Mr. Nash.

Clerk—Vacant.

Mr. Turner supervises the work of the Observatory generally, and has full power to act in all matters in my absence. Mr. Criswick has charge of the photographic mapping of the heavens, and has taken charge temporarily of the cash accounts, pending definitive arrangements still to be made by the Admiralty. Mr. Maunder is charged with spectroscopic and solar-photographic observations and reductions. Mr. Lewis has the charge of time-signals and chronometers, and Mr. Thackeray superintends the miscellaneous astronomical computations. Mr. Hollis has the care of the library and manuscripts and the longitude reductions. Mr. Crommelin is responsible for the altazimuth and equatorial computations, Mr. Bryant for the transit reductions and time determinations, and Mr. Hudson for the meridian-zenith-distance reductions.

In the magnetic and meteorological branch Mr. Ellis superintends the whole of the work, assisted by Mr. Nash, who is specially charged with the meteorological reductions and instrumental adjustments.

There are at the present time twelve computers attached to the astronomical branch, one to the astrographic, five to the spectroscopic and photographic, and five to the magnetic and meteorological.

Mr. C. R. Sayers, who has been temporarily appointed by the Admiralty to undertake the duties previously performed by the 2nd Division Clerk, dismissed last year, has assisted me very ably and zealously since November last, pending the definite appointment of a successor.

A gate-porter, a watchman and a gardener, as well as a foreman of works, with two carpenters and one or two labourers, a skilled mechanic with an assistant, and a charwoman, are also attached to the Observatory.

The whole number of persons regularly employed at the Observatory is 47.

At the close of the present year the Observatory will lose the valuable services of Mr. Ellis, who has been here since 1841 (except for the brief period 1852 March to 1853 May, when he had charge of the Durham Observatory), and attained the age for compulsory retirement last February. Under present circumstances his retirement at that time would have been very prejudicial to the interests of the Observatory, and I am happy to say that in consideration of this, the Government has authorized the retention of Mr. Ellis' services to the end of 1893, to enable him to complete the special discussions of magnetic and meteorological results for past years, now being made under his supervision.

Mr. T. C. Hudson has resigned his appointment here, and will leave the Observatory at the end of June.

IX. General Remarks :—

The work of the Observatory during the past year has been carried on under circumstances of exceptional difficulty. In the first place the operations for the determination of the longitudes of Paris and Montreal involved the absence of the Chief Assistant and of another Assistant for protracted periods during last summer and autumn. Secondly, for six months the Observatory was left entirely without the services of a Clerk, and the appointment of a permanent officer to undertake cash and other clerical duties has not yet been made. These duties, which have greatly increased of late years, have thus been thrown on the Astronomer Royal and his staff, and the scientific work of the Observatory has seriously suffered in consequence. It has been necessary for me to make strong representations to the Admiralty on this subject, and I have hopes that a satisfactory definitive arrangement will not be much longer deferred. Further, the delay in providing necessary accommodation for the Staff has greatly hampered the work, and much time and thought have been required to improvise temporary office rooms contingent on the season of the year. Under these circumstances it is due to the zeal and energy of the Assistants and Computers that the output of work for the past year is so good, and that, except in regard to the printing, arrears have not been suffered to accumulate. But it has not been possible for me, while harassed with constant interruptions on matters of administrative detail, to carry out the scientific investigations connected with the Observatory, which properly fall within the province of the Astronomer Royal. Thus, during the past year, I have had repeatedly to lay aside the important subject of the measurement of the plates of the Astrographic Chart in order to deal with details of cash accounts and other similar matters which properly pertain to the functions of a clerk. In this connexion I may mention that some years ago I proposed a

photographic corrector, which, at a comparatively small cost, would render an ordinary astronomical refracting telescope available for photography, but, though a trial instrument has been made, and though I have partly worked out the details of a more complete form, I have never been able to command sufficient leisure, tolerably free from interruptions, to enable me to complete the rather troublesome optical calculations. Such a corrector could be usefully applied to the new 28-inch telescope as well as to other large instruments, but under present conditions I fear that there is little prospect of my being in a position to work out the idea.

The growth of the Observatory buildings, involving the introduction of large masses of iron, raises the question of the possible disturbing effect on the magnets in their present position. Though the masses of iron would be at such a distance that they could not sensibly affect the registers of magnetic changes, which are purely differential, it is possible that the aggregate effect on the absolute determinations of the magnetic elements might become appreciable. Under these circumstances it is desirable that an auxiliary magnetic station for determination of absolute values of the magnetic elements should be established in the immediate neighbourhood of the Observatory, at such a distance that there would be no suspicion of disturbance from the iron in the buildings.

W. H. M. CHRISTIE.

Royal Observatory, Greenwich.
1893 May 11.