REPORT

OF

THE ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1890 *June 7.*

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Read at the Annual Visitation of the Royal Observatory, 1890 *June* 7.

The Report here presented refers to the year from 1889 May 11 to 1890 May 10, and exhibits the state of the Observatory on the last-named day.

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

The fittings of the photographic dark rooms in the new 18-foot dome have been completed, and all preparations made for work with the 13-inch Photographic Equatorial recently mounted there.

The Ball-Lobby and the staircase leading to the Octagon Room have been painted; and also the room assigned as a private room to the Computers.

The building of the new Porter's Lodge, which was sanctioned last year, has been somewhat delayed from various causes. The contract for its construction has just been signed, and the work will be begun immediately after the Visitation.

The Admiralty have authorized the building of a storehouse or museum for the better housing of the various portable instruments and apparatus belonging to the Observatory, as proposed in the last Report. After careful consideration, it appeared advisable to modify the original idea of a building of one storey occupying nearly the whole of the ground available for future extensions, and to arrange for a building of two storeys having a smaller area, designed to form the eastern wing of a larger structure, with the Lassell Dome as the central portion. The other wing would provide a suitable Computing Room for the Magnetic and Meteorological Branch, and sleeping accommodation for observers charged with observations in the early morning. The Ante-room of the Magnetic Observatory, which now serves as the Computing Room for that branch, is hardly fit for the purpose, as it is built of wood, and is not large enough for the proper accommodation of seven persons. The effective use of the Lassell telescope for the observation of occultations and phenomena would be greatly

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increased if it were mounted at a greater height, as it would be if the plan here suggested were carried out. In its present position neighbouring trees interfere greatly with the observations of the Moon and Jupiter when south of the equator, and the use of the instrument is much restricted in consequence.

The principal moveable instruments are thus distributed :—

At Greenwich—

Transits B, C, 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 last named is mounted on the Lassell Equatorial, and the parts of the mounting, which were lent to the late Rev. S. J. Perry for the Eclipse Expedition to the Salut Isles, have been returned.

Photoheliographs.—One complete (mounted in South Ground), two tubes (with object glasses), and a driving clock (used for the Personal Equation Instrument), and a complete mounting with driving clock previously lent to the Mountain Observatory Committee, and used 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 ; D, at Bethnal Green Museum (Science and Art Department).

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

Equatorials (6-inch).—" Lee " at 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 microscope-micrometer, constructed for measuring the Transit of Venus photographs, has been altered and adapted for the measurement of Stellar photographs.

A seismograph, made in San Francisco, from Professor Ewing's design, has been recently presented to the Observatory by Mr. Mateo Clark.

The annual comparison of the books and manuscripts with the Catalogue has been made, and one book is missing in addition to the two mentioned in the last Report, which have been struck off as "Lost." A MS. volume ("Observations of the Total Solar Eclipse of 1860") is on loan to Mr. E. J. Lowe, one of the observers of that eclipse.

II.—Astronomical Observations :—

Transit-Circle.—An amalgamated copper bottom was fitted to the mercury trough used in reflexion observations, on 1889 September 26, and the result has been very satisfactory. Observations are made with much greater facility and convenience, and also with greater accuracy, the mean difference between two bisections of a star's image having been reduced from 0″·80 to 0″·56. A new trough, entirely of copper, is now being constructed to replace the present one of iron. The reflector in the central cube of the instrument was regilded on 1889 December 10. The object glass of the transit-circle will probably require repolishing, as the interior surfaces of the lenses appear to have been affected by moisture.

The Personal Equation Instrument has not been recently used ; but it is proposed to determine with it the variation of personal equation with stellar magnitude, by the use of very small holes in metal plates (kindly supplied by Mr. E. J. Spitta, F.R.A.S.), the intensity of the light being varied by means of a wedge photometer, which has been made by Messrs. Troughton and Simms for this purpose, and also for photometric observations of eclipses of Jupiter's satellites.

The same rules as before have been adopted in observing the Sun, Moon, planets, and fundamental stars ; and no change has been made in the Working Catalogue of other stars prepared early in 1887, although it is probable that some considerable modifications must shortly be made in this part of our work to meet the requirements of the Photographic Chart of the Heavens. The Annual Catalogue of stars observed in 1889 contains 1,650 stars.

The following statement shows the number of observations made with the Transit-Circle in the year ending 1890 May 10 :—

Transits, the separate limbs being counted as separate observations	5,954
Determinations of collimation error	305
Determinations of level error	379
Circle observations	5,792
Determinations of nadir point (included in the number of circle observations)	379
Reflexion observations of stars (similarly included)	629

About 56 transits (included in the above number) have been observed with the reversion-prism eyepiece, to determine personality depending on the direction of motion.

At the request of Dr. Gill, special attention has been paid to the oppositions of the minor planets Victoria and Sappho. Victoria has been observed 15 times on the meridian, and Sappho 9 times; while 244 observations have been made of 41 comparison stars for Victoria, and 151 observations of 42 stars for Sappho. At the request of Dr. Auwers, observations of the Sappho stars will be renewed in the autumn of this year; and an investigation made of the variation of personality with magnitude, for use in reducing the observations to a uniform system.

As regards the computations :—

The transits are completely reduced (so as to exhibit mean R.A. 1890·0) to March 28, means of limbs and wires being taken to May 8. The copy for press is practically complete to the end of 1889, and is well advanced for observations made in the present year.

The investigation of personal equations is completed for 1889, and the values accord closely with those of previous years.

The circle observations are completely reduced to March 28, and the apparent N.P.D. is formed to April 27, circle readings, &c. being complete to date.

The apparent correction for discordance between the nadir observation and stars observed by reflection is $+0''{\cdot}07$. As before no correction has been applied for this discordance, which is virtually included in the correction for R—D.

Determinations of the astronomical flexure of the telescope by means of the collimators on 1889 May 14, 1890 January 14, 15, and April 9 (two determinations) gave the following results :—

$$+0''{\cdot}26,\ +0''{\cdot}05,\ +0''{\cdot}28,\ +0''{\cdot}38, \text{ and } +0''{\cdot}27.$$

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 1889; and the ledgers of mean R.A. and N.P.D. of stars, and the geocentric and heliocentric errors for the planetary results are all completed for 1889.

The R—D correction is found to be $-0''{\cdot}012 + 0''{\cdot}677$, Sin Z D, agreeing well with that found in previous years, though it is to be noted that before 1888 the rigorous method of least squares was not used. The effect of the actual method of computation however is not large, and the close accordance of the following values of the coefficients for the periodic term from 1883-1889 is valuable evidence of the stability of the instrumental conditions.

1883 + 0″·70	1886 + 0″·73	1888 + 0″·75
1884 + 0″·66	1887 + 0″·68	1889 + 0″·68
1885 + 0″·69		

The Colatitude of the transit-circle as found from the observations of 1889 is 38° 31′ 22″·05, differing by + 0″·15 from the adopted value. The correction to tabular obliquity of the ecliptic from solar observations in 1889 is + 0″·06, a smaller positive quantity than usual, but not such a conspicuous exception as the negative value −0″·28 found in 1888. The discordance between the results from the summer and winter solstices is + 0″·06, indicating that the mean of the observed distances from the pole to ecliptic is too small, by + 0″·03. The reading of the front court thermometer has been used in computing refraction for these observations ; but the excess of its readings over those of the ordinary exterior thermometer was not so large as in previous years, the monthly mean ranging from + 0°·1 in January to + 2°·4 in June. It is possible that the near neighbourhood of the hut for the portable transit mounted in the front court has had some effect on the readings of the front court thermometer. The post carrying the thermometer was on 1890 February 28 planted at a greater distance from this hut.

The mean error of the Moon's tabular place (computed from Hansen's lunar tables with Newcomb's corrections) is only + 0ˢ·010 in R.A. and + 0″·12 in longitude as deduced from 92 observations in 1889. These mean errors have always been positive since the introduction of the corrections to Hansen's tables in 1883, but it is reassuring to find that the apparent tendency to increase shewn by the observations in 1887 (R.A. + 0ˢ·059, Longitude + 0″·66) and 1888 (R.A. + 0ˢ·090, Longitude + 1″·21) is not confirmed in 1889. The mean error in N.P.D. is − 0″·57.

The computations for the Ten-Year Catalogue were announced in the last Report to be practically complete, and the Catalogue has since been published. Mr. Downing and Professor S. Newcomb, in papers communicated to the Royal Astronomical Society, have compared the places of the standard stars with those at present adopted in the Berlin Jahrbuch, in the Connaissance des Temps, and in the American Ephemeris, and with those of the fundamental Catalogue of the Astronomische Gesellschaft ; and find further evidence that the method of retaining only 12-hour groups of observations has been completely successful in eliminating the periodic errors from the clock star list.

The three thermometers in the horizontal shutter opening of the transit-circle room have been read simultaneously with the other thermometers about 150 times since the last Report. The readings taken in the years 1888 and 1889 have been discussed, and it is found that the distribution of temperature in the room is not quite symmetrical, although the thermometers have only been read on occasions when all the shutters had been open for some time. Calling the thermometer in the Front Court F, the ordinary exterior thermometer E, the three at the south, north and middle of the horizonal shutter opening S, N and M respectively, and the interior thermometer I, it is found that when F reads 32° the others exceed it by the following quantities, in the order E, S, N, M, I:— 0°·3, 1°·0, 1°.4, 2°·0, 3°·8 : and that with every 10° rise in

external termperature, these excesses increase with sensible uniformity by the amounts 0°·30, 0°·33, 0°·39, 0°·43, 0°·66. To eliminate the effects of uncorrected index error, the thermometers N and S were interchanged in 1890 January, but the subsequent readings shew that the index-errors are very accurately known. The effect of the direction of the wind upon the readings of the thermometers has not yet been considered.

Altazimuth.—The total number of observations made in the year ending 1890 May 10 is as follows :—

Azimuths of the Moon and stars	268
Azimuths of Mark I.	151
Azimuths of Mark II.	216
Azimuths of Mark III.	14
Zenith distances of the Moon	123
Zenith distances of Mark I.	145
Zenith distances of Mark II.	218
Zenith distances of Mark III.	16

The long focus lens for the observation of Mark II. (distant about 1,060 feet) was finally mounted by Messrs. Troughton and Simms on 1889 May 24, and the mark has since been regularly observed. The observation of Mark III. was discontinued after 1889 June 5.

With the reversion prism eyepiece 429 chronographic and 203 eye-and-ear double transits of the second limb of the Sun or Moon have been observed to determine the effect of apparent direction of motion on personality.

The altazimuth observations are completely reduced to March 30.

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.
1^h to 2^h mean solar time	0	2
2^h to 3^h ,,	0	8
3^h to 4^h ,,	4	9
4^h to 5^h ,,	5	6
5^h to 6^h ,,	5	10
6^h to 9^h ,,	21	4
9^h to 12^h ,,	26	0
12^h to 15^h ,,	19	0
15^h to 18^h ,,	12	3
18^h to 19^h ,,	3	6
19^h to 20^a ,,	4	6
20^h to 21^h ,,	1	4
21^h to 22^h ,,	0	5
22^h to 23^h ,,	0	0

The whole number of places of the Moon observed with the transit-circle is 100 or 8·0 per lunation, and with the altazimuth 63 or 5·3 per lunation.

The Moon's diameter has been measured with the transit-circle 3 times in R.A. and 7 times in N.P.D.

Clocks and Chronographs.—The Sidereal Standard was cleaned in October, and the clock "Hardy" in January. The Mean Solar clock was cleaned in 1889 May, after the disturbance caused by the renewal of the telegraph wires and batteries on their transfer to the Post Office authorities. The clocks are at present all in good order.

Reflex Zenith Tube.—Since the date of the last Report, 33 double observations of γ Draconis have been made and completely reduced to the end of 1889.

The new copper amalgamated mercury trough is found to work very well, and the star can now be observed much more easily than before. The observations made with the instrument have recently been scrutinized by Mr. Lane Poor in the Astronomical Journal, but with no more satisfactory results than before.

Equatorials.—The Lassell, South-east, Sheepshanks, and Shuckburgh equatorials are in good working order. Great difficulty has been experienced at times in turning the South-east Dome, and a careful examination recently made suggests that this may be largely due to the irregular shape of the cannon balls on which it rolls, and to a sagging of the dome curb in some parts, especially near the shutter opening, where it appears to have broken away from the upright beams which tie it to the structure. It is proposed to substitute properly turned spheres for the cannon balls, and to strengthen the connections between the curb and the framework of the dome. An enlargement of the shutter-opening is also advisable for the accommodation of the new 28-inch refractor.

The tube for the 28-inch refractor, which is of special construction, has been made by Sir H. Grubb in preparation for the object-glass which is now being figured. The experimental 4-inch object-glass referred to in the last report was mounted on the Sheepshanks' equatorial, and 18 photographs were taken with it last summer, the lenses being separated for photographic achromatism, and the crown lens reversed to correct for the spherical aberration introduced by the separation. The best distance of separation was determined, and the photographs obtained were found to be quite satisfactory. The completion of the 28-inch object-glass has been delayed presumably by the pressure of work on the 13-inch photographic telescopes, which have engaged so much of Sir H. Grubb's attention, but it is hoped that the new refractor will be ready for mounting very shortly.

The $12\frac{3}{4}$-inch refractor which will be dismounted shortly would be very useful for the observation of comets, occultations, and phenomena, for which it is well adapted. It might with advantage be mounted on the Lassell equatorial in substitution for the

much heavier tube and cradle of that instrument, the provision for rotation of the mirror and tube (which necessarily adds greatly to the weight) being dispensed with. The tube of the refractor would, I believe, provide a good attachment for a large mirror, $3^{m}\cdot43$ (11^{ft} 3^{in}) in focal length, which Mr. Common has generously offered to make for the Observatory. Reference has already been made to the expediency of mounting the Lassell equatorial at a greater elevation above the ground.

The 13-inch photographic refractor, with 10-inch guiding telescope by Sir H. Grubb, has been lately mounted in the new 18-foot dome over the Computing rooms, and one or two trial photographs have been taken with it. The definition appears to be very good for stars near the centre of the field, but the marginal images might perhaps be improved by a slight readjustment of the lenses.

Since the date of the last report, 14 occultations of stars by the Moon (9 disappearances and 5 re-appearances) and 13 phenomena of Jupiter's satellites have been observed with the equatorials, or with the altazimuth. These observations are completely reduced to the end of 1889. The occultation of Jupiter by the Moon on August 7 was observed with 5 instruments. The Lassell equatorial was rendered almost useless on this occasion by the surrounding trees, but the re-appearance of two satellites was observed. The trees often prevent the use of this equatorial for observing comets, occultations and phenomena of Jupiter's satellites, especially at the present time, when Jupiter is very low at opposition.

Comets have been observed with the Sheepshanks equatorial on 11 nights as follows :—Comet *e* 1889 on 6 nights, Comet *d* 1889 on 1 night, Comet *a* 1890 on 4 nights.

The conjunction of Mars and Saturn on September 19 was observed with the South-east equatorial under unfavourable atmospheric conditions. The planets could be observed in the same field by clamping the telescope and allowing them to transit by diurnal motion ; and the difference of N.P.D. was within the range of the telescope micrometer. Nineteen differential observations of R.A. and N.P.D. were thus made.

III.—Spectroscopic and Photographic Observations :—

For determinations of motions of approach or recession of stars 457 measures have been made of the displacement of the F line in the spectra of 26 stars, and 20 of the *b* line in the spectra of 5 stars, besides comparisons with the spectra of the Moon, the Sun, or the sky, as a check on the general accuracy of the results. Observations of Algol on 7 nights confirm as far as they go the previous results indicating orbital motion. The observations of Spica made in past years are found by Professor Bakhuyzen to be tolerably well represented on the hypothesis of orbital motion with a period of 4^{d} $0^{h}\cdot356$ agreeing well with that recently discovered by Dr. Vogel's photographic method. As the series of observations with the $12\frac{3}{4}$-inch refractor

(extending over 15 years), will be shortly brought to a conclusion, it is proposed to discuss them with a view to the detection of orbital motion, whether of long or short period, there being indications of this in the case of several stars.

The spectra of R Andromedæ, χ Cygni, and Uranus have been examined on several occasions, and Comet *e* 1889 on 1 night. The spectroscopic observations of all kinds are completely reduced.

In the year ending 1890 May 10, photographs of the Sun have been taken at Greenwich on 212 days, and of these 439 have been selected for preservation, besides 13 photographs with double images of the Sun for determination of zero of position.

For the year 1889 Greenwich photographs have been used on 173 days, and photographs from India and Mauritius filling up the gaps in the series on 182 days, making a total of 360 out of 365 on which photographs have been measured in this year.

The Sun has been free from spots on 211 days in the year 1889, the longest spotless period being October 23 to December 11. There were also eight other spotless periods of more than a fortnight. The mean daily spotted area in 1889 was 78, as compared with 89 for 1888 : but the mean daily area for the latter half of the year was nearly twice as great as for the earlier half, being 103 as compared with 53. Again, the mean distance of spots from the equator was 5°·46 in the first six months, and 14°·72 for the last six ; and both these facts thus point to the middle of the year 1889 as a well defined date for the Sun-spot minimum.

The photographic reductions are complete to 1890 January 6, and the copy for press to 1889 December 31 is in the printer's hands.

Photographs from India and Mauritius have been received from the Solar Physics Committee and have been measured as far as 1890 February 17 and February 14 respectively.

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

Ledgers of the positions and areas of spots for the years 1882, 1883, and 1884 are being formed. Similar ledgers for the years 1878–1881 (including the results from the Indian photographs, measured under the direction of the Solar Physics Committee), have been completed, and the mean results formed.

Melbourne photographs, available for filling up gaps in the series in the years 1875 and 1876, have been measured, and the reduction attempted ; but it appears, from an examination of the results, that the information received as to the orientation of the plates is incorrect, and until further particulars are obtained from Melbourne the reductions cannot be proceeded with. All the available photographs taken at Harvard College during the same years have now been measured and completely reduced, 64 having been measured in the past year.

The discussion of personality in measurements of 8-inch photographs by 9 observers, and the discussion of probable error in measurements of 4-inch photographs have been completed and published in the Photographic Results for 1888.

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, thanks to the two additional copper gas stoves mentioned in the last report, except in February and part of March, when the gas supply became bad. The defect was remedied by opening the ground in the Park and cleaning the gas pipes.

Recent measures shew a distinct improvement in the resistance of the earth current wires. Last year the values ranged for the Angerstein Wharf—Lady Well circuit, 7½ miles in length, from 217 to 267 ohms : in the present year the corresponding figures are 174 to 216. For the 5-mile circuit Blackheath—North Kent East Junction, the resistance is 173 to 199 ohms instead of 197 to 217 ohms.

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 1889. The time-scales for declination, horizontal force, and vertical force are complete to the end of 1889, 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 1889 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 1889. The temperature of the magnet basement at every hour has been read off from the sheets of the Richard thermograph to the end of 1889, and the daily and hourly means have been taken.

The following are the principal results for the magnetic elements for 1889 :—

Mean declination . . .	17° 34′·9 West.
Mean horizontal force . .	3·9494 (in British units). 1·8210 (in Metric units).
Mean dip	67° 22′ 52″ (by 9-inch needles). 67° 23′ 58″ (by 6-inch needles). 67° 25′ 36″ (by 3-inch needles).

In the year 1889 there were only two days of great magnetic disturbance, but there were also about twenty other days of lesser disturbance, for which tracings of the

photographic curves will be published, as well as tracings of the registers on four typical quiet days. The practice of publishing copies of the register on disturbed days, followed at this observatory since 1882, has been recently adopted at the Parc St. Maur Observatory ; but the days selected at the two places have not generally been the same. Consequent on a suggestion made by Mr. Ellis to the International Meteorological Congress at Paris in 1889, it has now been arranged with M. Mascart that these days shall be selected in concert, and the list for 1889 has already been thus prepared. Direct comparison of the results at the two places will thus be greatly facilitated ; and it is hoped that other Observatories will soon accept the same arrangement. By request of Professor Rücker, concerted action will also be developed in another direction. Several typical quiet days are to be selected in each month for determination of the diurnal inequality, so that the Greenwich results may be compared with those found at Falmouth, Kew, Stonyhurst, and other places.

The results for horizontal and vertical force, as published in the annual Volumes since 1883, have been satisfactorily corrected for temperature ; and for all years up to 1863 corrected results have been published in the Volumes for 1859 and 1867. In 1864 observations were interrupted by the construction of the basement. No deductions of daily and hourly values from the photographic records of the three magnetic elements have yet been published for the years 1865–1867, and the temperature corrections for horizontal and vertical force in the years 1868 to 1882 have been neglected in the published Volumes as presumably insignificant. But it has since been found that the correction is not negligible, and it is now proposed to publish results for 1865–1867, and corrected mean daily and hourly values of horizontal force for the remaining years 1868–1882. The temperature correction to vertical force cannot be advantageously applied, and it is not proposed to deal further with the results for vertical force in these years.

V. Meteorological Observations :—

The continuous registration of meteorological phenomena has been maintained as usual, and all the instruments are in good order. The Thomson electrometer, which had been out of order since the autumn of 1888, was finally adjusted by Mr. White, of Glasgow, and brought into use again in 1889 October, the amplitude of motion of the spot of light being increased more than twofold. The comparison of the old Robinson anemometer with the larger instrument, which has been in use since 1866, has been continued during the past year.

For the sake of continuity it appears better not to make any change at present in the method of reducing the Robinson anemometer results, although Mr. Dines's

experiments mentioned in the last Report showed that the theoretical factor 3·00, employed in converting the movement of the cups into wind-velocity, is too large for high velocities.

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, and daily and hourly means are taken to the end of 1889. The table of principal changes in the direction of the wind for 1889 is completed.

The mean temperature of the year 1889 was 48°·8, being 0°·4 below the average of the preceding 48 years. The highest air temperature in the shade was 86°·6 on August 1, and the lowest 18°·7 on March 4. The mean monthly temperature in 1889 was below the average in all months excepting May, June, and November. In February and December it was below the average by 2°·4 and 2°·2 respectively, and in May above by 3°·9.

The mean daily motion of the air in 1889 was 245 miles, being 39 miles below the average of the preceding 22 years. The greatest daily motion was 736 miles on October 7, and the least 25 miles on September 3. The greatest pressure registered was 15 lbs. on the square foot on October 7.

During the year 1889 Osler's anemometer showed an excess of about 26 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 1889 by the Campbell-Stokes sunshine instrument was 1156, which is about 146 hours below the average of the preceding 12 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 0·260, constant sunshine being represented by 1.

The rainfall in 1889 was 23·3 inches, being 1·3 inches below the average of the preceding 48 years.

VI.—Printing and Distribution of Greenwich Publications :—

The volume of Greenwich Observations for 1887, and the separate copies of Results, and of three Appendices (containing respectively, I. Meteorological Reductions in the years 1869 to 1876; II. the Ten Year Catalogue 1880·0; III. a list of corrections to refraction, and a revision of ecliptic investigations 1877 to 1886) were distributed in March last.

The volume for 1888 is all in type, and the whole has been sent for press, except the Transit-Circle Tables and the Magnetic and Meteorological Introduction.

As regards the volume for 1889, the whole of the Altazimuth Section and the Spectroscopic Results are printed, and the Photographic Results are in the printer's hands.

To meet the demands made for the Volume of Greenwich Observations, and for the Astronomical Results, the impression has been increased from 260 to 270 for the former, and from 150 to 180 for the latter, commencing with the year 1888.

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

The number of chronometers and deck watches now being tested at the Observatory is 165 (121 box chronometers, 19 pocket chronometers, and 25 deck watches). The annual competitive trial of chronometers commences on July 5, and the trial of deck watches on October 25.

In the year ending 1890 May 10 the average daily number of chronometers and deck watches being regularly rated was 209, the total number received was 663, the total number issued was 703, and the number sent for repair was 368.

The annual trial of chronometers (which lasts for 29 weeks) has been rather more searching than that of last year, as the range of temperature to which the instruments have been subjected has been nearly continuous from 42° to 99°. The mean temperature of the room ranged from 50° to 67°, and in the oven the chronometers were tested at mean temperatures of 75°, 85°, and 90° to 96½°. Notwithstanding this increase of severity, the chronometers were found to compare well with those tested in former years, and the performance of the first on the list (as inferred from the trial number) has never been surpassed, and only once equalled (in 1882). The average "trial number" of the first six chronometers was 18·9, which compares favourably with the corresponding value in former years.

For the annual trial of deck watches, 1889 October 26 to 1890 February 15, 25 watches were entered, and of these 19 were purchased for the Navy, the first 13 being classed "A," or equal in performance (on the 16 weeks' trial) to an average box chronometer. The trial was four weeks longer than that of other years, and yet the performance is, on the average, better than in any previous trial, the performance of the first four watches being superior to that of the best watch hitherto tested.

Two chronometers have been tested for the Crown Agents for the Colonies ; 7 for the Indian Government ; and 2 for Dr. Gill.

Experiments have been made in the past year on the uniformity of rate in deck watches and chronometers with reference to the time elapsed since winding. In 1889 October two deck watches, one keyless, with going barrel, and the other an ordinary key-winder, with fuzee, were carefully compared several times during the day, but no

systematic variation of rate could be detected. In 1890 February, 7 watches (all keyless) were compared at 0^h, 2^h, 4^h, 6^h, &c. after winding; but again no change of rate could be detected.

A somewhat different experiment was made with the box chronometers in the annual trial. These were wound for the last fortnight of the trial on alternate days, and the rates for the days on which they were wound were compared with those of the intermediate days. No systematic effect on the rate could be detected, except perhaps in the case of one chronometer near the bottom of the list in order of merit.

On 1890 January 25, the Greenwich time-ball was not raised on account of the violence of the wind ; and on 1890 April 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. There was also a failure in the 1 p.m. signal to the Post Office on November 27, but the fault was not at the Observatory. Owing to a mistake in the numeration of seconds on the chronograph, coupled with a sudden change of rate of the sidereal standard clock, the 1 p.m. signal was erroneous on September 2, 3, and 4. On all other days it was sent out correctly.

The automatic drop of the Deal time-ball failed on 21 days owing to interruption of the telegraph connexions, and on one day high wind prevented the raising of the ball. There have been frequent failures in the return signal, the arrangements for which are not in a satisfactory state. It appears that some time ago the Post Office authorities arranged for the substitution of a hand signal for the automatic return signal, which was found not to give a sufficiently long contact. The value of the return signal has thus been greatly diminished, and I propose to revert to the automatic signal, modified as regard the duration of contact, so as to suit the arrangements of the Post Office Telegraphs. It would be desirable that this signal should be sent at as short an interval as practicable after the ball-drop so as to serve as a check on the accuracy of the time-signal.

The contact springs of the Devonport time-ball clock having been readjusted after the failure mentioned in the last Report, signals have been received regularly since 1889 May 23, except on 26 days, of which seven were Sundays. 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 63 per cent. of the 337 days of observation, under $0^s{\cdot}5$ on 94 per cent., between $0^s{\cdot}5$ and $1^s{\cdot}0$ on 5 per cent. ; and exceeded 1^s on 3 days, all of them Sundays. Six of the 17 days on which the error exceeded $0^s{\cdot}5$ were also Sundays.

The automatic signals from the Westminster clock have not been received very regularly, there having been failures on 44 days in the year ending 1890 May 10. The error of the clock was insensible on 39 per cent. of the days of observation ; it amounted to 1^s on 42 per cent., to 2^s on 18 per cent., and to 3^s on 1 per cent.

Observations for the determination of the longitude, Dunkerque-Greenwich, were successfully carried out in June and July, a spare wire and the services of a clerk having been courteously placed at our disposal by the Post Office authorities. Two observers, Commandant Defforges and Mr. Turner, made observations in four groups of 2 nights each, or the equivalent in half nights, interchanging between the first and second group and again between the third and fourth. The reductions are complete as far as the first approximation to the result, but the final reduction of this longitude and also of the Paris-Greenwich longitude, for which observations were made in 1888, has been delayed by the discussion of a curious discrepancy between the results obtained for clock error at one of the stations in the latter by the two instruments mounted side by side, and used by the French observer and the English observer respectively. The difference amounts to nearly $0^{s}\cdot5$, but it has not yet been found possible to say with certainty which of the instruments has given an erroneous result. The two instruments used by the Greenwich observers were set up side by side in the Front Court on 1890 April 17, and a number of observations made with them simultaneously by Messrs. Turner and Lewis, showed a perfectly satisfactory accordance. Commandant Defforges proposes to come to Greenwich very shortly to discuss the results in reference to this discrepancy in concert with the Greenwich observers.

By request of the French observers, the difference of latitude between Greenwich and Paris was determined in July by simultaneous observations, with similar instruments. The result inferred for Greenwich is within $0''\cdot1$ of the adopted value.

During last summer, Lieutenants A. M. Field and H. E. Purey Cust, R.N., made a series of observations on the relative advantages of the portable transit and sextant, for determining local time, their report to the Admiralty being in favour of the former.

It was mentioned in the last Report that the Indian invariable pendulums had been mounted in the Record Room under General Walker's supervision. The three pendulums have each been swung 8 times, at pressures of both 2 inches and 27 inches, and the observations completely reduced, giving the following results for number of vibrations in a mean solar day, reduced to vacuum, a temperature of 62°, an infinitely small arc, and sea-level ; the corresponding values obtained at Kew being appended for comparison :—

Pendulum.	Greenwich.	Kew.
4	86,165·54	86,166·50
6	86,065·70	86,066·61
11	86,117·04	86,117·03

A clock with a new form of compensation was tested for Mr. R. Inwards for several months during the past autumn and winter.

VIII. Personal Establishment :—

To meet the increasing demands on the Observatory in certain sections of the work, and to relieve the Chief Assistant of some of his duties of supervision, the Government have recently agreed to strengthen the Staff of the Observatory by the addition of one First-class and one Second-class Assistant, but the appointments have not yet been made, and the Staff of Assistants remains the same as at the date of the last Report. It 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. Hollis, Mr. Lewis, Mr. Nash, and Mr. Thackeray.

2nd. Division Clerk—Mr. Wickison.

Mr. Turner supervises the whole of the work of the Observatory, with full power to act in all matters during my absence. Mr. Criswick is charged with the transit reductions and miscellaneous astronomical computations, and has during the past year done much experimental work in stellar photography, and in adjusting the new 13-inch photographic refractor. 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, and the reading out of the chronograph transits. Mr. Lewis superintends the time department and chronometers, and has undertaken most of the longitude computations. Mr. Maunder is charged with the spectroscopic and current photographic observations and reductions. Mr. Hollis has undertaken the photographic measures and reductions to supplement the Greenwich record for past years, and has superintended the reduction of the pendulum observations. 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 twelve 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 comparison of the Greenwich Lunar observations with Hansen's tables (through the intermediary of Burckhardt's tables), for the years 1847 to 1861, has been completed, and the results will very shortly be published in the Monthly Notices of the Royal Astronomical Society. The computations were performed partly at the Nautical Almanac Office and partly at the Royal Observatory, by means of funds obtained at the instance of the Royal Astronomical Society from the Government Grant. Since 1862 Hansen's tables have been used in the Nautical Almanac, and the Greenwich observations of the Moon have consequently been compared directly with them, but the results, as published in the annual volumes of Greenwich Observations, require correction for an error of sign in one of the terms of Hansen's tables (amounting to $1''{\cdot}2$ at its maximum), and for the motion of the Moon in the interval between the tabular and observed times of transit. Both these corrections have been taken into account in the comparison for the years 1847 to 1861, and for 1884 and subsequent years. It is therefore desirable that the corrections to the results for the intermediate period 1862 to 1883 should be applied, in order to make the whole series strictly comparable.

In the meteorological branch, the tabulation of results for the period of the fifty years of observations which will be completed at the end of 1890, would be very useful for many purposes. In the Twenty Years' Meteorological Reductions, the values were grouped generally in months, mainly for the determination of diurnal inequalities of the thermometer and barometer. In the tables of meteorological averages now proposed, the values would be grouped by days, so as to exhibit mean values for each day of mean daily temperature, maximum, minimum, barometer, velocity of wind, frequency of gales, rainfall, and cloud, obtained from the Greenwich Observations of fifty years, 1841-1890.

Several proposals have been made to me recently for the telegraphic determination of the difference of longitude between Greenwich and stations which are important in connection with Geodetic Surveys. The Superintendent of the McGill College Observatory, Montreal, has asked for the co-operation of Greenwich in a direct determination of longitude, with a view to making that Observatory the base station for the Geodetic Survey of Canada, the Canadian Pacific Telegraph Company having offered the use of their lines and connecting cable for the purpose. A re-determination of the longitude of Washington is proposed by the Superintendent of the United States Coast Survey, and in connection with this it may be advisable to fix the longitude of Porthcurno (the terminus of the trans-Atlantic cables). Lastly, M. Otto Struve has urged the importance of re-determining with improved modern appliances

the longitude of Valentia, as the extremity of the great European arc of longitude. It seems desirable that the Royal Observatory should take part in these operations, and the experience gained in the observations for the longitude of Paris and Dunkerque would greatly facilitate the work. Some additions to our instrumental appliances would be necessary for these and other longitude determinations which it might be expedient for us to undertake in the future.

W. H. M. CHRISTIE.

ROYAL OBSERVATORY, GREENWICH.
1890 May 12.