# REPORT

OF

# THE ASTRONOMER ROYAL

TO THE

# BOARD OF VISITORS

OF THE

## ROYAL OBSERVATORY, GREENWICH,

*Read at the Annual Visitation of the Royal Observatory*, 1898 *June* 4.

GREENWICH OBSERVATIONS, 1897.

# THE BOARD OF VISITORS.

| | |
|---|---|
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The Report here presented refers to the year from 1897 May 11 to 1898 May 10, and exhibits the state of the Observatory on the last-named day.

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

The completion of the Physical Observatory by the building of the East and West wings, for which funds were provided in the Navy Estimates for 1896, was not taken in hand till 1897 October. The work is now proceeding, though delayed by failure in the supply of terra cotta. Heating apparatus to warm the whole building by means of hot air has now been fitted up, but it was not available during the winter, its completion having been delayed till the latter part of March.

No progress has been made with the construction of the Magnetic Pavilion, which is urgently required, and for which provision was made in last year's Navy Estimates. The site selected on the east side of the Observatory, at a distance of about 350 yards, was approved by Her Majesty's Office of Works, who were prepared to hand it over formally last October. The drawings of the building were ready early in October, but the contract for its construction was not entered into till early in May, just before the date of this Report. It is hoped that no further delay will now occur, and that the building will be completed this summer.

Provision was made in last year's Navy Estimates for the erection of a balcony round the building in which the 28-inch telescope is mounted, so as to give an all-round view of the sky, and after the plans had been prepared, scaffolding was put up

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last February in preparation for the works. The plans, however, were subsequently reconsidered and largely modified, and the work has not yet been commenced.

The electric light installation has been extended to the Physical Observatory, and the Altazimuth Pavilion, and telephone communication between the office rooms in the old and new buildings of the Observatory respectively has been provided by the Post Office.

Provision has been made for an Accumulator House to take the place of the shed in which the accumulators are now placed, and it has been arranged to construct this as a basement on the north-east side of the Physical Observatory, where it will be conveniently placed for connecting with the electric mains.

The principal movable instruments are thus distributed:—

At Greenwich—

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

Altazimuth D.

Equatorials (6-inch).—Cooke No. 2; Simms No. 1; Hodgson and Corbett. (The telescopes are mounted respectively on the Thompson and 28-inch Equatorials.)

Photoheliographs.—No. 3, complete, mounted on the terrace roof of the South wing of the Physical Observatory for daily photography; the tube of No. 2, and the driving clock (in use for the Personal Equation Machine).

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).

Two Hilger Chronographs.

A single prism Spectroscope.

On loan—

Transits.—A, at the Cape Observatory; C, at Montreal.

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

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

Photoheliographs.—No. 1, complete, at the Cape Observatory; No. 5, complete, and No. 2 (without the driving clock), lent to the Science and Art Department; the object-glass of No. 2 lent to Captain Hills, R.E., for observation of the Solar Eclipse of 1898 January 22; No. 4, complete, at the Madras Observatory.

Clocks.—Dent No. 1916, and Dent No. 2013, at the Cape Observatory; Dent No. 2011, at the Kew Observatory; Dent No. 2010, at Devonport; and Arnold 2, at the University Observatory, Oxford.

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

A number of photographs representative of the work of the Observatory in different branches have been sent to the Royal Photographic Society's Exhibition at the Crystal Palace. [They have been returned since the date of this Report.]

The annual comparison of books in the Libraries with the catalogue has been made, and 7 books are reported missing, besides 6 books which were reported missing last year. Three of the books missing last year have since been found. It is probable that some of the books now missing have simply been misplaced, as the shelves are very crowded, the available space being quite inadequate to meet the constant increase in the number of books. A further difficulty is experienced from the inadequate arrangements for warming and ventilating the New Library building (erected in 1881, near the Magnet House), in which it has been found necessary to store the solar and stellar photographs, as well as books and records, pending the completion of the Physical Observatory, which will contain both library rooms and store-rooms. Both books and photographs in the New Library have suffered from damp in the winter months, the damage being very serious in the case of the plates for the Photographic Mapping of the Heavens, many of which have been rendered useless through damage to the gelatine films. It is hoped that before next winter it will be possible to store these valuable photographs in the Physical Observatory, the means of warming this building throughout having at length been provided.

II.—Astronomical Observations:—

*Transit Circle.*—The Sun, Moon, planets, and fundamental stars have been regularly observed on the meridian as in previous years. The number of observations made from 1897 May 11 to 1898 May 10, is as follows:—

| | |
|---|---|
| Transits, the separate limbs being counted as one observation | 11,441 |
| Determinations of collimation error | 297 |
| Determinations of level error | 651 |
| Circle observations | 10,626 |

| | |
|---|---|
| Determinations of nadir point (included in the number of circle observations) | 638 |
| Reflexion observations of stars (similarly included) | 536 |

The annual catalogue of stars observed in 1897 contains 5,047 stars.

As regards the computations :—

The transits are completely reduced (so as to exhibit Mean R.A. 1898·0) to May 3. The copy for press of the transits for 1897 is in the printer's hands.

The investigation of personal equations is completed for 1897.

The circle observations are completely reduced to May 3. The copy for press of this section for 1897 is in the printer's hands.

The correction for R–D discordance, the error of the assumed colatitude, and the position of the ecliptic have been investigated for 1897; and the whole of the planetary reductions are complete.

The apparent correction for discordance between the nadir observations and stars observed by reflexion for 1897 was found to be $-0''\cdot27$. The results of recent years are as follows :—

| | | | |
|---|---|---|---|
| 1888 | $-0''\cdot12$ | 1893 | $-0''\cdot34$ |
| 1889 | $+0\cdot07$ | 1894 | $-0\cdot27$ |
| 1890 | $+0\cdot08$ | 1895 | $-0\cdot31$ |
| 1891 | $+0\cdot07$ | 1896 | $-0\cdot34$ |
| 1892 | $-0\cdot25$ | 1897 | $-0\cdot27$ |

The zenith-point correction is derived when possible from the mean of two reflexion observations of North Stars, two of South Stars, and the nadir observations, so that the weight given to the nadir observations is one-fifth. When no reflexion observations of stars are secured a correction of $+0''\cdot25$ has been applied to the observations of the nadir in forming the zenith-point since 1897 January 1. In other cases no correction is necessary, as the discordance in the nadir observation is virtually corrected through the constant term in the R–D correction, so that the zenith-points depend essentially on reflexion observations of stars distributed over a large range of zenith-distance.

Observations of nadir have, when practicable, been made three or more times in the same day. When these are divided into groups according to the time of day at which they are taken, changes of zenith-point are shown as follows :—

| | Civil Time. | | | |
|---|---|---|---|---|
| | $9^h$—$15^h$ | $15^h$—$21^h$ | $21^h$—$3^h$ | No. of Days. |
| 1895 - - - | +0″·29 | 0″·00 | +0″·27 | 54 |
| 1896 - - - | +0″·20 | 0″·00 | +0″·16 | 84 |
| 1897 - - - | +0″·15 | 0″·00 | +0″·17 | 108 |

As the reflexion observations of stars are usually taken between $15^h$ and $21^h$, the changes in the nadir thus indicated would to some extent explain the discordance in question.

The correction for R–D discordance, found for 1897, viz., +0″·068 +0″·104 sin Z.D. is remarkably small. The values for the last ten years are as follows :—

| | | | | | |
|---|---|---|---|---|---|
| 1888 | +0″·010 | +0″·746 sin Z.D. | 1893 | +0″·057 | +0″·703 sin Z.D. |
| 1889 | −0·012 | +0·677 sin Z.D. | 1894 | +0·057 | +0·546 sin Z.D. |
| 1890 | −0·014 | +0·556 sin Z.D. | 1895 | +0·065 | +0·414 sin Z.D. |
| 1891 | −0·013 | +0·536 sin Z.D. | 1896 | +0·056 | +0·367 sin Z.D. |
| 1892 | +0·062 | +0·576 sin Z.D. | 1897 | +0·068 | +0·104 sin Z.D. |

The observations of the zenith distances of pairs of stars directly and by reflexion, alternately on alternate nights, have been continued, but only 37 pairs (all on the south side of the zenith) have been observed in the year ending 1898 May 10. The following table gives a comparison of the results with those obtained from the ordinary reflexion observations, showing a close agreement :—

| Mean Z.D. | R. observations taken immediately before D. | R. and D. observations on different nights. | No. of pairs of observations on different nights. |
|---|---|---|---|
| ° | ″ | ″ | |
| +22 | +0·20 | +0·12 | 3 |
| +40 | +0·19 | +0·21 | 24 |
| +52 | +0·45 | +0·61 | 4 |
| +60 | +0·50 | +0·46 | 6 |

The colatitude of the transit-circle, as found from observations of about 800 stars in 1897 is 38° 31′ 21″·69, differing by −0″·21 from the adopted value.

The correction to the tabular obliquity of the ecliptic from solar observations in 1897 is +0″·21. The discordance between the results from the summer and winter solstices is +0″·12, indicating that the mean of the observed distances from the pole to the ecliptic is too small by 0″·06. The apparent correction from the observations of the Sun to the right ascensions of the clock stars is +0ˢ·065. Since 1897 January 1 a thermometer, which was mounted in a screen in the Front Court on 1896 July 18, has been used for all observations, including those of the sun.

The mean error of the Moon's tabular place (computed from Hansen's lunar tables with Newcomb's corrections) is −0ˢ·142 in R.A. and +0″·27 in N.P.D. deduced from 95 observations. These are equivalent to an error of −1″·97 in longitude and +0″·16 in ecliptic north polar distance.

The preparation of the New Ten-Year Catalogue of Stars, 1887–1896, is making good progress. The Right Ascensions and North Polar Distances for all the years have been reduced to 1890. The means have been taken for the clock stars and for 732 stars in the Berliner Jahrbuch, which were completed in advance of the rest of the Catalogue in order that the results might be communicated to Dr. Auwers who wished to use them in the preparation of a Fundamental Catalogue. Copy for press of the Catalogue has been made as far as the entry of the names of the stars, precessions, secular variations, and proper motions.

In this Catalogue the equinox of the 1872 Nine-Year Catalogue and of the 1880 Ten-Year Catalogue (carried on with the Struve-Peters precession) is adopted, although the observations of the Sun appear to give a correction of 0ˢ.046, as it is considered that this change is largely due to the differences of personality in observations of the Sun owing to changes of observers.

The large number of circumpolar observations in this Catalogue and in the year 1897 furnish material for the discussion of the colatitude and refraction. The following table exhibits the difference between the N.P.D. from observations above and below pole as given by the Ten-Year Catalogue, 1880, the New Ten-Year for 1890, and the Annual Catalogue for 1897 , according as the observations are reduced with Bessel's refractions or with the Pulkova refractions, arranged in zones of five degrees.

Excess of N.P.D. above Pole.

| N.P.D. | Bessel's Refractions. | | | Pulkova Refractions. | | |
|---|---|---|---|---|---|---|
| | 1880 Catalogue. | 1890 Catalogue. | 1897 Annual Catalogue. | 1880 Catalogue. | 1890 Catalogue. | 1897 Annual Catalogue. |
| ° ° | ″ | ″ | ″ | ″ | ″ | ″ |
| 0— 5 | −0·40 | −0·32 | 0·00 | −0·15 | −0·07 | +0·25 |
| 5—10 | −0·04 | +0·07 | −0·03 | +0·23 | +0·34 | +0·24 |
| 10—15 | +0·03 | +0·07 | +0·48 | +0·31 | +0·35 | +0·76 |
| 15—20 | +0·17 | +0·22 | +0·68 | +0·50 | +0·53 | +1·00 |
| 20—25 | +0·19 | +0·11 | +0·36 | +0·55 | +0·47 | +0·72 |
| 25—30 | −0·19 | −0·19 | +0·26 | +0·23 | +0·23 | +0·66 |
| 30—35 | −0·52 | −0·33 | +0·26 | −0·01 | +0·18 | +0·77 |
| 35—41 | −0·40 | −0·38 | | +0·20 | +0·22 | |

In view of the very close agreement of the 1880 and 1890 Catalogues it is proposed to re-examine the division errors. A short note comparing the new Catalogue with several other Fundamental Catalogues is given in the Monthly Notices for 1898 April.

*Altazimuth.*—Observations with the old altazimuth were discontinued on 1897 November 29. The total number of observations made between 1897 May 11, and 1897 November 29, is as follows :—

| | |
|---|---|
| Azimuths of the Moon and Stars | 94 |
| Azimuths of Mark I. | 47 |
| Azimuths of Mark II. | 59 |
| Zenith distances of the Moon | 47 |
| Zenith distances of Mark I. | 48 |
| Zenith distances of Mark II. | 54 |

The total number of places of the Moon observed with the transit-circle is 111, or 8·3 per lunation, and with the altazimuth 25, or 4·3 per lunation, from May to November.

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

*The New Altazimuth.*—At the date of the last Report the axis of the instrument had been stiffened and modifications were being made in the friction rollers which relieve the weight of the instrument on the Ys. After several attempts this was arranged very satisfactorily in August by putting live rings (ball bearings) round the axis, the rings being suspended by strong springs. In this way a force tending to *pull* was substituted for one tending to *push* the telescope out of the pivots.

Changes have been made in the illumination of the field and the microscopes. A small rectangular prism has been cemented to the centre of the object glass, reflecting the light from a small electric lamp into the field. A small electric lamp for each microscope has been found to give a better illumination than was obtained by reflecting the light of a large central lamp by means of prisms. Steps for observing stars by reflexion and the nadir have been made. These also serve to shield the circles, the microscopes, and the uprights from the Sun and from radiation. The values of the revolutions of the micrometer screws and the intervals of the wires have been measured. The division-errors of the two circles have been determined for the five-degree divisions, and a provisional determination has been made for those of the single degrees. As one circle can be fixed in any position relatively to the other, any equal angular intervals can be compared on the two circles and the division-errors of both circles obtained by a symmetrical method free from cumulative error. A more symmetrical determination of the division-errors of the single degrees will be made shortly.

The instrument was brought into working order in December, when the observing steps were completed, but regular observations with it are only now being commenced, as the determination of division-errors and the observations necessary to test thoroughly the stability of the instrument have occupied several months. The instrument has been tested in reversed positions and in different azimuths. The reversing and rotating arragements are found to work quite satisfactorily. A new barometer has been obtained for use with the instrument and mounted on the pier of the North Collimator. Provision has been made in the Navy Estimates for a new chronograph for use with the altazimuth. At present the transit-circle chronograph is used, but there are inconveniences arising from its distance and from the risk of a confusion of observations, especially when the altazimuth is used on the meridian.

From 1897 November 5 to 1898 May 10, the following observations have been made with the instrument, mostly in the meridian :—

| | No. of observations. |
|---|---|
| Collimation error | 79 |
| Level error | 192 |
| Azimuth error | 23 |
| Nadir | 334 |
| R.A. of Stars | 94 |
| N.P.D. of Stars | 67 |
| R.A. of Moon | 6 |
| N.P.D. of Moon | 5 |

On one night observations of the Moon, stars, and adjustments were made in the prime vertical.

The observations on the whole show satisfactory stability in the instrument, the collimation, level, and azimuth being steady. Long series of observations of the nadir point have been made to test the stability of the microscopes and of the instrument generally for zenith distance observations. Discordances were found in the results given by the two circles, which, after a considerable time had been spent, were traced to the wheel carrying one of the sets of microscopes, which was found to have worked loose. This was remedied recently and the accordance in the results from the two circles appears now to be satisfactory. But large changes in the readings of the individual microscopes are found on turning the instrument into different azimuths, which, however, would not affect the observations, as the microscopes come back to sensibly the same readings for the same azimuth. As, however, this implies a displacement of the microscopes relatively to the circles when the instrument is turned, Mr. Simms is considering whether the supports of the microscopes and pivots can be stiffened.

*Clocks and Chronographs.*—The Standard Sidereal clock dropped seconds on several days in September. The contact springs were taken off and cleaned September 12–16, and the clock has gone satisfactorily since that date.

The electric dials sympathetic with the Mean Solar clock have been reconstructed according to the plan mentioned in the last Report. Electric dials have now been fitted up in the North and South rooms of the New Physical Observatory, and the wiring arrangements have been made so that similar dials can be fitted up in the East and West rooms as soon as they are ready for occupation. New wires have also been laid to enable the Sidereal Standard clock to work sympathetic dials, or to register

on chronographs in the New Altazimuth building and in the Thompson Equatorial Dome.

*Reflex Zenith Tube.*—Since the date of the last Report, 13 double observations of $\gamma$ Draconis have been made.

*Equatorials.*—During the year ending 1898 May 10, 37 disappearances and 36 reappearances of Stars occulted by the Moon have been observed by one or more observers. These include occultations of the Pleiades on 1897 July 23, and on 1898 January 3.

Comet *b* 1897 (Perrine) was observed with the Sheepshanks Equatorial on 5 nights and Comet *b* 1898 (Perrine) on 4 nights.

*Thompson Equatorial.*—At the date of the last Report, the 26-inch photographic object-glass of this equatorial was being tested by means of photographs taken inside and outside of the focus, the separation between the lenses being varied. As the result of these tests, it appeared that there was coma in the images at a distance from the centre of the field, which could only be got rid of by an alteration of the curves. The object-glass was returned to Sir Howard Grubb for this alteration last August, and is still in his hands. [Since the date of this Report the object-glass has been received here, and has been mounted. It appears from the photographs since taken that the coma is now corrected, but that a slight re-figuring is required. Sir Howard Grubb is doing this at the Observatory.] The 30-inch Cassegrain reflector, mounted on the other end of the declination axis, has been adjusted, and some photographs of the Moon, of star clusters, and of star fields have been obtained at the secondary focus. The focal length of the mirror is somewhat longer than that for which the tube was designed, and as it is not practicable to take photographs with it in the primary focus, Dr. Common proposes to supply another mirror of the correct focal length, 11 feet 3 inches. The photographic spectroscope has been completed, and is mounted at the back of the cell of the 30-inch mirror, but the diagonal prism to reflect the rays from the Cassegrain telescope into the collimator has not yet been mounted and adjusted. The Thompson 9-inch photoheliograph was dismounted last December for use in India in the observation of the eclipse of the Sun of January 22, a concave secondary magnifier of 3 inches diameter being substituted for that in ordinary use. A series of photographs of the corona and of the partial phase, on the scale of 4 inches to the Sun's diameter, were obtained with it at Sahdol, in Central India. The instrument was brought back in March, and is now being mounted again on the tube of the 26-inch telescope.

*The 28-inch Refractor.*—This instrument was in use for micrometric measurements from 1897 May 11 to 1898 May 10, with the exception of about seven weeks, from August 5 to September 23, when it was used for photography, the crown lens being reversed. During the year 273 double stars have been measured, each star being measured on the average on two nights; the distance between the components of these stars is less than 1″·0 in 156 cases, and in 63 less than 0″·5. Among the stars whose distance is more than 1″·0 apart are included a number which are difficult to measure on account of the great difference of magnitude of the components. Among the many interesting stars measured the following may be specially mentioned.

| | Distance. | Magnitudes. | | Distance. | Magnitudes. |
|---|---|---|---|---|---|
| | ″ | | | ″ | |
| Sirius | - 5·0 | 1 and 10 | β 1255 | - 1·5 | 6 and 13 |
| Procyon | - 5·0 | 1 „ 10 | Σ 1728 | - 0·1 | 6 „ 6 |
| β 1071 | - 5·0 | 3 „ 14 | O Σ 269 | - 0·1 | 6½ „ 7 |
| β 1014 | - 1·2 | 7 „ 12½ | κ Pegasi | - 0·1 | 4 „ 5 |
| β 552 | - 0·4 | 7 „ 10 | β 883 | - 0·3 | 7½ „ 7½ |

A list of unpublished measures of Burnham stars, made with the 28-inch refractor, has been supplied to Professor Burnham for incorporation in his catalogue which is now in the press.

The equatorial and polar diameters of Neptune were measured on six nights, and the position of the Satellite on ten nights.

From 1897 August 5 to September 25 the instrument was used with the crown lens in the photographic position. During this time 110 measurable images of 17 double stars were obtained on dry collodion plates. The closest of these pairs are—

| | Magnitudes. | Distance. |
|---|---|---|
| | | ″ |
| Σ 2881 - - - | 7·7 and 8·2 | 1·6 |
| Σ 2723 - - - | 6·4 „ 8·2 | 1·5 |
| Σ 2900 - - - | 6·0 „ 9·2 | 1·5 |
| Σ 2799 - - - | 6·6 „ 6·6 | 1·3 |

*Astrographic Equatorial.*—During the year ending 1898 May 10, 526 plates have been taken on 132 nights. Of these 107 have been rejected, viz.—30 because the exposure was interfered with by cloud, or because the images were too faint to show 9th magnitude stars with a 20$^s$ exposure; 16 because the plates were fogged owing to moonlight or twilight; 26 owing to bad guiding; 12 owing to wrong setting; and 23 owing to miscellaneous defects.

The following statement shows the progress made with the photo-mapping of the heavens:—

| | For the Chart (Exposure 40$^m$). | For the Catalogue (Exposures 6$^m$, 3$^m$, and 20$^s$). |
|---|---|---|
| Number of photographs taken | 363 | 147 |
| „ successful plates | 285 | 118 |
| „ fields photographed successfully | 283 | 110 |
| Total number of successful fields reported 1897 May 10 | 551 | 814 |
| Number of photographs, previously considered successful, rejected during the year | 6 | 15 |
| Total number of successful fields obtained to 1898 May 10 | 828 | 909 |
| Number still to be taken | 321 | 240 |

A number of miscellaneous photographs (included in the total number of 526 given above) have also been taken:—

| | No. of Plates. |
|---|---|
| For adjustments of the equatorial | 8 |
| Typical areas (Chart plates) | 3 |
| Typical areas (Catalogue plates) | 5 |

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

Since the numbers given above as to the number of successful photographs were prepared, an examination of all the plates on the shelves has been made, and has shown that 166 catalogue plates out of 909, and 90 chart plates out of 828, have deteriorated, owing, probably, to the effect of damp in the building in which they have

to be stored pending the completion of the new Physical Observatory. It has been explained, in the preceding section of this Report, that there is difficulty in warming this building adequately, and that the books, as well as the photographs stored there, have suffered from damp. The film has, in some cases, left the glass, and in the others shows signs of doing so. Of the 166 damaged catalogue plates, 57 have been completely measured, 23 partially measured, and 86 are not measured.

Positives on glass of all the 90 damaged chart-plates had been taken, and these are uninjured.

Of the fields still required, 197 are within 10° of the Pole, and no photographs of this part of the sky have yet been taken, the work being purposely deferred till near the epoch 1900. It is proposed to begin taking these now, and the settings of the scales for the guiding stars are partly computed.

During the year positives on glass have been made of 216 chart plates, which, with the 447 mentioned in last year's Report, gives 663 as the total number of chart plates which have been copied.

*Réseau* Gautier No. 72 was replaced by No. 80 on 1898 January 24, as the former, which had been in use since 1896 September 16, showed more scratches and pin-holes than could be conveniently stopped out.

The re-measurement of the plates placed in the reversed position in the micrometer mentioned in the last Report has been continued. During the year 46,500 pairs of images ($6^m$ and $3^m$), have been measured, as well as the diameters of the $6^m$ images. The number of quarter plates measured in the year is 774. All the direct and reversed measures have been compared. Wherever the differences amounted to more than 1″·5, the measures have been repeated, and stars overlooked in one measure have been re-measured.

The measurement of the plates is completed from Dec. 64° N. to 68° N., and for R.A. $0^h$ to $12^h$ from 68° N. to 69° N. Up to the present time 304 plates out of a total of 1,149 have been fully measured (both $6^m$ and $3^m$ images twice in reversed positions). The total number of separate stars is about 41,000, being an average of 63 stars per square degree. For the same zones the number per square degree in the Bonn Durchmusterung is 12·1, and in the Astronomische Gesellschaft Catalogue 5·8.

The investigation of the personality of the measurers in the direct and reversed positions of the plates has been completed. This personality never amounts to so

much as 0″·4, and is, in the case of most of the measurers, very consistent. The mean of a direct and reversed measure by the same measurer appears to almost entirely eliminate it. Corrections for personality are being applied in the copy for press from 64° N. to 68° N., and in order to eliminate the personality in future, it is now arranged that the same pair of measurers shall measure the $6^m$ and $3^m$ images in both the direct and the reversed positions of the plate. This practice was begun in Zone 68°.

The copy for press of the measures from Dec. 64° N. to 68° N. is nearly finished. The results there given are the means of four measures (direct and reversed measures of the $6^m$ and $3^m$ images) corrected for personality of measurement. The diameters of the $6^m$ images (the mean of two measures by different measurers) are also given. The zone and number of all stars which occur in the Bonn Durchmusterung is given opposite the measures, as this will facilitate identification of the stars, and will also bring together material for the comparison of the magnitudes of the B.D. with the diameters of the images.

No plate constants have been determined during the year, but the standard co-ordinates have been computed from the Christiania Catalogue for the stars between Dec. 68° and 69° from $0^h$ to $20^h$ on one series of plates, and $0^h$ to $22^h$ $30^m$ on the other.

III.—Spectroscopic and Heliographic Observations :—

Observations with the visual spectroscope have been suspended during the past year pending the adaptation of the photographic spectroscope to the 30-inch reflector of the Thompson Equatorial.

In the year ending 1898 May 10, photographs of the Sun have been taken with the Dallmeyer photoheliograph, mounted on the terrace roof of the South wing of the Physical Observatory, on 191 days, and of these 355 have been selected for preservation, besides 9 photographs with double images of the Sun for determination of zero of position-angle. With the Thompson 9-inch photoheliograph 22 photographs of the Sun were also taken upon 12 days. Photographs to supplement the Greenwich series have been received from India or Mauritius up to 1898 February 22.

For the year 1897 Greenwich photographs have been selected for measurement on 183 days, and photographs from India and Mauritius (filling up the gaps in the series) on 181 days, making a total of 364 days out of 365 on which photographs are available.

There has been but little change in the mean daily spotted area of the Sun for the period covered by this Report as compared with the preceding one. The progress towards minimum has shown itself rather in the increase of days when the Sun was wholly free from spots—42 as compared with 6 as given in the previous Report—than in the poverty of the displays of spots on the days when the Sun's surface was disturbed.

As regards the measurement of the photographs, the Greenwich photographs have been measured in duplicate up to 1898 March 30, and the Indian and Mauritius photographs up to 1898 January 20. The reductions are complete to 1897 November 3; the copy for press of the Daily Results has been sent to the printer up to that date, and the Spot Ledger has been completed to the same date. The conversion of the measures into heliographic longitude and latitude has been effected for the Greenwich photographs as far as 1898 February 16, and for the Indian and Mauritius up to 1897 December 8.

An examination of the solar photographs stored in the New Library and in the Museum of the Physical Observatory shows that in both cases some of the photographs, both gelatine and wet collodion, have suffered from damp, spots of mildew being found on the film, though much more frequently the mildew is confined to the uncoated side of the glass.

IV.—Magnetic Observations :—

The variations of magnetic declination, horizontal force, and vertical force, and of earth currents have been registered photographically, and accompanying eye observations of absolute declination, horizontal force, and dip have been made as in former years.

Small agitations, due to the running of trains on the South London Electric Railway, the nearest point of which is at a distance of $4\frac{1}{4}$ miles from the Observatory, can be seen in the Horizontal Force and Vertical Force traces, synchronising with the disturbances in the Earth Current registers. These small effects can be traced from the year 1890, but owing to the distance of this electric railway they do not seriously interfere with the magnetic registers. A proposal which has been recently made in a Bill before Parliament to use electricity for a proposed tram-line in the neighbourhood of the Deptford Cattle Market, at a much less distance from the Observatory ($1\frac{1}{4}$ miles) would, probably, if carried out, have destroyed the value of our magnetic records, and it has been successfully opposed.

The magnetic reductions for 1897 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. The time-scales for the magnetic registers are complete; the base line values, deduced from eye observations, are entered on the sheets, and the hourly ordinates of the photographic curves for declination are read out and reduced. The temperature of the magnet-basement at every hour has been read from the Richard thermograph sheets, and the daily and hourly means have been taken. The time-scales for earth currents are laid down. The dip and deflexion observations are completely reduced.

The principal results for the magnetic elements for 1897 are as follows :—

| | |
|---|---|
| Mean declination | 16° 50′·4 West. |
| Mean horizontal force by the Gibson instrument in the Library | 3·9877 (in British units).<br>1·8387 (in Metric units). |
| Mean dip | 67° 5′·5 (by 9-inch needles).<br>67° 6′·8 (by 6-inch needles).<br>67° 7′·1 (by 3-inch needles). |

These results are to a certain extent affected by the iron in the new Physical Observatory and in the new Altazimuth Pavilion. To eliminate this effect as far as circumstances would allow, observations have been made during the past year on the site selected for the new Magnetic Pavilion in Greenwich Park, which is presumably free from any disturbing effect of iron. The Horizontal Force has been observed monthly on this site with the two deflection instruments (Gibson and Elliott), the declination occasionally with the Elliott instrument, and the dip with a Kew Dip Circle (Dover 74), kindly lent by the Science and Art Department, South Kensington.

It appears from these observations that the declination at the Observatory has been increased by 3′ to 4′ through the introduction of iron.

The mean horizontal force obtained with the Gibson instrument in the Park is 1·8366 in metric units. In the same units we have also the following differences :—

| | |
|---|---|
| Gibson in Library—Gibson in Park | +0·0021 |
| Elliott in Library—Elliott in Park | +0·0084 |
| Elliott in its usual position in Library—Elliott on Gibson Pier | +0·0060 |
| Gibson in Park—Elliott in Park | +0·0010 |

These results show a very satisfactory accordance, and further indicate that the disturbance at the usual position of the Elliott instrument is much greater than at the Gibson Pier which is only at a distance of 13 feet N.N.W. (magnetic) from the usual position of the Elliott instrument.

As mentioned in last year's Report, the collimation glass of the Elliott instrument has been securely re-fixed. The mounting of the mirror has been improved, and the moment of inertia of the deflecting magnet re-determined provisionally.

The dip as determined in the Library is less than that determined on the site in Greenwich Park with the portable dip circle, Dover 74, the difference being 6′·0 and 6′·7 respectively for the two needles employed.

The magnetic disturbances in 1897 have been comparatively trifling. There were no days of great magnetic disturbance and 16 days of lesser disturbance. Tracings of the photographic curves for these days, selected in concert with M. Mascart, will be published in the annual volume as usual. The calculation of diurnal inequalities from 5 typical quiet days in each month has been continued.

Information and results of observations have been supplied in reply to inquiries on various occasions during the year.

Dr. Van Rÿckevorsel visited the Observatory on 1897 October 18 and took notes of the Magnetic and Meteorological reductions. Some unpublished results of Magnetic Declination for 1865, 1866, and 1867 were supplied to him.

Dr. Lockyer has recently spent some time in the Observatory, studying the magnetic methods and instruments.

V.—Meteorological Observations :—

The meteorological instruments are all in good order. The registration of atmospheric pressure, temperature of the air and of evaporation, pressure and velocity of the wind, rainfall, sunshine, and atmospheric electricity has been continuously maintained.

The driving wheel of Osler's anemometer clock was repaired by Kullberg, on 1897 July 19.

In the early part of this year the meteorological ground has again been cumbered with masses of terra cotta for the new wings of the Physical Observatory.

The new sunshine recorder which has been in use since the beginning of 1897 gave for that year a total record of 1,543 hours of sunshine, as compared with 1,575 hours recorded at Kew and 1,279 hours at Bunhill Row. A comparison of the old and new glass balls was maintained throughout 1897, and the results for each month are exhibited in the following table :—

| | | New Ball. | Old Ball. | Excess with New Ball. |
|---|---|---|---|---|
| 1897 | January. | 19·8 | 10·8 | 9·0 |
| | February | 34·1 | 24·2 | 9·9 |
| | March | 123·4 | 101·7 | 21·7 |
| | April | 144·7 | 124·8 | 19·9 |
| | May | 251·6 | 220·6 | 31·0 |
| | June | 178·3 | 145·8 | 32·5 |
| | July | 252·7 | 213·7 | 39·0 |
| | August | 219·8 | 183·9 | 35·9 |
| | September | 114·5 | 90·8 | 23·7 |
| | October | 111·7 | 85·9 | 25·8 |
| | November | 41·7 | 29·7 | 12·0 |
| | December | 50·3 | 36·5 | 13·8 |
| Totals for the year | | 1542·6 | 1268·4 | 274·2 |

The deterioration of the old ball is fully discussed by Mr. Curtis in the Quarterly Journal R.Met.Soc., Vol. XXIV.

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 and completely reduced for the barometer, and read out and partly reduced for the dry and wet bulb thermometers to the end of 1897. The table of principal changes of the wind for 1897 is complete.

The mean temperature of the year 1897 was 50°·3, being 0°·9 above the average for the 50 years 1841–1890.

During the twelve months ending 1898 April 30, the highest daily temperature in the shade recorded on the open stand was 90°·2 on June 24. The highest reading recorded in the Stevenson screen was 87°·4 on the same day. The monthly mean

temperatures were in excess of their corresponding averages in every month with the exception of May, September, and March. In January the excess amounted to 5°, the mean temperature for that month being 43°·6. In the preceding 57 years there is one instance only of a higher mean temperature occurring in January, viz., in 1884, when it was 43°·9. A mean value equal to the present January value (43°·6) was also recorded in two other years (1875 and 1890). The winter of 1897–1898 was remarkably mild throughout, and the temperature of the air fell to freezing point (or below) on 29 days only,—10 of these occurring in March and 7 in December. The lowest temperature recorded during the winter was 23°·3 on December 24. [The lowest temperature recorded in January was 30°·0.] The mean temperature for the five months 1897 October to 1898 February, was 44°·6, being 2°·4 in excess of the average value. During the whole period of 57 years (1841 to 1897) this value has only been exceeded three times, viz., in the winter of 1876–1877, when the mean for the five months was 45°·8, in the winter of 1845–1846, when it was 44°·8, and in the winter of 1865–1866, when it was 44°·7. A mean value of 44°·6 (the same as that for the present year) was also recorded in the winter of 1848–1849, and in that of 1868–1869.

The mean daily horizontal movement of the air in the twelve months ending 1898 April 30 was 288 miles, which is 7 miles above the average for the preceding 30 years. The greatest recorded movement was 879 miles on December 29, and the least 68 miles on November 23. The greatest recorded pressure of the wind was 26 lbs. on the square foot on November 29 and March 24, the extreme hourly velocity being 49 miles on November 29.

During the year 1897 Osler's anemometer showed an excess of 37 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 the twelve months ending 1898 April 30, by the Campbell-Stokes instrument was 1,529 out of the 4,454 hours during which the Sun was above the horizon, so that the mean proportion of sunshine for the year was 0·343, constant sunshine being represented by 1.

The rainfall for the year ending 1898 April 30 was 17·33 inches, being 7·21 inches less than the 50 years' average. The number of rainy days was only 149. This is a very small annual rainfall; the three smallest falls during the preceding fifty years being 16·38 inches in 1864, 17·61 inches in 1867, and 17·70 inches in 1858.

VI.—Printing and Distribution of Greenwich Publications :—

Satisfactory advance has been made in the printing since last year, and arrears are gradually being overtaken.

The copies of the Greenwich Observations for 1894 were distributed in September.

The copies of the volume for 1895 have just been received and are being distributed.

As regards the volume for 1896, the whole of the heavy sections of Transits and Meridian Zenith Distances is printed, and proofs of the Ledgers have been read and returned to the printers. The whole of the Altazimuth Section, the Heliographic Results, and the Magnetic and Meteorological Results are printed, with the exception of the plates and the Introduction for the last-named section.

As regards the volume for 1897, the manuscript of the Transits and Zenith Distances has been sent to the printers. The whole of the Altazimuth Section is printed, and the Heliographic Results as far as April 4. The Rates of Chronometers and Deck Watches in the Annual Trial 1897–98 are also in type.

The amount of printing in the sections of Transits and Meridian Zenith Distances in 1897 is diminished to about one-third of that in previous years, in accordance with the scheme adopted last year, by which full details of the observations are only given in the case of planets and fundamental and adjustment stars. This will greatly relieve the pressure in preparing the copy for press, and in passing the sheets through the press.

VII.—Chronometers, Time Signals, Longitude Operations, &c. :—

The number of Government marine chronometers and deck-watches now being tested at the Observatory is 372, viz., 252 box chronometers, 32 pocket chronometers, and 88 deck-watches. In addition to these, there are on trial for the Indian Government 3 box chronometers, and 3 pocket chronometers, and 3 box chronometers are being tested after repair. In the year ending 1898 May 10 the average daily number of chronometers and deck-watches being rated was 463 ; the total number received was 1,202, the total number issued 1,135, and the number sent for repair 463. These include 11 box chronometers, 6 pocket chronometers, and 1 deck-watch for the Indian Government. The trial of 42 chronometers for the Indian Government, mentioned in the last Report, was finished in 1897 June, and 17 of the chronometers were purchased.

For the annual trial of chronometers, which lasted 29 weeks, with a range of temperature from 41° to 102°, 98 chronometers were sent in, and of these, 51 have been purchased for the Navy, and 3 for the Indian Government. The performance of the chronometers is remarkably good, and the improvement shown in recent years is maintained.

The deck-watches in the annual trial were confined to class A, and were tried in the positions "dial up," "pendant up," "pendant right" and "pendant left"; 150 were entered, and of these, 37 were purchased for the Navy. The performance of the watches was very satisfactory. In consequence of the difficulty of securing accurately divided seconds' dials, the Admiralty have offered an extra premium for watches with centre-seconds dials, as these have been found as reliable as others, while the divisions are larger and more accurate. There were 15 "tourbillon" watches in the annual trial. The next competitive trial of chronometers commences on July 2, and of deck-watches on October 2.

The Greenwich time-ball was not raised on five days during the year owing to the violence of the wind. On October 10 the ball fell $2^m$ before the time signal. It was raised again and dropped correctly. On February 12 and March 1 the ball fell before $13^h$. It was raised and dropped at $14^h$ on these days. Examination of the cause of the ball dropping before the signal on these days showed that the piston was much worn where it rests on the clips. The piston, clips, and machinery in general were completely overhauled and put in good order. On two days during the repairs, March 17 and 18, the ball was not raised.

There were no failures in the Greenwich time signal at $13^h$, but on January 14 it was $0^s{\cdot}5$ late.

The automatic drop of the Deal time-ball failed on five days owing to interruptions of the telegraph connections, on one day owing to a defect in the relay, and on one day owing to a defect in the machinery. A new cog-wheel was put on the winding apparatus in July. On 10 days the ball was not raised owing to high wind. Mr. William Newby, the attendant in charge of the time-ball, retired, owing to failing health, on January 24, and the care of the time-ball was handed over to Mr. J. G. Hayward on that date. In connection with this change stock was taken and an inventory made of the Government property in the Time-Ball Tower, by Mr. Bowyer, the Established Computer attached to the Time Department.

The return signal from the Devonport clock failed on 56 days (18 of these were Sundays), and could not be observed on 11 days owing to interruption by telegraph

signals. The apparent error of the clock-signal (after daily correction of the clock by aid of a time signal from Greenwich) did not exceed $0^s{\cdot}2$ on 89 per cent. of the 291 days of observation, did not exceed $0^s{\cdot}5$ on 99 per cent., and never exceeded $1^s{\cdot}0$.

The return signal from the Portsmouth clock (similarly corrected by the help of a signal from Greenwich) failed on 50 days (30 of these were Sundays), and could not be observed on 7 days owing to interruption by telegraph signals. The apparent error of the clock-signal did not exceed $0^s{\cdot}2$ on 85 per cent. of the 298 days of observation, did not exceed $0^s{\cdot}5$ on 98 per cent., and exceeded $1^s{\cdot}0$ on one occasion.

The automatic signals from the Westminster clock have been received throughout the year, except on 38 days, when the signal failed. The apparent error of the clock was not greater than $0^s{\cdot}5$ on 28 per cent. of the days of observation, not greater than $1^s{\cdot}0$ on 54 per cent., not greater than $2^s{\cdot}0$ on 85 per cent., not greater than $3^s{\cdot}0$ on 94 per cent., and never exceeded $4^s{\cdot}0$.

A mean solar clock made for the Perth Observatory, W. Australia, was under examination from 1897 September to 1898 May. It is fitted with hourly and seconds contacts and with galvanic apparatus for correction of its error. It has given considerable trouble, but is now ready for use.

Provision has been made this year for the determination of the longitude of Killorglin (Co. Kerry) or some other suitable station in the west of Ireland, as supplementing the longitude determinations of Valentia and Waterville in connection with the western extremity of the great European arc of longitude. It is proposed to undertake this work in the autumn, the portable transits which are to be used having now been thoroughly tested by longitude observations made at two contiguous stations in the Front Court of the Observatory, as mentioned in the last Report.

It may be mentioned here that the Astronomer Royal (taking with him the Thompson 9-inch photographic telescope) and Mr. Maunder went to India to observe the total eclipse of the Sun on January 22. Successful large scale photographs of the Corona were obtained with the Thompson photographic telescope, and also a series of photographs of the partial eclipse for determination of the Moon's position relatively to the Sun, the local time and the longitude of the station being determined by Major Burrard, R.E., and Lieutenant Crosthwait, R.E., of the Indian Survey.

VIII.—Personal Establishment:—

As the result of a competitive examination of candidates, nominated from among the Supernumerary Computers by the Astronomer Royal, Mr. H. Furner was appointed an Established Computer on November 26.

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

Chief Assistants—Mr. Cowell, Mr. Dyson.

Assistants—Mr. Hollis, Mr. Lewis, Mr. Maunder, Mr. Nash, Mr. Thackeray.

Second-Class Assistants—Mr. Bryant, Mr. Crommelin.

Clerical Assistant—Mr. Outhwaite.

Established Computers—Mr. Bowyer, Mr. Davidson, Mr. Edney, Mr. Furner, Mr. Rendell, and one vacancy.

The two Second-Class Assistants will be replaced by Higher Grade Established Computers as vacancies occur.

Mr. Dyson and Mr. Cowell have the general superintendence of all the work of the Observatory, Mr. Dyson taking special charge of the Astronomical Department, and Mr. Cowell of the Astro-physical Department, in which is included the Magnetic and Meteorological Branch. Mr. Maunder is charged with the heliographic photography and reductions. Mr. Lewis has charge of the time-signals and chronometers, and of the 28-inch equatorial. Mr. Thackeray superintends the miscellaneous astronomical computations, including the preparation of the New Ten-Year Catalogue. Mr. Hollis has charge of the photographic mapping of the heavens, the measurement of the plates, and the computations for the astrographic catalogue. Mr. Crommelin undertakes the altazimuth and Sheepshanks equatorial reductions, and Mr. Bryant the transit and meridian zenith distance reductions and time-determinations. In the magnetic and meteorological branch, Mr. Nash has charge of the whole of the work. Mr. Outhwaite acts as responsible accountant officer, has charge of the library, records, manuscripts, and stores, and conducts the official correspondence. As regards the Established Computers, Mr. Bowyer, Mr. Furner, Mr. Davidson, and Mr. Rendell assist Mr. Lewis, Mr. Thackeray, Mr. Hollis, and Mr. Bryant respectively, and Mr. Edney assists Mr. Nash.

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

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

The whole number of persons regularly employed at the Observatory is 52.

IX.—General Remarks :—

The record of the past year's work reflects great credit on the staff of Assistants and Computers, who have worked with a zeal and energy which I have pleasure in acknowledging. As will be seen from the Report, the work in the various branches has been carried on actively and the computations are kept well up to date. The observations for the next Ten-Year Catalogue (epoch 1900), the preparation of the last Ten-Year Catalogue (epoch 1890), the measures of double stars with the 28-inch refractor, and the photography, measurement, and computations for the Astrographic Chart and Catalogue have all advanced very satisfactorily, though the building operations in progress have seriously hampered the Staff. In the Magnetic Branch the continuity of the records of the magnetic elements—disturbed by the introduction of iron in the new buildings—has been kept up by special supplementary observations in Greenwich Park, which have been made under difficulties, pending the building of the new Magnetic Pavilion.

The two new instuments—the Thompson Photographic Equatorial and the Altazimuth—have required much time and thought in testing and perfecting, so that the best attainable results might be secured. The 26-inch photographic object-glass was found, as the result of exhaustive trials, to require correction in regard to lateral pencils, and Sir H. Grubb has removed the fault by alteration of the curves of the lenses. He is now engaged in perfecting the figure of the object-glass. The difficulties with the new Altazimuth mentioned in the last Report have been overcome by Mr. Simms, and the instrument is in good working order. But the stability of the microscopes in relation to the circles appears to be not altogether satisfactory, and an improvement in this respect is desirable. With proper care, however, very accurate observations may be secured in the existing state of the instrument. It is to be expected that there will be difficulties incidental to all new instruments, which can only be successfully overcome by persistent care and thought. The circumstance that these difficulties have had to be dealt with in the case of two new and complex instruments at the same time somewhat complicated the situation during the past year.

W. H. M. CHRISTIE.

Royal Observatory, Greenwich,
1898 May 11.