REPORT

OF

THE ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1894 *June* 2.

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The Report here presented refers to the year from 1893 May 11 to 1894 May 10, and exhibits the state of the Observatory on the last-named day.

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

The South wing of the Physical Observatory, intended to relieve the pressure in the Chronometer room, was at length completed after many delays on April 20, and is now being prepared for occupation. The building of the North wing and completion of the central octagon by the addition of a storey and the erection of the 30-feet Lassell Dome over it, which was authorized more than a year ago, has not yet been commenced, but it is understood that tenders for the work have been invited, and it is hoped that there will not be much further delay in providing this much needed extension. The details of this building have required careful consideration, and the plans have been skilfully worked out by Mr. Crisp under the supervision of the Director of Works for the Navy to meet the special requirements.

The Photoheliograph hut and instrument were temporarily mounted on the concrete terrace roof of the South wing for daily observation of the Sun on April 26, the rotatory roof of the hut having been altered to make it portable.

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The generating plant for the electric light installation, supplied by Messrs. Johnson and Phillips, was set up and brought into successful action at the end of March, as soon as the progress of work on the new building would allow. The gas engine and dynamo are placed in the ground floor of the new South wing of the Physical Observatory, the accumulators in the adjoining shed, and a Brooke's electric main is laid from the South wing to the Transit Circle lobby, from which distributing leads can readily be carried to the principal instruments and office rooms. This has, however, not yet been arranged, and the use of the electric light plant is at present confined to charging portable accumulators for use with some of the instruments.

New gas and water mains have been laid to the Physical Observatory, with a separate service to the gas engine.

The plans of the building for the new Universal Transit Circle or Altazimuth have been prepared under the supervision of the Director of Works, and it is hoped that the work will be commenced very shortly. Great pains have been taken by Mr. Crisp in designing this building to adapt it to the somewhat peculiar conditions with a due regard to architectural appearance, and the result appears to be in every way satisfactory.

A permanent timber stage with sliding platform has been put up on the South side of the Great Equatorial to give access to the 28-inch object-glass, and has been found very useful.

The Post Office authorities have courteously arranged to place a wall letter-box for the convenience of the Observatory in the boundary wall near the entrance.

The principal moveable instruments are thus distributed :—

At Greenwich—

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

Altazimuth D.

Equatorials (6-inch).—Cooke No. 2; Simms No. 1; Hodgson; and the tube and object glass of the Corbett.

Photoheliographs.—No. 3, complete, mounted on the terrace roof of South wing of Physical Observatory for daily photography; No. 4, mounted temporarily in the Lower Museum; the tube with object glass of No. 2, and the driving clock (in use 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.

Altazimuths.—A, at the Science Schools, South Kensington; B, at the Cape Observatory; E, at the Royal Naval College, Greenwich.

Equatorials (6-inch).—Lee at Hong Kong Observatory; Simms No. 2, lent to the Science and Art Department; 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 Expedition of April 1893.

Photoheliographs.—No. 1, complete, at the Cape Observatory; No. 5, complete, and the mounting of No. 2 (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; Dent No. 2010, at Devonport; and Arnold 2, at the Oxford University Observatory.

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

A prismatic compass, a spectroscope slit, a $1\frac{1}{2}$-inch collimator object glass, and a $2\frac{3}{4}$-inch prism of 62°, lent for the Eclipse Expedition of 1893, have not yet been returned.

A number of the moveable instruments are now being arranged in the glass cases in the Museum, or set up in the South wing as a preliminary to the completion of the inventory, but the work cannot be satisfactorily finished till the North wing is completed, as the building operations greatly hamper the arrangements.

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

II.—Astronomical Observations :—

Transit-Circle.—The Sun, Moon, planets, and fundamental stars have been regularly observed on the meridian, and owing in great measure to the fine weather which prevailed through a great part of the year, and also to the circumstance that a computer was occasionally employed to assist the observer by reading the microscopes, an exceptionally large number of observations have been obtained, as will be seen from the following statement of the number of observations from 1893 May 11, to 1894 May 10 :—

Transits, the separate limbs being counted as one observation	11,352
Determinations of collimation error	294
Determinations of level error	614
Circle observations	10,962
Determinations of nadir point (included in the number of circle observations)	554
Reflexion observations of stars (similarly included) . .	696

The annual catalogue of stars observed in 1893 contains 2758 stars.

Thus the average number of transits observed was no less than 31 each day, or if we exclude Sundays 36. As an instance of the number of observations which have been made under very favourable conditions, it may be mentioned that on three consecutive days in February no fewer than 458 transits and 460 zenith distances were observed.

As regards the computations :—

The transits are completely reduced (so as to exhibit Mean R.A. 1894·0) to April 17, and Observed R.A. corrected for instrumental errors and clock errors to May 4. The copy for press for 1893 is in the printer's hands.

The investigation of personal equations is completed for 1893.

The circle observations are completely reduced to April 17, and the apparent N.P.D. is formed to May 6. The copy for press for 1893 is in the printer's hands.

It will be seen from the above statement that, notwithstanding the exceptionally large number of meridian observations, the reductions are kept well up to date.

The apparent correction for discordance between the nadir observations and stars observed by reflexion for 1893 is $-0''{\cdot}34$.

From the observations made last year it was found that though the microscope screws showed signs of wear, the mean of the six microscope readings was not sensibly in error over the available range, owing to the reversal of three of the screws.

A large number of observations of flexure of the transit-circle have been made by means of the collimators under Mr. Thackeray's direction. The mean flexure, determined from 184 observations, was very small, being only $+0''{\cdot}15$. The observations grouped according to temperature gave the following results, the suffixes denoting the number of observations in each group—

44°	48°	52°	58°	62°	67°	75°
$-''{\cdot}02_{6}$	$+''{\cdot}09_{12}$	$+''{\cdot}04_{16}$	$+''{\cdot}14_{25}$	$+''{\cdot}19_{43}$	$+''{\cdot}20_{22}$	$+''{\cdot}35_{32}$

The quantities measured are so small that the increase of flexure with the temperature, which these numbers indicate, cannot be certainly affirmed.

The correction for R—D, the error of the assumed colatitude, and the position of the ecliptic have been investigated for 1893 ; and the whole of the planetary reductions for 1893 are complete.

The correction for R—D, $+0''{\cdot}057 + 0''{\cdot}703$ sin Z.D., agrees well with the results for recent years. A discussion made by Mr. Turner having suggested that the R—D correction may be affected by the circumstance that the reflexion observation is in practice always made before the direct, 130 observations of stars have been made in which the direct observation was taken first, and the results are now being discussed by Mr. Turner.

The colatitude of the transit-circle as found by the observations of 1893 is $38°\ 31'\ 22''{\cdot}07$, differing by $+\ 0''{\cdot}17$ from the adopted value.

The correction to the tabular obliquity of the ecliptic from solar observations in 1893 is + 0″·54. The discordance between the results from the summer and winter solstices is − 0″·10, indicating that the mean of the observed distances from the pole to the ecliptic is too large by 0″·05. The apparent correction from the observations of the sun to the right ascensions of the clock stars is + 0ˢ·090. From a discussion of the values since the introduction of Leverrier's tables in 1864 Mr. Dyson and Mr. Thackeray conclude that the large corrections found in recent years are largely due to change of personality in observations of the Sun's R.A. resulting from the changes of staff at the Observatory. It is hoped that this question may be cleared up soon by observations of limbs with the personal equation instrument, which had been necessarily deferred owing to the pressure of longitude and other work. 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 December (+ 0°·6) and in January (+ 1°·3) and greatest in June (+ 3°·8), April (+ 3°·5) and March (+ 3°·4). The mean for the year is + 2°·6.

The mean error of the Moon's tabular place (computed from Hansen's lunar tables with Newcomb's corrections) is + 0ˢ·034 in R.A. and + 0″·64 in longitude, as deduced from 143 observations in 1893. The mean values of these quantities for the ten years 1883–1892 are + 0ˢ·044 and + 0″·61.

The mean error of the Moon in N.P.D. for 1892 is − 0″·52.

It was noticed that the star places in the Five-Year Catalogue when compared with the positions of the Ten-Year Catalogue of 1880 reduced to 1890 shewed in some cases rather large discordances. Mr. Thackeray has accordingly examined some 20 stars which have been observed continuously since 1836, in order to detect any changes in their proper motions, of which there appears to be evidence in the case of some of the stars. The results obtained so far confirm the general accuracy of Prof. Auwers' proper motions.

Altazimuth.—A new azimuth level and a new zenith distance level were mounted on 1893 July 17 to replace two which had been broken shortly before. On 1893 June 3 the wires were broken and the eye-piece and its slides bent and damaged on the occasion of the Annual Visitation of the Observatory. New wires were mounted by Messrs. Troughton and Simms on June 13.

The total number of observations made in the year ending 1893 May 10 is as follows :—

Azimuths of the Moon and Stars	319
Azimuths of Mark I.	132
Azimuths of Mark II.	141
Zenith distances of the Moon	148
Zenith distances of Mark I.	126
Zenith distances of Mark II.	130

The observations have been completely reduced as far as 1894 March 14.

The following table shows 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	3
14^h to 15^h ,,	0	10
15^h to 16^h ,,	4	12
16^h to 17^h ,,	6	7
17^h to 18^h ,,	5	9
18^h to 21^h ,,	21	2
21^h to 0^h ,,	30	—
0^h to 3^h ,,	26	—
3^h to 6^h ,,	17	1
6^h to 7^h ,,	5	7
7^h to 8^h ,,	4	8
8^h to 9^h ,,	2	9
9^h to 10^h ,,	0	4
10^h to 11^h ,,	0	4

The whole number of places of the Moon observed with the transit-circle is 120 or 9·9 per lunation, and with the altazimuth 76 or 5·8 per lunation.

The Moon's diameter has been measured with the transit-circle 3 times in R.A. and 13 times in N.P.D.

The new universal transit-circle or altazimuth is being constructed by Messrs. Troughton and Simms, and satisfactory progress has been made towards completion. All the heavy portions of the instrument, including the rotating and reversing gear.

are made, and have been put together, the object glasses for the instrument and collimators are practically finished, as well as the eye end with its micrometers, and the circles, microscopes, &c., are in hand.

Clocks and Chronographs.—The Standard Sidereal clock has been going very well during the past year. The alteration in the barometric correction mentioned in the last Report seems to have lessened the amount of error. The discussion of the rate has been deferred until a longer period of observation is secured.

The tappers of the chronograph which had been worn out were renewed in January. The clock Hardy was repaired on January 12, and Dent 2017, which is in the Astrographic dome and was found to be rusty, on March 3.

The adaptation of the mean solar clock Dent 2012, with zinc and steel pendulum, to send out the hourly signals and work the sympathetic dials by reverse currents at the alternate seconds, was completed by Mr. Kullberg on 1893 May 21, and from that date all signals were sent by this clock instead of by the electrical mean solar clock Shepherd. The clock worked satisfactorily till 1894 Jan. 20, when the contacts began to fail, and as it could not be relied on to drive the Observatory sympathetic dials satisfactorily, the clock Shepherd was generally used from that date till May 4, when a new set of contacts was applied to Dent 2012, and since then it has worked the sympathetic dials and sent out the hourly signals satisfactorily. Advantage was taken of the break to arrange for substituting the clock Dent 2012 for Shepherd, or *vice versâ*, without loss of time.

Reflex Zenith Tube.—Since the date of the last Report, 25 double observations of γ Draconis have been made.

Equatorials.—A valuable gift has been made to the Observatory by Sir Henry Thompson, who has generously offered a sum of £5000 to provide a large photographic telescope with accessories, which would serve as the complement of the 28-inch visual telescope just completed. This munificent offer was readily accepted by the Admiralty, and after careful consideration and discussion, a photographic telescope of 26 inches aperture and 22 feet 6 inch focal length, equatorially mounted, was ordered of Sir H. Grubb on May 5, the instrument to be completed in 18 months. This telescope will be of exactly double the dimensions (aperture and focal length) of the Astrographic Equatorial which has proved so successful, and it will be mounted on

a very firm stand which will allow of complete circumpolar motion without the necessity for reversal on the meridian, which has been felt as a drawback in the Astrographic Equatorial. It will be erected on the central tower of the new Physical Observatory, under the 30 feet dome which is shortly to be placed there, and will carry the $12\frac{3}{4}$-inch Merz refractor as a guiding telescope and the Thompson 9-inch photoheliograph. It will thus be mounted under very favourable conditions for work, and will be in every respect a most effective instrument.

The new 28-inch refractor has been brought into working order after much time spent in the erection of the instrument, in the adjustment of the object glass, and in the provision of various fittings at the eye end, which were not supplied till the end of February. As mentioned in the last Report, the erection of the telescope on the existing mounting was commenced on 1893 April 21 and was completed by June 7, but the object glass was not mounted till the end of July, when Sir Howard Grubb came over to place the lenses in their cells and adjust them. The amount of separation of the lenses which gave the best correction for colour was carefully determined by trials on stars, and the slight residual spherical aberration was corrected by Sir Howard Grubb by retouching the central part of the crown lens. It was found advisable to shorten the tube 12 inches to adapt it to the resulting focal length, and this was accordingly done in the latter part of September, when Sir Howard Grubb completed the adjustment of the object glass. This was finished by October 1, when, under good atmospheric conditions, the definition was found to be very fine. Since then the object glass has been tested on various objects with very satisfactory results. A sketch of Jupiter and some measures of double stars have been made, and the colour correction of the object glass has been determined on stars by readings for focus at different parts of the spectrum. The weather, however, was not favourable for work with a large aperture during the winter months.

After new slow motion screws of larger diameter and finer pitch had been applied, arrangements were made on January 23 to try the object glass in the photographic position, with the crown lens reversed and the lenses separated on the plan proposed by Sir G. G. Stokes. The determination of the best distance between the lenses and the exact adjustment of the crown lens for tilt and centering relatively to the flint has necessarily taken a long time, as small modifications were required in the cells and special contrivances had to be devised for the delicate adjustment of the heavy crown cell and lens. A large number of photographs have been taken at

different distances inside and outside of the focus corresponding to different positions of the crown lens, and affording interesting information which will be useful in connection with the Thompson 26-inch photographic telescope.

The mounting of the half prism spectroscope on the 28-inch telescope has been delayed till the present time, as it was found necessary to mount the Dallmeyer photoheliograph on this telescope in the position which the spectroscope would occupy, in order to carry on the daily photographic record of the Sun during the building operations in the South ground. It has been arranged to mount the spectroscope parallel to the tube of the telescope, the rays being thrown into the collimator by two reflections, and the necessary castings are now being made. When the mounting is completed this powerful instrument will be available for the work for which it was specially intended, viz., the spectroscopic determination of motions of approach or recession of stars.

The measures of double stars made by Mr. Lewis with the $12\frac{3}{4}$-inch Merz refractor mounted on the Lassell Equatorial were continued for a short time during the past year. The whole series consists of 864 measures of distance and 726 of position angle of 120 double stars, viz. :—15 stars of distance less than $0''{\cdot}5$; 21 between $0''{\cdot}5$ and $1''{\cdot}0$; 43 between $1''{\cdot}0$ and $2''{\cdot}0$; 14 between $2''{\cdot}0$ and $3''{\cdot}0$; and 27 stars over $3''{\cdot}0$. The total number of nights on which measures were made was 52.

Since the date of the last Report, 19 disappearances and 7 reappearances of stars occulted by the Moon have been observed, as well as 70 phenomena of Jupiter's satellites. The occultation of Spica on March 22 could not be observed owing to clouds. All the observations are completely reduced to 1894 March 25.

Comet *b* 1893 has been observed with the Sheepshanks equatorial on 11 nights, Comet *c* 1893 on 13 nights, Comet *a* 1894 on 6 nights, Comet *b* 1894 on 4 nights, and the Crab Nebula (for determination of personality in cometary observations) on 1 night.

With the Astrographic equatorial 923 plates, with a total of 2143 exposures, have been taken on 183 nights in the year ending May 10. Of these 181 have been rejected, viz. :—85 from photographic defects, 6 from mechanical injury, 32 from mistakes in setting, 7 from the plate being wrongly placed in the carrier, 6 from failure

in clock driving, and 45 from interference by cloud. The following statement shows the progress made with the photographic mapping of the heavens in the year 1893 May 11 to 1894 May 10 :—

	No. of Photos taken.	Successful Plates.
Astrographic Chart (exposure 40^m)	280	220
Plates for Catalogue (exposures 6^m, 3^m and 20^s) .	508	387
Number of Fields photographed for the Chart . .		200
" " " " Catalogue .		367
Total Number of Fields photographed since the commencement of the work for the Chart . . .		333
Total Number of Fields photographed since the commencement of work for the Catalogue . . .		610

It has been a practice to take a trail on each night on a catalogue plate as a check on the orientation, and during the year 99 plates with trails have thus been secured.

The following miscellaneous photographs (included in the total number of 923 given above) have also been taken :—

	No. of Photos.
Nova Aurigæ	8
For zero of scales	10
North Pole (for adjustments of Equatorial) . .	20
Pleiades with various exposures	9
Comet Quénisset	5
Comet Denning	1
Praesepe	2

Two plates taken of the Pole on July 21 showed that the Polar Axis of the instrument was too far West by $37\frac{1}{2}''$ and too low by $20''$. These errors were corrected by means of the adjusting screws in azimuth and altitude, another plate, taken on July 25, showing that the adjustment of the polar axis was nearly perfect.

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

At the request of the Superintendent of the Nautical Almanac Office the field about D. M. + 27°.275 was photographed on two occasions for identification of stars. Two plates have also been taken of the great Nebula in Andromeda.

Some experimental plates of Jupiter, Saturn, Venus, double stars and lunar craters, have also been taken with the image enlarged about 14 times by a secondary magnifier.

Catalogue and Chart plates of the fields around D.M. + 9°.2785 and β Leonis have been taken for comparison with the same field taken with the 28-inch refractor.

The *réseau* used since 1892 May 23 was removed from the slide on 1893 October 4, and another, also supplied by M. Gautier, coated with collodion, substituted for it. This is in good condition but shows one or two pin-holes. A *réseau* is occasionally developed alone on a plate for the detection of spurious images on the Chart plates.

Each plate has undergone a preliminary examination to see whether it was generally satisfactory, and whether the adopted limits of magnitude were approximately reached, as inferred from the $20^{sec.}$ exposure, which should give 9th magnitude stars of Argelander's scale.

Four plates of the same region have been measured several times by two observers for determination of probable error and personality in such measures, and of error of setting.

Four plates, arranged so that each overlaps two others, have been partially measured, both by using the reference to the millimetre glass scale and to the *réseau* lines, for testing the method of connecting rectilinear measures on one plate with those on another. The reductions are not yet quite complete, but in both methods the accidental errors were found somewhat larger than at first hoped. One source of error was noticed which has not been elsewhere remarked, viz., that due to a slight curvature in some of the so called plate-glass plates. This brings some portions of the plate nearer the microscope than others, and affects the angle subtended by the *réseau* lines or " runs." It does not influence measures made by reference to the millimetre glass scale, where each point is brought vertically under the centre of the microscope.

To test the optical photographic distortion up to considerable distances from the centre, seven plates with the Pleiades photographed in the four corners have been measured. It appears that the distortion is practically insensible up to 60′ from the

centre, and is still small up to 80′, but is not quite the same in the four corners of the plate. On examination, the character of the images in the four corners is also found to vary slightly, the coma being slightly inwards in one corner and outwards in another. The perpendicularity of the plate and object glass to the optic axis were examined and found to be satisfactory.

For the more rapid measurement of the stellar photographs, Prof. Turner has suggested the use of a glass scale in connection with a microscope, by means of which the position of the star's image relatively to the *réseau* lines might be estimated with sufficient accuracy for practical purposes, and a glass diaphragm with two scales at right angles, divided to $\frac{1}{20}$ of a millimetre (representing 3″ in the sky) has accordingly been made by Mr. Simms for use with the microscope of the Astrographic micrometer. By means of the perpendicular slides of the micrometer, the star's image is placed accurately at the intersection of the two scales, and the position of the *réseau* lines relatively to it is read off on the two cross-scales by estimation to $\frac{1}{200}$ of a millimetre (0·001 of a *réseau* interval), representing 0″·3 in the heavens. The diameter of the star's disk in two perpendicular directions is also easily read off by estimation to $\frac{1}{200}$ of a millimetre, thus giving a measure of the photographic magnitude. This method seems from the trials already made to be a very promising one for dealing with the vast number of stars to be measured on the plates, and it is believed that the accuracy thus obtained will prove to be as great as is attainable under the circumstances.

The Catalogue of guiding stars for the San Fernando Zone − 3° to − 5°, 0^h to 12^h, and 18^h to 24^h, has been made, and the settings computed as far as existing Catalogues would allow, pending the reception of the re-observed places from Strassburg.

The portion − 3° to − 5°, 12^h to 18^h, was sent to San Fernando in May, 1893.

III.—Spectroscopic and Photographic Observations :—

No spectroscopic observations have been made during the past year, the mounting of the spectroscope on the new 28-inch refractor having been delayed through causes already mentioned.

The telescope and camera of the Dallmeyer photoheliograph had again to be removed in September from the wooden dome, where the new buildings cut off the view of the Sun, but the first floor of the new museum, being no longer available for

it, it was mounted on the 28-inch refractor in the 36 foot dome, the transfer being completed by October 12. After the completion of the South wing of the new Physical Observatory, it was established on the terrace roof of that building on April 24, in a convenient position with a good horizon.

In the year ending 1894 May 10, photographs of the Sun have been taken with this instrument on 177 days, and of these 294 have been selected for preservation, besides 10 photographs with double images of the Sun for determination of zero 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 throughout the year, and photographs of the Sun have been obtained with it on 184 days, of which 289 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 230 days during the year.

For the year 1893 Greenwich photographs have been selected for measurement on 216 days, and photographs from India and Mauritius (filling up the gaps in the series) on 143 days, making a total of 359 days out of 365 on which photographs are available.

The solar activity was fully maintained throughout the whole of 1893, the mean daily spotted area for the year being considerably in excess of that for 1892. The great spot of 1892 February still remains the largest hitherto seen in the present cycle, but in 1893 August a very fine group attained dimensions but little inferior, and the groups of 1893 November and 1894 February were very large. The characteristic of the year has, however, been rather the great number of groups visible at the same time than the extent of any one of them. Thus in August and December 1893 as many as 16 or 18 distinct groups of spots have been seen on the disk at the same time. The work of measurement and reduction has been therefore much heavier in 1893 than even in 1892, no fewer than 27 books of the form used in the main portion of the reduction being required in 1893, as against 22 in 1892, and 13 in 1891. But so far as the present year has yet advanced there has been a distinct falling off both in the numbers of the groups of spots, and in the mean daily spotted area.

The measures are in a forward state, the Greenwich photographs having been measured up to April 28, and the Indian and Mauritius photographs so far as they have been received. The conversion of the measures into heliographic longitude

and latitude is also well advanced, having been carried forward for the Greenwich photographs to 1894 March 5, and for the Indian and Mauritius photographs to 1894 January 17, the date of the last negative received.

IV.—Magnetic Observations :—

The variations of magnetic declination, horizontal force and vertical force, and of earth currents have been registered photographically, and accompanying eye observations of absolute declination, horizontal force and dip have been made as in former years. The period has been one of much less magnetic activity than last year, but there was a large increase occurring in 1894 February, at the time of the great sun spot. Copies of the magnetic and earth current registers during the disturbances of Feb. 20–March 1 and March 30–April 1, have been supplied to Mr. Preece for discussion in connection with disturbances on the telegraph lines.

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 1893. The time-scales for the magnetic registers are complete to the end of 1893, and the base line values, deduced from eye observations, are entered on the photographic sheets. The hourly ordinates of the photographic curves for the declination, horizontal force and vertical force are completely read out and reduced for 1893 ; the time scales for earth currents are complete to the end of 1893. The dip observations are completely reduced to the present time, and the deflexion observations for absolute measure of horizontal force to the end of 1893. The temperature of the magnetic basement at every hour has been read from the sheets of the Richard thermograph to the end of 1893, and the daily and hourly means have been taken.

The following are the principal results for the magnetic elements for 1893 :—

Mean declination . . .	17° 11′·4 West.
Mean horizontal force . .	3·9661 (in British units). 1·8287 (in Metric units).
Mean dip	67° 16′ 32″ (by 9-inch needles). 67° 17′ 53″ (by 6-inch needles). 67° 18′ 52″ (by 3-inch needles).

In the year 1893 there were 5 days of great magnetic disturbance, and also 20 other days of lesser disturbance. Tracings of the photographic curves for all of these days are being made and will be published in the annual volume according to the arrangements 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, except during the months of March, April and May, 1893, when it was away at Charlton. The mean of the monthly values for 1893 (for 9 months) is 1·8325, which is 0·0035 greater than the mean obtained from the observations made with the old instrument for the same period. Last year there was a similar excess of ·0023, and in 1891 June—December, an excess of ·0030.

It was mentioned in the last report that experiments were being made at Messrs. Johnson and Phillips' factory, Charlton, to determine what effect the new dynamo unshielded and with a triple iron shield would have on the magnetographs. These experiments were finished on 1893 May 31, and the unifilar magnetometer which was used in them, was brought back to the Observatory on 1893 June 2. The results, which indicated that the effect of the shielded dynamo on the magnets at the Royal Observatory would be insensible, are discussed in a paper published in the "Electrician" of 1893 August 25. The dynamo with its triple shield was mounted in the South wing of the new Physical Observatory in 1894 March, and has been running since March 29. No effect that can be detected has been produced by it on the Declination and Horizontal Force Magnets.

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 has been continuously maintained, except that on a few days in the winter the register of atmospheric electricity was interrupted by freezing of the water in the exit pipe.

It was mentioned in the last Report that a gearing had been applied to the clock of the Osler anemometer by which the table carrying the record could be made to move at twelve times its usual rate. This has been used on many days when there was a high wind, and the high and rapidly changing pressures, which occur with gusts of wind, have been recorded with great delicacy. It would, however, be

advantageous to have a still more open time-scale to exhibit the brief duration of violent gusts, and it is proposed to modify the gearing so as to give a movement at twenty-four times the usual rate.

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 and the electrometer to the end of the year 1893. The table of principal changes in the direction of the wind for 1893 is complete.

The mean temperature of the year 1893 was 51°·1, being 1°·6 above the average for the 50 years 1841–1890.

During the twelve months ending 1894 April 30, the highest air temperature in the shade exceeded 80° on 28 days. It was 91°·0 on June 19, 93°·0 on August 16, 94°·2 on August 17, and 95°·1 on August 18. In the 53 years since 1841, higher temperatures have been recorded only twice previously (on both occasions in July). The lowest was 12°·8 on January 5, the maximum on that day being only 19°·0 and the mean daily temperature 15°·9. The mean temperature on August 18 was 79·6, being the highest mean value recorded in August since 1841. The mean temperature of January 5 was lower than any previously recorded since 1841, with two exceptions. The mean monthly temperature was above the average in all months excepting September, November, and January, 1894. In May it was 4°·6, in August 3°·9, in March 2°·7, and in April 3°·8, above the average. In November it was 1°·5 below the average.

The mean daily motion of the air in 1893 was 270 miles, being 11 miles below the average of the previous 26 years. The greatest daily motion in the twelve months ending 1894 April 30, was 942 miles on February 11, and the least was 40 miles on July 15. The greatest pressure registered was 37 lbs. on the square foot on December 12, being the greatest which has been registered since the substitution of the flexible chain for the stiff copper connecting wire in 1882. The greatest pressure previously recorded was 31 lbs. in March 1888. A pressure of 35 lbs. was recorded on February 11.

During the year 1893 Osler's anemometer showed an excess of 29½ 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 1893 by the Campbell-Stokes sunshine instrument was 1454, the greatest number on record since the commencement of the registration in 1877. This is 171 hours above the average of the preceding 16 years, after allowance is made for the small difference of indication of the Campbell and Campbell-Stokes instruments. The aggregate number of hours during which the Sun was above the horizon was 4454, so that the mean proportion of sunshine for the year was 0·326, constant sunshine being represented by 1.

The rainfall for 1893 was 20·1 inches, being 4·4 inches below the average of the 50 years 1841–1890. From March 1 to September 30 (the period of the great drought) the rainfall amounted to only 7·77 inches, while the average for the 50 years 1841–1890 for those months is 14·22 inches.

The mean amount of cloud for the year on the scale 0–10 was 5·75. The average amount as determined by Mr. Ellis (Quarterly Journal, Royal Meteorological Society, Vol. XIV.) from 70 years' observations is 6·75.

Many applications for meteorological information have been answered during the year.

VI.—Printing and Distribution of Greenwich Publications :—

The printing has not gone on satisfactorily during the past year, the arrangements made for expediting its progress, referred to in last year's report, not having been carried out by the Printers, although they have been kept amply supplied with manuscript, and the proof sheets have been returned to them as expeditiously as possible. The printing has now fallen greatly into arrear, notwithstanding all our efforts, and the time has come when the question must be seriously considered.

The copies of the volume of Greenwich Observations for 1891 have not yet been received, though the complete volume was passed for press last November. A specimen bound copy was received at the end of January, but as there were important omissions it was necessary to have a corrected copy, which was received on March 2 and returned the same day. The copies of the Introduction, Spectroscopic and Photographic Results, and Magnetical and Meteorological Results for 1891, and of the Five Year Catalogue of 258 Fundamental Stars Epoch 1890 were received on April 7. Owing to a misapprehension on the part of the Printers the separate copies of the principal portion of the Astronomical Results 1891 were not struck off, and this section is now being set up in type again.

As regards the volume for 1892, Transits are printed to November 26, Meridian Zenith Distances to November 29, the printing of the Altazimuth section is complete, the Photographic Results are printed to June 7, and the Magnetical and Meteorological Results are completely printed with the exception of the Introduction.

The whole of the manuscript of the Transits, Meridian Zenith Distances, and Altazimuth Results for 1893, as well as the Chronometer and Deck-watch Rates 1893–94, has been sent to the Printers, and the manuscript of the Photographic Results for 1893 is practically complete.

As regards the Meteorological Reductions 1841–1890, the printing of the tables of Mean Daily Temperatures and Daily Maximum and Minimum Temperatures for the 50 years is completed with the exception of one sheet, of which proof has been received. The manuscript of the Magnetic Reductions 1865–1867 is awaiting revision before being sent to the Printers.

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

The number of chronometers and deck-watches now being tested at the Observatory is 268 (159 box chronometers, 18 pocket chronometers, and 91 deck-watches). In addition to these, there are on trial for purchase by the Indian Government 5 two-day chronometers for the Mathematical Instrument Office, Calcutta, and 1 eight-day for Colaba Observatory. In the year ending 1894 May 10, the average daily number of chronometers and deck-watches being regularly rated was 320 ; the total number received was 947, the total number issued was 882, and the number sent for repair was 471. During the year 26 box chronometers, 3 pocket chronometers, and one deck-watch have been tested for the Indian Government.

For the annual trial of chronometers (which lasted for 29 weeks) with a range of temperature from 35° to 104°, 43 chronometers were sent in, and of these, 23 have been purchased for the Navy. Considering the severity of the trial the performance of the chronometers generally has been good, the first and second being of special excellence.

The deck watches in the annual trial were separated into two classes, A and B, 76 being entered (by their makers) as A and 24 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, 50 have been purchased for the Navy, 33 being classed

as A, and 17 as B. The performance of the watches in both classes was very satisfactory and showed a marked improvement on last year, the first watch in class A having the smallest trial number (28·7) since the trials have been instituted.

The next competitive trial of chronometers commences on July 7, and the trial of deck-watches on October 27.

On five days the Greenwich time-ball was not raised on account of the violence of the wind. On one day (January 4) it fell before the proper time as the snow had prevented it from resting properly on the clips. On March 8 the ball was accidentally dropped 18 seconds before the time, and on March 25, 1^m before the time. On 1893 May 21 no time signal left the Observatory at 13^h owing to a failure in the electric connexions, and on September 14 the Greenwich signal at 13^h did not reach the General Post Office, in consequence of alterations which were being made there.

The automatic drop of the Deal time-ball failed on 9 days owing to interruption of the telegraph connexions, and on five days the ball was not raised owing to high wind. The automatic return signal has worked well since it was reintroduced on 1893 May 9, thanks to the attention which Capt. Wrottesley, R.E., of the Post Office Telegraphs, has given to the perfecting of the arrangements. Amongst other improvements a spring platform has been designed and fixed under his supervision by Quarter-Master Sergeant Fawssett, R.E., to take the shock of the ball-drop, which was found to shake the building injuriously, when the cylinder had been cleaned out to allow of a free ball-drop, the air-cushion being ineffective owing to large windage in the cylinder.

The return-signal from the Devonport clock failed on 85 days. Of the remaining 280 days 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 57 per cent., under $0^s{\cdot}5$ on 94 per cent., under $1^s{\cdot}0$ on 98 per cent., and exceeded $1^s{\cdot}0$ on four occasions.

The return-signal from the Portsmouth clock (similarly corrected by the help of a daily signal from Greenwich) failed on 73 days. The apparent error of the clock-signal was under $0^s{\cdot}2$ on 77 per cent. of the 292 days of observation, under $0^s{\cdot}5$ on 97 per cent., under $1^s{\cdot}0$ on 99 per cent., and exceeded $1^s{\cdot}0$ on two occasions.

With a view to diminishing the risk of failure in the return-signals, a separate wire with galvanometer has been provided connecting the Observatory with the General Post Office.

The automatic signals from the Westminster clock have been received regularly throughout the year ending 1894 May 10, except on 14 days when the signal failed. The error of the clock was under $0^s.5$ on 24 per cent. of the days of observation, under $1^s.0$ on 41 per cent., under $2^s.0$ on 79 per cent., under $3^s.0$ on 94 per cent., under $4^s.0$ on 98 per cent., and exceeded $4^s.0$ on 5 days.

Longitude Operations: The provisional result of the longitude Paris—Greenwich as determined by the English observers in 1892 June and July, gave $9^m\ 20^s.84$ as the difference between Cassini's meridian of Paris and that of the transit-circle at Greenwich, thus confirming the result $9^m\ 20^s.85$ found in 1888. The provisional result of the determinations by the French observers also confirms exactly their previous result, $9^m\ 21^s.06$.

On 1893 June 21, Commandant Defforges came to Greenwich to discuss the cause of the discrepancy, and it was suggested that it might be due to an abnormal difference of level between either of the two adjacent observing stations, or to abnormal lateral refractions different at two adjacent stations. Experiments were therefore made in August by means of a floating collimator to measure the inclination of the verticals at the two contiguous longitude stations in the Front Court, with the result that no abnormal deviation could be detected.

Transit observations have also been made on the two piers to determine the difference of longitude between them with the same instruments as were used in the Paris—Greenwich longitude determinations, but though the results obtained up to the present time seem on the whole unfavourable to the existence of an anomaly of this kind, more observations are wanted before this point can be finally decided.

The reduction of the Greenwich—Waterville—Canso—Montreal longitude is completed with the exception of the results for Waterville—Canso, in regard to which there is a discordance of $2\frac{1}{4}$ seconds between the first and fourth stages, probably due to some misunderstanding of the information supplied by Prof. McLeod. The results have been sent to Prof. McLeod, but at present no sufficient explanation has been afforded. This point, which has been laid aside lately owing to pressure of other matters, is now under consideration. The results for Greenwich—Montreal and Greenwich—Waterville appear to be quite satisfactory.

Mr. Plummer, Director of the Bidston Observatory, Liverpool, having arranged for a determination of the longitude of his Observatory, signals were exchanged on eight nights in August last, Mr. Plummer making time determinations at Liverpool for

comparison with the transit-circle observations at Greenwich. He came to Greenwich from January 1 to 9 for determination of personal equation, but cloudy weather prevented observations. He again visited Greenwich from April 20 to May 2, and secured observations on six nights with the small transit in the Transit Pavilion for comparison with the transit-circle observer. It is proposed to have a second exchange of signals shortly.

VIII. Personal Establishment :—

The Observatory has during the past year lost two principal members of the staff, and has further suffered from other changes and from the delay in filling up vacancies. On February 28 Mr. Turner resigned the office of Chief Assistant, which he had filled with much ability for nearly ten years, having been appointed Savilian Professor of Astronomy at Oxford, and Mr. F. W. Dyson, M.A., Fellow of Trinity College, Cambridge, was appointed his successor on March 1. Mr. W. Ellis, Superintendent of the Magnetic and Meteorological Branch, retired in accordance with the rules of the service on December 31, after a long and honourable connection with the Royal Observatory of more than fifty years, and Mr. W. C. Nash, Assistant in the Magnetic and Meteorological Branch, was promoted to fill the vacancy thus occasioned in the staff of First Class Assistants. Mr. Hudson resigned his post of Second Class Assistant on July 10, before the end of his period of probation. Mr. L. Le Brun, Assistant Paymaster, R.N. (retired), was appointed on June 10, after a long interval, to succeed the Second Division Clerk, but he found himself unequal to the performance of the duties, and was finally compelled, through ill health, to resign on March 19. Mr. C. Cass, from the Department of the Accountant-General of the Navy, took over his cash duties from April 2, pending the appointment of his successor, Mr. H. Outhwaite, a Second Division Clerk in the Admiralty, who, however, had not entered on his duties at the date of this Report.

The two vacancies in the staff of Second Class Assistants have not yet been filled up, as after a delay of more than six months the Government have not come to any decision in regard to the re-organisation of the staff recommended by the Board of Visitors, with a view to strengthening the supervising power and increasing the permanent staff in order to obviate the difficulties experienced through the frequent changes in the computers, who, owing to the growth of the work of the Observatory, now take an important share in the regular observations of all classes as well as in the computations.

The vacancies in the staff, and the provisional arrangements which they have necessitated, have caused great difficulties in carrying on the work, and it is only through the zealous co-operation of Assistants and Computers, and the excellent spirit with which the whole Staff has worked to meet the emergency, that it has been possible to cope with the exceptionally heavy work of the past year.

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

Chief Assistant—Mr. Dyson.

First Class Assistants—Mr. Criswick, Mr. Lewis, Mr. Maunder, Mr. Nash, Mr. Thackeray.

Second Class Assistants—Mr. Bryant, Mr. Crommelin, Mr. Hollis, and two vacancies.

Clerk—Vacant.

Mr. Dyson has the general superintendence of all the work of the Observatory, with full power to act in my absence. Mr. Criswick has charge of the photographic mapping of the heavens, and has also kept the cash accounts occasionally. 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 and meridian zenith-distance reductions. Mr. Hollis has the care of the library and manuscripts, of the longitude reductions, and of much miscellaneous correspondence which should naturally be undertaken by the Clerk. Mr. Crommelin undertakes the altazimuth and equatorial computations, and Mr. Bryant the transit-reductions and time-determinations.

In the magnetic and meteorological branch, Mr. Nash has the charge of the whole of the work.

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

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.

Owing to the extent of the Observatory buildings and the amount of office work, involving frequent communication between the Astronomer Royal and the individual members of the Staff, scattered over a space of about two hundred yards, the services of a Messenger, as in other Government Offices, are required to save loss of time and interruption of work of the Staff, but up to the present time no provision has been made for this necessary adjunct to an establishment where a staff of nearly 50 persons is employed.

IX. General Remarks :—

During the past year the work of the Observatory has been exceptionally heavy, and it has had to be carried out under conditions which have made it very difficult. The want of proper accommodation for the Staff, which has now at length been recognized by the Admiralty, has caused much waste of time due to the dispersal of the Staff and separation from important branches of their work, a necessary result of the provisional arrangements which have perforce been adopted to meet the emergency. Though steps are now being taken to provide a portion of the accommodation required, the progress is very slow, and in the meanwhile the difficulty of making arrangements for the Staff to carry on the work of the Observatory becomes more and more acute.

Four vacancies in a staff of twelve persons have occurred during the last year, the Chief Assistant, the Superintendent of the Magnetic and Meteorological Branch, a Second Class Assistant on probation, and the newly appointed Assistant Paymaster for Clerical Duties, having resigned their offices. These resignations have necessarily caused serious disorganisation of the work, which has been greatly increased by the delay in filling up two of the vacancies, as to which the Government have not yet come to any decision after a lapse of more than six months, the question of a proposed partial re-organisation of the staff being involved, as mentioned in the preceding section. In view of the serious effect of changes in the staff of observers on the continuity of the Greenwich series of observations, it is very important that due consideration should be given to scientific requirements in the organisation of the staff, and that a sufficient number of trained observers should be appointed to carry on the systematic observations of various classes which have to be undertaken at the Observatory. As the limited numbers of the present permanent staff do not adequately provide for this, and as the present mode of appointment by the Civil Service Commissioners under open competition does not ensure that the candidates are qualified as observers, a modification of the existing scheme appears to be required to secure the continued activity of the Observatory.

As regards the *matériel* of the Observatory, the past year has been characterized mainly by preparation for future work. The 28-inch Refractor has been mounted, and got into working order both for visual and photographic observation. The new Universal Transit Circle or Altazimuth has been well advanced towards completion, and a 26-inch Photographic Telescope equatorially mounted, the noble gift of Sir H. Thompson, has been ordered from Sir H. Grubb. The building of the South wing of the new Physical Observatory has been completed, and the plans of the North wing and Central Tower have been prepared and approved, as well as those of the new Altazimuth Pavilion.

W. H. M. CHRISTIE.

ROYAL OBSERVATORY, GREENWICH.
1894 May 11.