REPORT

OF

THE ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1891 *June* 6.

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The Report here presented refers to the year from 1890 May 11 to 1891 May 10, and exhibits the state of the Observatory on the last-named day.

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

The new Porter's Lodge, mentioned in last year's Report, was completed last autumn.

After much consideration it has been decided that the Museum or Storehouse for portable instruments and apparatus should be built so as to form the central octagon of a future cruciform structure in the South ground, which would accommodate the Physical Branch of the Observatory, and would carry the Lassell Equatorial and Dome at such a height above the ground that the neighbouring trees would not interfere with the effective use of the instrument. The building for the Museum (consisting of the two lower storeys of the octagon) was commenced at the beginning of March and is now nearly completed so far as the structure is concerned. In consequence of a recent decision of the Admiralty to largely increase the number of chronometers and deck watches for the Navy, additional accommodation for chronometers is required immediately, the space in the present Chronometer Room being insufficient even for existing requirements. A proposal is now under the consideration of the Admiralty to provide this by appropriating the room under the Chronometer Room and the Lower Record Room to chronometers, the South wing of the proposed Physical Observatory being built to receive the contents of these two rooms.

In other directions the difficulty of providing in the existing Observatory buildings for the accommodation of the increasing staff and of the accumulating material is severely felt, and it is very desirable that the pressure on the space available should now be relieved by means of a comprehensive scheme, which would supply a suitable fireproof brick building to replace the wooden sheds and huts which now disfigure the Observatory grounds, and to provide for the expansion which has taken place in late years and which may be expected to continue in the future. Amongst the requirements which are now pressing and for which provision would be made in the proposed building may be mentioned :—

(1) A computing room for the Magnetical and Meteorological Branch in lieu of the small Ante-room of the Magnetic Observatory which is built of wood and unsuited to present requirements.

(2) A computing room for the new Astro-photographic Branch.

(3) Fireproof rooms for the photographic records and books of calculations in these two branches.

(4) A library for the Physical Branch (Magnetical and Meteorological, Spectroscopic and Photographic).

(5) A store room for the stock of publications of the Observatory, at present housed in a wooden shed where they suffer much from damp.

(6) A laboratory and dark galleries for spectroscopy and photography.

(7) Bedrooms for occasional use by the observers.

An essential part of the scheme would be the mounting of the Lassell Equatorial, with the $12\frac{3}{4}$-inch refractor substituted for the Lassell reflector, on the central octagon (above the spectroscopic and photographic laboratory) in a position in which it could be used with great advantage for equatorial observations of various kinds.

A permanent Transit Pavilion has been erected in the Front Court (in the line of Bradley's meridian) in place of the wooden hut set up in 1888 for the Paris-Greenwich longitude operations, as experience has shown that this is a very convenient site for longitude determinations and for the instruction of Officers and others in transit observing. It was hoped that the building would have been ready for the determination of the longitude of Montreal this summer, but the work was not commenced till the beginning of March and there has been further delay in the construction of the roof, which consists of a pair of semi-domes sliding apart so as to give a clear opening of 2 ft. 6 ins. These were specially designed in the Department of the Director of Works to the Admiralty to satisfy the astronomical conditions and avoid abnormal refraction at any part of the opening.

To provide for the efficient working of the 28-inch refractor about to be mounted on the South-east Equatorial, the Admiralty have authorized the construction of a new iron-framed dome, 36 feet in diameter, to be erected on the South-east tower in place of the existing wooden drum, which, as mentioned in the last Report, has been so much strained in the course of thirty years, that there is great difficulty in turning it. An attempt was made to render the existing dome more serviceable by bolting the framework together more thoroughly and by substituting properly turned spheres for the cannon balls, but though the dome is not now liable to stick fast as formerly, it is still very difficult to turn, and cannot be considered serviceable. The new 36-foot dome which is being constructed by Messrs. T. Cooke & Sons is of peculiar form, adapted to the conditions of the case, the diameter being greater than that of the tower on which it is erected. A general description of its special features is given in the Monthly Notices R.A.S. for 1891 May.

The shelves in the Battery Basement have been renewed, teak being substituted for deal.

The principal moveable instruments are thus distributed :—

At Greenwich—

Transits B, C, D, and E, and the Transit with axis view.

Altazimuth D.

Equatorials (6-inch).—"Cooke, No. 2," "Simms, No. 1," "Hodgson," and "Corbett." The telescope tube of the latter, which was mounted on the Lassell telescope, has been dismounted to make way for the Thompson photoheliograph.

Photoheliographs.—One complete (No. 4, mounted in the South Ground), two tubes (E 2, A 5, with object glasses), and a driving clock (used for the Personal Equation Instrument), and a complete mounting with driving clock (No. 3) used last in the Cape Ledo Eclipse Expedition.

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.

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, and "Simms, No. 2" at Bethnal Green Museum.

Photoheliographs.—One complete at the Cape Observatory, one complete 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, and "Dent, No. 2011" at Kew Observatory.

The Indian Invariable Pendulums mounted in the Record Room were returned to Kew on 1890 July 10.

A photographic telescope with 9-inch object-glass by Grubb, and a prism of 9 inches diameter by Hilger have been generously presented to the Royal Observatory by Sir Henry Thompson. The telescope has been mounted on the Lassell telescope as a photoheliograph, to give 8-inch pictures of the Sun, a camera with Dallmeyer doublet (from Photoheliograph No. 4), and an exposing shutter, specially designed to give very short exposures, being attached to it.

Six more electric hand lamps (Pitkin's) and an Ampère gauge (Sir W. Thomson's) have been purchased.

In view of the advantage resulting from the use of electric lighting for the photographic equatorial and for other instruments, it is very desirable that an electric light installation should be provided for the Observatory, so that this method of lighting, which is specially adapted to the requirements of an observatory, may be applied to the instruments generally. The system now in use of charging storage cells from primary batteries is necessarily extravagant, and it does not admit of the desired extension.

The annual comparison of the books and manuscripts with the Catalogue has been made, and one book is missing in addition to that mentioned in the last Report. The MS. volume ("Observations of the Total Solar Eclipse of 1860") which was on loan to Mr. E. J. Lowe, has been returned.

The New Library has been placed in charge of the Magnetic and Meteorological Department, and the rearrangement of this Library occupied the Staff for a considerable time last autumn.

II.—Astronomical Observations :—

Transit-Circle.—A new mercury trough, made entirely of copper and amalgamated inside, was mounted on 1890 June 5, and has since been in continuous use in reflexion observations with very satisfactory results. No other change of importance has been made in the regular course of observation with the Transit-Circle. The object-glass of the Transit-Circle appears to have become permanently stained, probably through damp, and it is proposed to have it repolished.

The Sun, Moon, and planets have been observed with the same regularity as before, but in the case of the severe night watches, relief has been given by allotting to a special observer as a morning watch the observation of the Moon, when she transits between 2h. and 7h. a.m., instead of as before between 3h. and 6h. a.m. By detailing one of the qualified computers to occasionally assist by reading microscopes, it has been found possible to maintain and even increase the amount of work done, with much less fatigue to the observer. The annual catalogue of stars observed in 1890 contains 2072 stars.

The following statement shows the number of observations made with the Transit-Circle in the year ending 1891 May 10 :—

Transits, the separate limbs being counted as separate observations	6036
Determinations of collimation error	307
Determinations of level error	390
Circle observations	5789
Determinations of nadir point (included in the number of circle observations)	387
Reflexion observations of stars (similarly included)	593

About 49 transits (included in the above number) have been observed with the reversion-prism eye-piece, to determine personality depending on the direction of motion.

For determining the variation of personal equation with the magnitude of the star, 324 transits, not included in the above, have been observed. The apparent magnitudes of the stars are altered by placing a wire gauze screen in front of the object-glass of the telescope, and part of a transit is observed with clear aperture, part with obscured. The comparison of the two results gives the difference of personal equation for a definite change of magnitude. The amount of this change has been determined from 2,590 estimations made by the observers, checked by their estimations of magnitudes with the full aperture, and with known diaphragms. The discussion of these results is nearly completed, and will shortly be published in the *Monthly Notices* of the Royal Astronomical Society. It appears that all the four regular observers record the times of faint stars later than bright, the difference per magnitude being about $0^{s}.01$.

As regards the computations :—

The transits are completely reduced (so as to exhibit Mean R.A. 1891·0) to April 18, means of limbs and wires being taken to May 9. The copy for press for 1890 is in the printer's hands.

The investigation of personal equations is completed for 1890, and the values accord closely with those of previous years.

The circle observations are completely reduced to April 23, and the apparent N.P.D. is formed to May 3, circle readings, &c. being complete to date. The copy for press for 1890 is in the printer's hands.

The apparent correction for discordance between the nadir observation and stars observed by reflection is $+0''\cdot08$, and as before no correction for this discordance has been applied.

Determinations of the astronomical flexure of the telescope by means of the collimators on 1890 June 19, September 29, and 1891 May 5 gave results $+0''\cdot47$, $-0''\cdot35$, and $+0''\cdot06$. No correction for flexure as distinct from the R—D correction has been applied since 1879.

The correction for R—D, the error of assumed colatitude, and the position of the ecliptic have been investigated for 1890 ; and the ledgers of mean R.A. and N.P.D. of stars, and the geocentric and heliocentric errors for the planetary results for 1890 are all completed and the press copy prepared.

The R—D correction is found to be $-0''\cdot014 + 0''\cdot556$ Sin Z D, the second term being a little smaller than in previous years since 1883.

The Colatitude of the transit-circle as found from the observations of 1890 is $38^\circ\ 31'\ 21''\cdot81$, differing by $-0''\cdot09$ from the adopted value. The correction to tabular obliquity of the ecliptic from solar observations in 1890 is $-0''\cdot06$; this quantity has been small for the last three years. The discordance between the results from the summer and winter solstices is $-0''\cdot22$, indicating that the mean of the observed distances from the pole to the ecliptic is too small by $-0''\cdot11$. The reading of the front court thermometer was used in computing refraction for these observations : and the mean monthly excess of its readings over those of the ordinary exterior thermometer ranged from $+0^\circ\cdot1$ in January and December to $+3^\circ\cdot5$ in September. These values are in better agreement with the results of years previous to 1888, though still somewhat small. In 1888 July a transit hut was erected for longitude work in the Front Court, and was apparently too near the thermometer ; the post carrying the latter was on 1890 February 28 planted at a distance of 10 feet from the western face of the hut. During the period 1888 August to 1890 January the maximum mean monthly excess was $2^\circ\cdot4$.

The mean error of the Moon's tabular place (computed from Hansen's lunar tables with Newcomb's corrections) is only + 0^{s}·020 in R.A. and + 0″·23 in longitude as deduced from 96 observations in 1890, confirming the return to a small value shewn in 1889 (+ 0^{s}·010 and + 0″·12) after an apparent increase in the two preceding years (+ 0^{s}·059, + 0^{s}·090 and + 0″·66, + 1″·21 respectively). The mean error in N.P.D. is − 0″·95.

The three thermometers in the horizontal shutter opening of the transit-circle room have been read simultaneously with the interior and two exterior thermometers till recently, and the whole series of observations is now being discussed.

Altazimuth.—The total number of observations made in the year ending 1891 May 10 is as follows :—

Azimuths of the Moon and stars	253
Azimuths of Mark I.	123
Azimuths of Mark II.	193
Zenith distances of the Moon	118
Zenith distances of Mark I.	124
Zenith distances of Mark II.	188

With the reversion prism eyepiece 23 chronographic and 13 eye-and-ear double transits of the second limb, and 12 chronographic double transits of the lower limb of the Moon have been observed to determine the effect of apparent direction of motion on personality.

The altazimuth observations are completely reduced to March 31.

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	6
15^{h} to 16^{h} ,,	1	8
16^{h} to 17^{h} ,,	5	9
17^{h} to 18^{h} ,,	4	8
18^{h} to 21^{h} ,,	18	5
21^{h} to 0^{h} ,,	28	—
0^{h} to 3^{h} ,,	19	—
3^{h} to 6^{h} ,,	15	2
6^{h} to 7^{h} ,,	2	4
7^{h} to 8^{h} ,,	5	6
8^{h} to 9^{h} ,,	1	5
9^{h} to 10^{h} ,,	0	2
10^{h} to 11^{h} ,,	0	4

The whole number of places of the Moon observed with the transit-circle is 98 or 8·0 per lunation, and with the altazimuth 62 or 5·0 per lunation.

The Moon's diameter has been measured with the transit-circle 3 times in R.A. and 17 times in N.P.D.

Clocks and Chronographs.—The Sidereal Standard was cleaned in April and the clock "Hardy" in December. The clock "Dent 2017" was mounted in the dome for sidereal photography on 1891 March 14; and "Dent 2016" is now being fitted with contact springs for use in longitude operations. The clocks are at present all in good order.

A pin in the chronograph gave way on 1890 June 9 causing some damage, which was however promptly repaired, and the instrument has since been in good order. Two portable chronographs are being made by Mr. Hilger for use in longitude work and are nearly complete.

Reflex Zenith Tube.—Since the date of the last Report, 14 double observations of γ Draconis have been made and completely reduced to the end of 1890. M. Lœwy's recent work seems to show that the determination of the constant of aberration with this instrument is more trustworthy than had been supposed; though the circumstance that the observations give a negative parallax for γ Draconis suggests that there is some unexplained source of error.

Equatorials.—The Lassell, South-east, Sheepshanks, and Shuckburgh Equatorials are in good working order. As already mentioned the photographic telescope recently presented by Sir Henry Thompson has been mounted below the Lassell telescope in the place previously occupied by the Corbett refractor, and arranged for taking solar photographs of 8 in. in diameter. A new comet eyepiece, with position circle of six inches diameter, has been fitted to the Sheepshanks Equatorial, for the more accurate observation of comets.

Sir H. Grubb reports that the object glass and tube of the 28-inch refractor are now practically ready for mounting; but I propose to delay this operation until the completion of the new dome on the South East tower mentioned in the first section of this Report.

The photographic equatorial has been brought into working order after some delay, occasioned by the necessity for working out details of plate holders, réseau-frame and other accessories after the instrument was set up. Unfortunately when it was otherwise ready for use the ratchet to the weight barrel of the driving clock (which was of the silent form) gave way on 1890 October 27 letting the heavy weight fall. The barrel was sent to Sir H. Grubb who applied an ordinary ratchet to it, with a new steel pinion, and returned it on 1890 November 24. The instrument has since worked very

satisfactorily and is admirably adapted to its purpose, the electrically controlled clock-work in particular being very efficient.

Since the date of the last report, 18 occultations of stars by the Moon (9 disappearances and 9 reappearances) and 37 phenomena of Jupiter's satellites have been observed with the equatorials, or with the altazimuth. These observations are completely reduced to 1891 March 31.

Comet *a* 1890 has been observed with the Sheepshanks Equatorial on 18 nights.

During the partial Solar Eclipse of 1890 June 17 a few measures of differences of R.A. and N.P.D. of cusps were observed in intervals between the clouds with the South-East Equatorial, with a view to determining the correction to the tabular place of the Moon. The observations have been completely reduced and the results have been published in the Monthly Notices for November 1890.

Several observers were ready to observe the Transit of Mercury on 1891 May 10, but the sky was cloudy throughout the morning.

Work with the 13-inch photographic refractor was seriously delayed by the accident to the driving clock, and later by the illness of Mr. Criswick; but 81 stellar photographs have been taken, all of which must be regarded as more or less experimental. Ferrous oxalate development was used throughout and all the plates were photographically impressed with the réseau kindly supplied by Prof. Vogel. The exposures have varied from a few seconds to about an hour; and trails have been taken both on the equator and near the pole to test the adjustment for orientation. Several different kinds of plates have been used including Cramer, Seed, Paget, Star, Mawson & Swan, and Ilford; and on the whole the choice seems to lie between the Star and the Ilford plates.

Some trial photographs of Polaris have been taken with the Dallmeyer 4-inch photoheliograph object-glass, which it is proposed to use as an auxiliary telescope to test the quality of the night by short exposures on Polaris during the exposures for the Chart plates.

III.—Spectroscopic and Photographic Observations :—

For determination of motions of approach or recession of stars 286 measures have been made of the displacement of the F line in the spectra of 31 stars, and 14 of the *b* line in the spectra of 6 stars, besides comparisons with the spectra of Mars, the Moon, the Sun, or the sky, as a check on the general accuracy of the results. The series of observations with the $12\frac{3}{4}$-inch refractor is now practically completed, and the results are under discussion. An examination of those for the 21 stars most frequently observed, shews that there is a systematic error depending on the hour angle; thus necessitating a correction for the position of the spectroscope at the observation.

In the year ending 1891 May 10, photographs of the Sun have been taken at Greenwich on 224 days, and of these 483 have been selected for preservation, besides 18 photographs with double images of the Sun for determination of zero of position.

For the year 1890 Greenwich photographs have been measured on 209 days, and photographs from India and Mauritius filling up the gaps in the series on 152 days, making a total of 361 out of 365 on which photographs have been measured in this year.

The Sun has been free from spots on 175 days in the year 1890, as compared with 211 days in 1889 ; there were only 3 spotless periods of more than 14 days in 1890, viz. :—February 2–27, March 24–April 9, and June 11–July 3, while in 1889 there were 9 such periods.

The mean daily spotted area has increased from 78-millionths of the Sun's visible hemisphere in 1889 to 100 in 1890.

The measures of the photographs, and the reductions of areas and positions of spots and faculæ are complete to the end of 1890.

Photographs from India and Mauritius have been received from the Solar Physics Committee as far as 1891 February 4 and January 23 respectively.

As regards the further discussion of the results of former years :—

46 Melbourne photographs, available for filling up gaps in the series in the year 1877, have been measured, and these, together with those for the years 1875 and 1876, referred to in the last Report, have been completely reduced, the orientation of the wires having been inferred by comparison with measures of Greenwich and Harvard College photographs on neighbouring days, as no satisfactory details of this adjustment could be furnished from Melbourne. The copy for press, both of the daily results and the ledgers of Sun-spots, is completed for these years.

Ledgers of the positions and areas of spots for the years 1882 and 1883 are completed and ready for press, and those for 1884 and 1885 are being formed. When this is done, the reductions for the whole series of years from 1875 to the present time will be complete, those of the Indian photographs for the years 1879 to 1881 having been completed at South Kensington, under the supervision of the Solar Physics Committee.

IV.—Magnetic observations :—

The photographic record of the three magnetic elements, and the supplementary eye observations, have been continued as before. The temperature of the basement in which the photographic instruments are installed has been maintained at about 67°

throughout the year, except in December and part of January, when the gas supply again became deficient, and the ground in the Park was again opened to clean the pipes, which were found to be so much corroded that it will be necessary to renew them. They have been in use as gas-pipes for 40 years, and had previously served as water-pipes before the existing water main was laid down.

The resistance of the earth current wires has been further reduced by replacing portions of the circuits with new copper wire in October last. The resistance of both circuits has thus been reduced from about 200 ohms to 150 ohms.

In December last, the earth current traces began to show anomalous fluctuations which had not been before remarked, commencing about 7^h (civil time) and terminating about 23^h. The cause of these disturbances, which did not generally occur on Sundays, has not yet been discovered, but it has been noticed that they do not appreciably interfere with the record of any true disturbance.

The galvanometers in connection with the earth current apparatus have lately been irregular in scale value; the amount of displacement of the spot of light on the photographic sheet for a definite current having varied considerably from time to time. It is hoped that this defect may be remedied by some small changes at present under consideration.

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 1890. The time-scales for declination, horizontal force, and vertical force are complete to the end of 1890, 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 1890 for all three elements, and the daily and hourly means are all taken; the time scales for earth currents are laid down. The dip observations are completely reduced to the present time, and the deflexion observations for absolute measure of horizontal force to the end of 1890. The temperature of the magnet basement at every hour has been read off from the sheets of the Richard thermograph to the end of 1890, and the daily and hourly means have been taken.

The following are the principal results for the magnetic elements for 1890 :—

Mean declination . . .	17° 28′·6 West.
Mean horizontal force . .	3·9546 (in British units). 1·8234 (in Metric units).
Mean dip	67° 21′ 19″ (by 9-inch needles). 67° 22′ 53″ (by 6-inch needles). 67° 24′ 24″ (by 3-inch needles).

Dr. A. Schuster has pointed out in a paper in the *Philosophical Magazine* (No. 190, p. 275), that the cause of this well established systematic discordance between the results for dip from needles of different lengths is probably the displacement of the centre of gravity by the bending of the longer needles under their weight.

In the year 1890 there was only one day of great magnetic disturbance, but there were also about 20 other days of lesser disturbance, for which tracings of the photographic curves will be published, these days having been selected in concert with M. Mascart according to the arrangement mentioned in the last Report. At the suggestion of Professor Rücker, also mentioned in the last Report, diurnal inequalities calculated from 5 typical quiet days in each month of the year 1889, for all three magnetic elements, will be published in the volume for that year.

With a view to the exact determination of the effect on the declination magnet of the iron used in the new building in the South Ground, and to obtain independent determinations of the magnetic declination and horizontal force at Greenwich, a new unifilar instrument has been obtained, whose constants have been determined at Kew.

The reduction of the magnetic results for the years 1865–1867, and the correction of those for 1868–1882, mentioned in the last Report, is well advanced; and it has ultimately been decided to correct also the vertical force measures in these years for temperature.

It may be mentioned that the recent magnetic survey of the British Isles by Professors Rücker and Thorpe has been found very useful in answering the frequent enquiries made by mining surveyors as to the value of the magnetic declination in various parts of England. Various particulars of the Greenwich magnetic work have been communicated to M. Sack, of Lübeck, who is engaged in a discussion of the observations from 1883 to 1889.

V. Meteorological Observations :—

The continuous registration of meteorological phenomena has been maintained without interruption, except for four days in February when the old thermograph and shed in the magnetic ground were dismounted, and the new thermograph and shed were transferred from the South Ground to the position formerly occupied by the old instrument, to make way for the new buildings in the South Ground. Advantage was taken of the opportunity to clean the new thermograph thoroughly. The comparison of the old Robinson anemometer with the larger instrument, which has been in use since 1866, has been continued during the year.

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 electrometer to the end of 1890, and some work has been done in taking means. The table of principal changes in the direction of the wind for 1890 is completed.

The mean temperature of the year 1890 was 48°·6, being 0°·6 below the average of the preceding 49 years. The highest air temperature in the shade was 82°·8 on August 5, and the lowest 13°·1 on March 4. This latter is the lowest temperature registered in March since 1841, being the same as that recorded on 1845 March 13. The mean monthly temperature in 1890 was below the average in all months excepting January, March, May, and September. In December it was below the average by 10°·0, and in January above by 5°·2.

The mean daily motion of the air in 1890 was 272 miles, being 10 miles below the average of the preceding 23 years. The greatest daily motion was 837 miles on January 26, and the least 32 miles on August 6. The greatest pressure registered was 14·5 lbs. on the square foot on January 26.

During the year 1890 Osler's anemometer showed an excess of about 3 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 1890 by the Campbell-Stokes sunshine instrument was 1255, which is about 35 hours below the average of the preceding 13 years, after making allowance for difference of the indications with the Campbell and Campbell-Stokes instruments respectively. 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 0·282, constant sunshine being represented by 1.

The rainfall in 1890 was 21·9 inches, being 2·7 inches below the average of the preceding 49 years.

The winter of 1890-91 was remarkable for a long period of exceptionally cold weather which commenced on 1890 November 25. From this day till January 22 the mean temperature on every day except January 13 was below the average. The temperature was continuously below 32° on November 27, 28, December 10 to 19, 22, 23, 25, 28 to 30, January 2, 6 to 8, 10, 11, 17 to 19. The greatest defects from the average of 20 years were on November 28 (− 19°·1), December 22 (−20°·7), and January 10 (−19°·3). The lowest temperatures recorded during the three months were 18°·3 on November 28, 13°·4 on December 22, and 12°·0 on January 10. The mean temperature of December 1890 was 29°·8, or 10°·0 below the average of the preceding 49 years, the coldest December on record

since 1841 previous to 1890 being that of 1879 whose mean temperature was 32°·4. In this same month, 1890 December, only $2^{h}\cdot4$ of Sunshine were recorded.

It may be mentioned that copies of the monthly values of rainfall from 1814 to 1840 contained in the old Meteorological Journal of the Royal Observatory have been given to Mr. Symons.

The tabulation of meteorological elements for fifty years, grouped together by days, to which reference was made in the last Report, has been commenced, the formation of the tables of daily maximum temperature and mean daily temperature being nearly complete.

VI.—Printing and Distribution of Greenwich Publications :—

The volume of Greenwich Observations for 1888, and the separate copies of Results, and the Spectroscopic and Photographic Results for 1889, were distributed in December last.

The volume for 1889 is all in type except the Magnetic and Meteorological Introduction, which is in the printer's hands ; and the remainder has been sent for press except the Transit-Circle Tables.

As regards the volume for 1890, the whole of the Altazimuth Section and the Spectroscopic Results are in type, and the Transits and Meridian Zenith Distances are in the printer's hands.

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

The number of chronometers and deck watches now being tested at the Observatory is 169 (113 box chronometers, 20 pocket chronometers, and 36 deck watches). The annual competitive trial of chronometers commences on July 4, and the trial of deck watches on October 24.

In the year ending 1890 May 10 the average daily number of chronometers and deck watches being regularly rated was 200, the total number received was 617, the total number issued was 628, and the number sent for repair was 269.

The annual trial of chronometers (which lasts for 29 weeks) was still more searching than that of the previous year, the range of temperature to which the instruments were subjected having been nearly continuous from 34° to 100°. The weekly mean temperature of the room ranged from 43° to 67°, and in the oven the chronometers were tested at mean temperatures of 75°, 85°, and 92° to 98°. The "trial numbers" however, compare well with those of former years, and the first chronometer is a very fine one. The average trial number of the first six chronometers was 20·3.

For the annual trial of deck watches, 1890 October 25 to 1891 February 14, 31 watches were entered, and of these 22 were purchased for the Navy, the first 5 being

classed "A," or equal in performance (on the 16 weeks' trial) to an average box chronometer. Owing to the exceptionally cold weather of the past winter, the trial has been more severe than usual, and the performance of the watches is not, on the whole, so good as in the previous year. The first watch has, however, a slightly smaller trial number than the first of last year. In future trials the watches will be separated into two classes, A and B; and for those entered as of Class B, the trial in positions will be limited to "dial up" and "pendant up," these watches being intended for ordinary use on board ship, whilst the watches of Class A would serve as pocket chronometers.

Nine chronometers have been tested for the Austrian Government.

Harrison's two machines for measuring time, his prize chronometer, and Larcum Kendall's copy, with nine chronometers exemplifying various stages of development, one pocket chronometer, one deck watch, and the working model of a chronometer, have been lent to the Naval Exhibition at Chelsea.

The want of space in the chronometer room has been felt in various ways. Owing to the crowded state of the shelves it has not been found practicable to place trial chronometers in different positions with reference to the magnetic meridian, in order to ascertain whether their rates are influenced by terrestrial magnetism, and the testing of navy chronometers and deck watches has been carried out with much difficulty at times. In view of the large proposed increase in the number of chronometers to be purchased annually, and the consequent probable increase in the number entered for trial, the allotment of more space to chronometers has become imperative, and I propose to use in this connexion the room immediately below the present chronometer room as soon as space can be provided in the new buildings for the mechanician, who now works there, for the instruments, &c., at present stored there, and for the convenient transaction of other business (such as the reception of chronometer makers, the packing of publications, &c) to which this room is occasionally devoted. In the meanwhile, a little space may be gained in the chronometer room by fitting up shelves for deck watches round the central pillar.

On 1890 November 7, the Greenwich time-ball was not raised on account of the violence of the wind; and on 1891 March 1 the springs of the Mean Solar clock failed to act, so that the ball did not drop, nor was any signal transmitted to the Post Office. On 1890 December 27, the train of the Mean Solar clock dropped $2^{sec.}$ and the signal was in error to this amount. On all other days it was sent out correctly.

The automatic drop of the Deal time-ball failed on 17 days owing to interruption of the telegraph connexions, and on one day high wind prevented the raising of the ball. As mentioned in the last Report, arrangements have been made for reverting

to the automatic return signal from Deal, modified so that it is made at an interval of eight seconds only after the ball drops, to serve as a check on the accuracy of the time-signal. This arrangement was finally brought into action on 1890 December 18, and with a few exceptions has performed extremely well. The beginning and end of the signal are both observed, and it is found that the beginning is more regular than the end, the average error in the former, as observed, being only about $0^s{\cdot}1$. The duration of the signal has gradually lengthened from about 2^s in December to $3^s{\cdot}7$ in May, which would seem to point to some wear in the contacts.

Signals from the Devonport clock have been received regularly since the date of the last Report, except on 30 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 69 per cent. of the 333 days of observation, under $0^s{\cdot}5$ on 95 per cent., between $0^s{\cdot}5$ and $1^s{\cdot}0$ on 5 per cent., and exceeded 1^s on one occasion only, and that a Sunday. Nine of the 14 days on which the error exceeded $0^s{\cdot}5$ were also Sundays.

The automatic signals from the Westminster clock have been received regularly throughout the year ending 1891 May 10, except on 14 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 22 per cent., to 3^s on 5 per cent., and to 4^s on 2 per cent.

To reduce the tendency to give sparks at the contact springs, condensers have been placed by the Post Office authorities in all the clock and observing circuits which require them, and the arrangement has worked quite satisfactorily.

The reductions for the longitude Paris–Greenwich are now completed and ready for publication. In reference to the discrepancy between the results of the French and English observers, mentioned in the last Report, Commandant Defforges visited Greenwich in 1890 June, and went carefully through the reductions with Mr. Turner and Mr. Lewis. No mistake was found in the work but several questions of some importance were raised. The results of the discussion and of subsequent correspondence are summed up in two papers by Mr. Turner and one by Colonel Bassot and Commandant Defforges, in the Monthly Notices of the Royal Astronomical Society, Vol. LI., pp. 155, 407, and 413 respectively. As the matter now stands the English definitive result for the difference of longitude between the Greenwich Transit Circle and Cassini's Meridian is $9^m\ 20^s{\cdot}86$, while the French result (not yet published) is about $0^s{\cdot}15$ greater, a discordance which though only about half of that found in the preliminary discussion, is still so large, that there seems to be no alternative but to repeat the work with special precautions suggested by the experience gained.

The reductions of the longitude Dunkerque–Greenwich have been delayed by the above discussion, but are now proceeding.

The proposal to determine the longitude of Montreal as the base station for the Geodetic Survey having been sanctioned by the Admiralty last December, arrangements have been made in concert with Prof. McLeod of the McGill College Observatory, Montreal, for a determination of the longitudes Montreal—Canso—Waterville—Greenwich, the termini of the cable, Canso and Waterville, being occupied as longitude, and not merely as transmitting stations, a course which seems advisable in view of the great geodetic importance of these points. The necessary funds have been voted, and the Commercial Cable Company have generously placed their cable at our disposal. It is proposed to use the portable transits B, C, D & E for this work, four observers being engaged, each of whom shall carry with him from station to station his own instruments. The chronographs for the two English observers are being constructed by Mr. Hilger, and the electrical apparatus is being supplied by Messrs. Siemens. After a preliminary visit of Prof. McLeod to Canso, and of Mr. Turner to Waterville, to settle the observing sites and other general arrangements, it is hoped that one stage of the operations may be completed in August and September of this year, but without any observer crossing the Atlantic, for which, owing to delays beyond our control, we shall scarcely be prepared in the present year. The interchange of observers will be effected next year at a time to be hereafter determined, precautions being of course taken to check any change in personal equation.

The determination of the longitude of Washington has been deferred for the present.

During the past year, Lieutenants Heming, Monro, and Smyth, R.N., and Captain Haynes, R.E., have at various times been instructed in transit observing. Mr. S. Hirayama, of the Tokio Observatory, was at work for some weeks studying the general organization of the Observatory.

VIII. Personal Establishment :—

The promised addition to the staff, which should strengthen the supervising power, has as yet resulted only in the appointment of another Second-class Assistant, Mr. Andrew C. D. Crommelin, who will enter on his duties on May 11. The staff is thus constituted, the names in each class being arranged in alphabetical order :—

Chief Assistant—Mr. Turner.

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

Second-class Assistants—Mr. Crommelin, Mr. Hollis, Mr. Lewis, Mr. Nash, and Mr. Thackeray.

2nd. Division Clerk—Mr. Wickison.

Mr. Turner supervises the work of the Observatory generally, and has full powe to act in all matters during my absence. Mr. Criswick is charged with the transit reductions and miscellaneous astronomical computations, and has done much work in stellar photography, to which it is hoped that he will be enabled to devote more time when the staff has been increased. Mr. Downing is responsible for the altazimuth and equatorial computations, and has the care of the library and manuscripts. Mr. Thackeray has charge of the meridian zenith-distance and zenith-tube reductions. Mr. Lewis superintends the time department and chronometers, and undertakes most of the longitude computations. Mr. Maunder is charged with the spectroscopic and photographic observations and reductions. Mr. Hollis has undertaken the measures and reductions of solar photographs to supplement the Greenwich record for past years, and the selection of guiding stars for the Astrophotographic Chart, besides some miscellaneous work. In the magnetic and meteorological branch, Mr. Ellis superintends the whole of the work, and is assisted by Mr. Nash, who has special charge of the meteorological reductions and instrumental adjustments.

At the present time ten computers are attached to the astronomical branch, two to the spectroscopic and photographic, and five to the magnetic and meteorological.

A gate-porter, a watchman, and a gardener complete the establishment. A foreman of works, with two carpenters and a labourer, and a skilled mechanic, are also employed continuously.

IX. General Remarks :—

The preparatory work for the photographic map of the heavens has occupied a good deal of attention during the past year, a number of new questions being raised in this application of photography to systematic astronomical work, which have necessarily required careful consideration on the part of the Chief Assistant and myself. Under these circumstances the want of increased supervising power for the Observatory has been severely felt and this want has not been in any way met by the appointment, after a long delay, of an additional Second Class Assistant. The recent meeting at Paris of the International Committee for the photographic map, in which I took part, settled the bases of the work in a general way, but for working out the details, both practical and theoretical, much remains to be done, and under the existing conditions of the Observatory staff it is difficult for the Chief Assistant and myself to supervise this adequately, and to deal effectually with the important points of principle involved in the discussion of the excellent photographs which have been obtained by Mr. Criswick and his assistants.

The same difficulty has been felt in reference to the important work of determination of longitudes, in which the Royal Observatory should naturally take part. The

discussion of the results for the longitude Paris–Greenwich in 1888 has brought to light various difficulties which seem to attend all such operations and to lead to uncertainty in the result. The removal of these difficulties has been a subject of anxious consideration as a preliminary to the determination of the longitude of Montreal and the redetermination of the longitude of Paris, but, under the circumstances of the past year, it has been found extremely difficult to give the requisite amount of thought to the working out of the conditions essential to success.

Reference has been already made to the need for a considerable addition to the existing buildings, in order to accommodate suitably the Physical Branch of the Observatory. This need was first brought prominently into notice by the demands of the Audit Office for an audit of instruments and apparatus, which implied that there should be a suitable building in which to store them, and this is now being provided. Recently attention has been called to the crowded state of the chronometer-room, which makes it impracticable to receive the additional number of chronometers now required for the Navy until more space has been provided. In other directions the same pressure on the space available has been felt, office rooms, store rooms, and sheds being all crowded. For many years past the material growth of the Observatory has been met from time to time by the erection of wooden sheds, which, though possibly suitable for temporary purposes, are quite out of place in a permanent Observatory, one of these having served as the Computing Room of the Magnetical and Meteorological Branch ever since its establishment fifty years ago. The time would seem to have come when an effort should be made to provide the Royal Observatory with buildings befitting its position as a permanent institution.

W. H. M. CHRISTIE.

Royal Observatory, Greenwich.
1891 May 11.