# REPORT

OF

# THE ASTRONOMER ROYAL

TO THE

# BOARD OF VISITORS

OF THE

## ROYAL OBSERVATORY, GREENWICH,

*Read at the Annual Visitation of the Royal Observatory,* 1905 *June* 3.

GREENWICH OBSERVATIONS, 1904.

# THE BOARD OF VISITORS.

| | |
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The Report here presented refers to the year from 1904 May 11 to 1905 May 10, and exhibits the state of the Observatory on the last-named day.

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

The accumulators for the electric light were renewed in November, the new batteries being erected on November 28, and brought into use on December 1.

Standards for the electric lamps outside the New Observatory building were supplied and fixed in March.

The oak fencing on both sides of the pathway, from the Great Equatorial as far as the Altazimuth, was renewed during January and February.

The domes of the Astrographic, Sheepshanks, and Great Equatorials, and of the Altazimuth and Transit Pavilions were painted externally during the months of October and November.

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Three new book cases have been supplied and fixed in the South wing of the New Observatory (principal floor). A treble extension ladder for use in the domes and buildings has been purchased.

The principal movable instruments are thus distributed:—

At Greenwich—

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

Altazimuth E.

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

Photoheliographs.—Nos. 2, 3, and 5. (The object glass of No. 5 has been lent to Professor Turner since the Eclipse Expedition of 1898.)

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

Two Hilger Chronographs.

A single prism Spectroscope.

On loan—

Transit A, at the Cape Observatory.

Altazimuths.—A, at the Science Schools, South Kensington; B, at the Cape Observatory; D, to the Colonial Office for use of Major Watherston for Longitude Observations on the Gold Coast.

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

Photoheliographs.—No. 1, complete, at the Cape Observatory; No. 4, complete, at the Kodaikanal 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 mounted above the roof of the Octagon Room of the Royal Observatory, lent for exhibition at South Kensington Museum.

A $2\frac{1}{2}$-inch transit, a small collimating telescope, and three observing chairs have been transferred from the Greenwich Hospital School Observatory to the Royal Observatory, and Altazimuth E has been returned from the same Observatory.

The 4-inch rapid rectilinear lens, borrowed for use in the photographic determination of places of stars in the immediate neighbourhood of the Pole, has been returned to the Royal Astronomical Society.

Photoheliograph No. 3 has been exchanged for a similar one at Mauritius, still called No. 3. This exchange was effected to avoid break in the continuity of the Mauritius photographs during repairs to their Photoheliograph, and to avoid unnecessary transhipment.

As regards the Libraries, special attention has been given to the North Library (containing the Transactions of Societies and Periodical Literature). A new Card Catalogue has been made on the same lines as for the Astronomical Library, and a large amount of binding has been carried out. The Magnetic and Meteorological (East) Library is in good order, except for large arrears of binding, arising from the number of unbound contributions received. These arrears can now be dealt with in succession to those of the North Library.

The annual examination of the library has been made, the books on the shelves being compared with the catalogues. Three books are missing from the shelves, and are not entered in the lending book, in addition to nine books which were missing last year. Of the 20 books reported as missing last year, 11 have since been found.

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 from 1904 May 11 to 1905 May 10 is as follows:—

| | |
|---|---|
| Transits | 15,842 |
| Determinations of collimation error | 304 |
| Determinations of level error | 599 |
| Circle observations | 14,461 |
| Determinations of nadir point (included in the number of circle observations) | 595 |
| Reflexion observations of stars (similarly included) | 397 |

The transits are completely reduced (so as to exhibit Mean R.A. 1905·0) to 1905 April 11.

The circle observations are completely reduced to 1905 April 2, and as far as Apparent N.P.D. to April 12.

Very great progress has been made in the observation of the reference stars for the Greenwich section of the Astrographic Catalogue (Dec. 65° to the Pole), about 9,500 observations of R.A. and N.P.D. having been added during the year. The comparatively few observations required to secure five observations of each of the reference stars (more than 10,000 in number) will easily be obtained by the end of the year, as there are only 5 stars requiring 3 observations, 100 requiring 2, and 1,500 requiring one observation only in order to carry out the programme. In fact, it may be taken that the observations for this catalogue are practically completed. The catalogue, which will be terminated this year, will contain, besides the Reference Stars for the Astrographic Catalogue, the 834 Zodiacal Stars given in the Nautical Almanac, for 1897. It is hoped that five observations of each of these stars will be secured. The Clock Stars have been well observed throughout the nine years, a minimum number of three observations of R.A. and two of N.P.D. being obtained each year with very few exceptions. The greatest credit is due to the observers for the heavy work throughout the nine years from 1897, which has alone made the completion of so large a catalogue possible.

It is proposed to begin next year a New Nine-year Catalogue of the Stars of magnitude 9·0 and brighter between the limits + 24° to + 32° of N. declination, this being the Oxford astrographic zone, for which they serve as reference stars. The re-observation of these stars, which for the most part fall within the Cambridge zone of the Astronomische Gesellschaft Catalogue, will afford valuable data for their proper motions, besides giving fundamental positions for the Oxford astrographic plates.

The investigation of personal equations is complete for 1904.

The correction for R–D discordance, and the position of the ecliptic, have been investigated for 1904.

The corrections for variation of latitude (kindly communicated in advance by Prof. Albrecht) have been applied to the planetary observations for 1904, and

are being applied to the observations of stars in the ledgers. The colatitude determination for 1904 is not yet completed, as the application of these corrections has necessarily involved delay. The value found for 1903 is 38° 31′ 21″·83 with Bessel's refractions.

The apparent correction for discordance between the nadir observation and stars observed by reflexion for 1904 is — 0″·41. The values found since 1892 range from — 0″·20 to — 0″·41, and since 1897 January 1 a correction of — 0″·25 has been applied to observations of the nadir in forming the zenith point on days when no reflexion observations of stars were obtained.

Observations of level and nadir have been made, when practicable, three or more times on the same day. The following table shows the mean values of the diurnal changes of the level and nadir, observations within three hours of noon, 6 p.m., and midnight, respectively, being grouped together:—

| — | Diurnal Change of Level. | | | Diurnal Change of Nadir. | | |
|---|---|---|---|---|---|---|
| | Noon. | 6 p.m. | Midnight. | Noon. | 6 p.m. | Midnight. |
| 1898 - | + 0″·25 | 0″·00 | + 0″·18 | + 0″·17 | 0″·00 | + 0″·17 |
| 1899 - | + 0·30 | 0·00 | + 0·18 | + 0·17 | 0·00 | + 0·17 |
| 1900 - | + 0·39 | 0·00 | + 0·23 | + 0·14 | 0·00 | + 0·04 |
| 1901 - | + 0·28 | 0·00 | + 0·26 | + 0·17 | 0·00 | + 0·09 |
| 1902 - | + 0·22 | 0·00 | + 0·20 | + 0·20 | 0·00 | + 0·17 |
| 1903 - | + 0·14 | 0·00 | + 0·22 | + 0·04 | 0·00 | + 0·09 |
| 1904 - | + 0·27 | 0·00 | + 0·29 | + 0·06 | 0·00 | + 0·15 |

The correction for R–D discordance found for 1904 is + 0″·047 + 0″·267 *sin* Z.D., a value agreeing well with the results of recent years.

The correction to the tabular obliquity of the ecliptic from solar observations in 1904 is + 0″·11. The discordances between the results of summer and winter solstices is + 0″·04, indicating that the mean of the observed distances from the pole to the ecliptic is apparently too small by 0″·02. The apparent correction from observations of the Sun to right ascensions of clock stars is — 0ˢ·046.

In determining these quantities the correction for variation of latitude has been applied.

The mean error of the Moon's tabular place (computed from Hansen's lunar tables with Newcomb's corrections) is $-0^s\cdot204$ in R.A., and $+0''\cdot01$ in N.P.D. deduced from 78 observations. These are equivalent to a mean error of $-3''\cdot16$ in Longitude and $+0''\cdot34$ in E. N.P.D.

The comparison between theory and the Greenwich meridian observations of the Moon from 1750 to the present time, undertaken by Mr. Cowell, has been completed for the longitudes, and the discussion from 1847 to 1901 is completed for the latitudes. The only point left outstanding is the motion of the node, for which it is necessary to discuss as long a series of observations as possible. The results obtained for the longitudes are summarised in a series of papers in the *Monthly Notices of the Royal Astronomical Society*. In particular, the paper in Vol. LXV., No. 2 (1904 December), gives the co-efficients of 145 terms as obtained directly from observation, with a comparison with the theoretical co-efficients given by Hansen, Delaunay, M. Radau, and Dr. Hill. The publication of the details of the whole investigation will be shortly proceeded with.

The re-reduction of Groombridge's observations was completed at the date of the last report, and during this year the printing of the results has been pushed on. The Introduction has also been prepared for press. A discussion of the proper motions determined by comparison with modern Greenwich observations and a determination of the constant of precession and of the direction of the solar motion by Mr. Dyson and Mr. Thackeray is given in the *Monthly Notices of the Royal Astronomical Society*, 1905, March.

*Altazimuth.*—The instrument has been used in the meridian in four positions during the year, the positions being changed regularly each two months. Observations of the Sun, Moon, planets, and the fundamental stars contained in the National Ephemerides, and in Newcomb's Fundamental Catalogue, have been made throughout the year.

The instrument has been used regularly for extra-meridian observations of the Moon during the first and last quarters of the lunation.

Since the beginning of 1905 observations of the crater Mösting A, as well as of the limbs of the Moon, have been obtained in the second and third quarters

whenever it is observable. The observations of transits will serve to connect the observations of the first and second limbs made before and after full respectively; and the observations of zenith distances will, in combination with similar observations now being made at the Cape Observatory, serve to determine the parallax of the Moon.

Mösting A has also been observed with the transit-circle when practicable.

The following observations have been made during the year:—

| | No. of Observations. |
|---|---|
| Collimation, Level, and Azimuth | 306, 553 and 142 respectively. |
| Nadir: Reflexion observations of stars | 549 and 187 ,, |
| Flexure | 17 |
| R.A. and N.P.D. of Sun, planets, and stars (in meridian) | 1,498 and 1,392 ,, |
| R.A. and N.P.D. of Moon (in meridian) | 50 and 48 ,, |
| R.A. and N.P.D. of Mösting A | 17 |
| Azimuth and Zenith distance of stars (extra meridian) | 361 |
| Azimuth and Zenith distance of Sun and planets (extra meridian) | 31 |
| Azimuth and Zenith distance of Moon (extra meridian) | 58 |

A second determination of pivot errors was made during 1905, January—March, the results obtained agreeing satisfactorily with the previous determination made in 1899, November.

Observations were made in 1905, March and April, to determine the value of one revolution and the errors of the screw of the telescope-micrometer.

The altazimuth observations are completely reduced to the end of 1904, including the correction for latitude variation. The star-ledgers for 1904 have also been formed. Of the observations for 1905, the meridian zenith distances are reduced to April 23, and the transits to May 5. The extra-meridian observations are completely reduced to 1904 December 31.

The R–D discordance has been investigated separately for each two months of the year during which the instrument remained in one position. The direct observations have also been compared with the positions given in Newcomb's Fundamental Catalogue. In this way a correction of 0″·29 has been derived, agreeing with the constant part of the R–D correction, which, applied with one sign to two positions of the instrument and the opposite sign to the other two, reduces the observations to the mean which would have been obtained had the stars been equally observed in all positions of the instrument.

The observations of the Moon both in and out of the meridian seem very satisfactory, as shown by the agreement between the two instruments, transit-circle and altazimuth.

The following table shows the number of days on which observations of the Moon were obtained with the transit-circle and altazimuth, respectively, in the year ending 1905 May 10 :—

| Time of Moon's Meridian Passage. | Transit Circle. | | Altazimuth. | | |
|---|---|---|---|---|---|
| | | | Meridian. | | Extra Meridian. |
| | Limb. | Mösting A. | Limb. | Mösting A. | Limb. |
| h. h. | | | | | |
| 1–2 G.M.T. | 0 | | 0 | | 2 |
| 2–3 | 0 | | 0 | | 6 |
| 3–4 | 2 | | 0 | | 8 |
| 4–5 | 5 | | 1 | | 9 |
| 5–6 | 3 | | 3 | | 5 |
| 6–9 | 24 | | 14 | 4 | 6 |
| 9–12 | 22 | 2 | 18 | 5 | 0 |
| 12–15 | 20 | 1 | 7 | 3 | 0 |
| 15–18 | 15 | 1 | 4 | 4 | 6 |
| 18–19 | 6 | | 3 | 1 | 2 |
| 19–20 | 4 | | 0 | | 5 |
| 20–21 | 3 | | 0 | | 7 |
| 21–22 | 0 | | 0 | | 1 |
| 22–23 | 0 | | 0 | | 1 |

The total number of observations is 104 with the transit-circle and 108 with the altazimuth, viz. :—50 in the meridian, and 58 out of the meridian.

Taking both instruments, observations of the Moon have been obtained on 133 days during the year. The observations of Mösting A have only been made since 1905, Jan. 1.

*Reflex Zenith Tube.*—During the year, 949 double observations and 58 single observations have been obtained, the number of different stars observed being 61. The brighter stars have been observed for as long periods of the year as possible. Thus 78 observations of $\gamma$ Draconis, 60 of $\beta$ Draconis and 45 of $i^2$ Cygni, distributed throughout the year, have been obtained; 34 observations of 30 Draconis extend from May 11 (in continuation of last year's series) to September 1 and from March 12 to May 10; while the group of five stars, 27 Lyncis, $f$ Ursæ Majoris, Bradley 1306, Groombridge 1542, and $\theta$ Ursæ Majoris, was observed continuously from the middle of November to the middle of April, and the two stars $\beta$ and 9 Lacertae from August 29 to December 20. The reduction of the observations is completed to 1904 June 30, the work having fallen somewhat behind owing to the heavy pressure of the transit-circle observations and reductions.

*Clocks and Chronographs.*—The transit-circle chronograph has been repaired by Messrs. E. Dent & Co., and some improvements have been made in the train of wheels. A platform and guiding cheeks have also been introduced to guard against jerks when the barrel is being put in the chronograph.

The contact pallets of the Mean Solar Clock (Dent 2012) have been repaired.

The Clock Hardy, which was much rusted owing to damp weather, has been cleaned by Messrs. Kullberg, who have made alterations in the case to protect the clock from damp as far as possible.

*Equatorials.*—During the year ending 1905 May 10, 42 disappearances and 15 reappearances of stars occulted by the Moon have been observed by one or more observers. Fourteen of the stars of which the disappearance was observed were below the limit of magnitude ($6^m \cdot 5$) hitherto adopted in the Nautical Almanac, and the occultation was not notified there. It is satisfactory to note that from 1907 the Nautical Almanac will include such stars in its occultation list.

*The 28-inch Refractor.*—This instrument has been used throughout the year for micrometric measurements of double stars. The total number of double stars measured during the year is 603; of these, 143 have their components less than 1″·0 apart, and 60 less than 0″·5. The close pairs whose distance apart is less than 1″·0 have been measured on the average on $2\frac{1}{2}$ nights each, and the wider pairs on 2 nights. The wider pairs consist of bright stars with faint companions, stars of special interest, and stars from Struve's catalogue, which have not been measured within the last 30 years.

The following list includes some of the most interesting and difficult stars measured during the year :—

| | Distance. | Magnitudes. | | Distance. | Magnitudes. |
|---|---|---|---|---|---|
| κ Pegasi | 0″·1 | 3·9 and 5·0 | ζ Boötis | 0″·3 | 3·5 and 3·9 |
| δ Equulei | 0·2 | 4·1 „ 4·1 | $\gamma^2$ Andromedæ | 0·3 | 5·0 „ 6·2 |
| OΣ 278 | 0·2 | 7·5 „ 7·5 | De. 15 | 0·5 | 8·2 „ 8·6 |
| β 1266 | 0·2 | 7·2 „ 7·5 | Σ 2525 | 0·5 | 7·4 „ 7·6 |
| β 524 | 0·2 | 6·0 „ 7·0 | Hough 312 | 0·9 | 6·5 „ 12·0 |
| Σ 2367 | 0·2 | 7·2 „ 7·6 | ζ Herculis | 1·1 | 3·0 „ 6·5 |
| β 151 | 0·3 | 4·5 „ 6·0 | β 1251 | 1·4 | 6·0 „ 11·5 |
| Σ 2107 | 0·3 | 6·5 „ 8·0 | 70 Ophiuchi | 1·9 | 4·1 „ 6·1 |
| β 612 | 0·3 | 6·3 „ 6·5 | Hussey 483 | 1·7 | 8·0 „ 13·0 |
| Σ 1637 | 0·3 | 6·5 „ 8·0 | Procyon | 4·5 | 1·0 „ 13·0 |

Series of measures have been obtained of κ Pegasi (7 nights), δ Equulei (10 nights), and 70 Ophiuchi (14 nights).

A marked deterioration of the images of stars which could not altogether be accounted for by atmospheric conditions has been noticed of late, and as it seemed possible that this might be due to tilt of the lenses, owing to some modification of their original adjustment, a careful examination was made recently. It was found that the paper packing under two of the metal clips holding the lenses in position had dropped out, and thus a tilt between the two lenses may have been introduced. The defect was remedied, and the star images are now quite satisfactory.

*Thompson Equatorial.—With the* 26-*inch Refractor*, 65 photographs of Neptune and its Satellite have been taken on 33 nights. The occulting shutter has been used as in previous oppositions. These photographs are now being measured. A discussion by Mr. Dyson and Mr. Edney of the measures of the photographs taken in the three previous oppositions, published in the *Monthly Notices of the Royal Astronomical Society*, 1905 April, shows the value of these photographs and the importance of continuing these observations.

*With the* 30-*inch Reflector*, the following photographs have been taken:—

119 photographs of 59 minor planets.
77 photographs on 62 nights of Comet *a* 1904.
2 photographs on 1 night of Comet *b* 1904.
13 photographs on 12 nights of Comet *c* 1904.
8 photographs on 8 nights of Comet *a* 1905.

The photographs of comets and minor planets have not yet been measured, but provision has been made for taking up this work when the measurement and reduction of the Eros photographs are completed.

*Measurement and Reduction of the Eros Photographs.*—At the date of the last report 119 plates taken with the Astrographic Equatorial, and 55 taken with the Thompson Equatorial, had been measured. During this year the remainder of the photographs taken have been measured, making in all 198 with the Astrographic Equatorial and 152 with the Thompson Equatorial. The reduction of the measures is in the following stage:—By comparison of the measures of the reference stars with their meridian places, the corrections to the centre and the orientation of each of the Astrographic plates have been found. Using these plate constants, photographic positions of the reference stars have been deduced, and the means derived from a number of photographs have been taken as improved positions of these stars to be used in further reductions. The positions of the comparison stars (stars within 25′ of the centre of the plate and of about the same magnitude as Eros) have been deduced, and the position of the planet on each photograph will be obtained *viâ* these stars as well as *viâ* the reference stars. These stars serve as reference stars for the photographs taken with the Thompson Equatorial where the field covered by the photographs is only half that of the Astrographic photographs. It is expected that the reductions for both sets of photographs will be completed in two months.

*Astrographic Equatorial.*—Work with this instrument has been in the main confined to replacing Chart plates which, though satisfactory in other respects, are, owing to slight photographic defects, unsuitable for production of enlarged prints.

Altogether 224 photographs have been taken on 83 nights. Of these 42 have been rejected; 22 with exposure unfinished, owing to cloud, or as not reaching the standard in showing faint stars; 11 owing to faults in the plate; 9 owing to errors in setting or faults shown in development.

The remaining 182 plates are made up as follows:—

| | |
|---|---|
| Chart plates (exposure $40^m$) - - - - | 139 |
| Catalogue plates (exposure $6^m$, $3^m$ and $20^s$) - - - | 21 |
| Suspected Variables - - - - - | 6 |
| Plates for Adjustment - - - - - | 16 |

The measurement of the Catalogue Plates for the Greenwich Section is now completed. Since the last report 47,200 measures of pairs of images ($6^m$ and $3^m$) have been made. The number of plates measured in the year is 102, covering 128 square degrees between declination 83° and the pole. The number of plates measured up to the date of last year's Report was 1,051. Adding the 102 plates measured this year, the total of plates measured is 1,153, being the 1,149 of the Greenwich Section + 4 additional photographs of the polar field.

In addition, re-measures have been made of discordant observations in the Zones 77°, 78°, and 79°, and measures of the reference stars outside the limits common to the overlapping plates, but within the réseau lines, for the Zones 75° and 76°.

Means of measures have been taken and examined for Zones 79°, 80°, and part of Zone 81°.

Copy for press has been prepared during the year for Zones 76°, 77°, 78°, 79°, with the exception of the identification of the B.D. stars and the addition of the reference stars outside the limits of the overlapping plates for the three latter zones.

The measures of the five zones 72° to 76° have been printed during the year. These zones contain 46,184 separate stars, covering an area of 481 square degrees of the sky, and occupy the first 437 pages of Vol. II. of the Greenwich Astrographic

Catalogue. The remaining 529 square degrees between Dec. 77° and the pole will contain about 52,700 separate stars.

The following table gives the total number of separate stars which have been measured and will be contained in the Greenwich section of the Astrographic Catalogue, compared with the corresponding numbers in the *Bonn Durchmusterung* and the *Astronomische Gesellschaft Catalogues*:—

| Limits of Declination. | Number of Stars measured. | Number in B.D. | Number in A.G.C. | A.G.C. |
|---|---|---|---|---|
| 64°–65° | 8,954 | 1,932 | 1,200 | Helsingfors. |
| 65°–70° | 49,016 | 8,159 | 3,700 | Christiania. |
| 70°–75° | 49,900 | 5,872 | — | Dorpat. |
| 75°–80° | 42,300 | 4,451 | 3,777 | Kazan. |
| 80°–90° | 28,580 | 4,770 | — | — |

As regards the Chart plates, the stars in Zones 72° and 73° have been counted during the year. The following table of the total number of stars shown with exposures 20ˢ, 3ᵐ, 6ᵐ, 40ᵐ, as well as the number shown in duplicate, is in continuation of the table given last year. The first column for each exposure gives the number of stars shown in duplicate—*i.e.*, on *both* of the overlapping plates:—

| Zone. | No. of Square Degrees. | Number in B.D. | | Number shown on Photographs. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 9ᵐ·0 and brighter. | Total Number. | Exposure 20ˢ | | Exposure 3ᵐ | | Exposure 6ᵐ | | Exposure 40ᵐ | |
| 72° | 108 | 442 | 1,148 | 1,249 | 2,247 | 5,585 | 9,770 | 7,860 | 10,090 | 31,859 | 35,001 |
| 73° | 102 | 377 | 1,091 | 1,168 | 1,987 | 5,592 | 8,857 | 7,424 | 9,122 | 27,088 | 29,556 |
| Totals - | 210 | 819 | 2,239 | 2,417 | 4,234 | 11,177 | 18,627 | 15,284 | 19,212 | 58,947 | 64,557 |
| Number per square degree | | 3·9 | 10·7 | 11·5 | 20·2 | 53·2 | 88·7 | 72·8 | 91·5 | 280·7 | 307·4 |
| Ratios - - | | 1·0 | 2·7 | 2·9 | 5·2 | 13·6 | 22·7 | 18·7 | 23·5 | 72·0 | 78·8 |

The reproduction of enlarged prints of the Chart plates has been carried on satisfactorily throughout the year. In the three Zones 65°, 66°, 67°, reproductions

of 197 plates from $12^h$ to $24^h$ of R.A. and from $0^h$ to $8^h$ have been made, and copies distributed to about 50 observatories and representative institutions. Another batch of reproductions from 20 plates will be made and distributed before the issue of this report. As soon as Zones 65°, 66°, and 67°, containing 232 plates, are completed, the three Zones 68°, 69°, and 70° will be taken in hand, beginning at R.A. $12^h$. Positives and satisfactory trial prints of 48 fields in these Zones between $12^h$ and $18^h$ have been obtained, and there remain 6 fields which it is proposed to re-photograph.

III. Spectroscopic and Heliographic Observations :—

No observations have been made with the spectroscope during the year.

In the year ending 1905 May 10, photographs of the Sun have been taken on 242 days with the Thompson Photoheliograph. The Dallmeyer Photoheliograph was also used on three of these days. Of the photographs taken, 507 have been selected for preservation, besides 31 with double images of the Sun for the determination of zero of position angles. Supplementary photographs have been received from India to 1905 March 11, and from Mauritius to 1904 September 29.

For the year ending 1904 December 31, Greenwich photographs have been selected for measurement on 209 days, and photographs from India and Mauritius (to fill up the gaps in the series) on 151 days, making a total of 360 days out of 366 on which photographs are at present available. Photographs were taken in Mauritius for three of the six days yet unrepresented, and will no doubt be received in due course.

The measurement and reduction of the photographs are completed for 1904, with the exception of 7 days, for which photographs from Mauritius have only just come to hand or are still required. The Greenwich photographs for 1905 are measured to March 14, and those from India to January 28.

The solar activity has shown a great increase during the year ending 1905 May 10, and the Sun has not been free from spots on a single day during that period. The mean daily spotted area for 1904 was more than half as great again as that for 1903, and early in the present year a number of exceptionally large groups were observed. The group which was seen first on the east limb on 1905 January 28 had a greater total area than any other group which has been photographed at the Royal Observatory.

The measures of areas and positions of sunspots on photographs lent from the Harvard College Observatory, Cambridge, U.S.A., and the Melbourne Observatory

some years ago, in order to fill the gaps in the Greenwich series of solar photographs for the years 1874–77, are prepared for press, and when these are printed the sun-spot ledgers from 1874 to 1885 can be completed without delay. From 1886 onwards the spot-ledgers have been given annually in the Heliographic Results.

IV. Magnetic Observations :—

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

The regular determinations of magnetic declination, horizontal force and dip have been made with the new declinometer, the Gibson deflexion instrument, and the Airy dip circle mounted in the Magnetic Pavilion.

The magnetic reductions for 1904 are completed to the following stages :—

The eye observations of the declination and horizontal and vertical force magnets are completely reduced, and the hourly ordinates of the photographic registers are read off and tabulated. 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 declination, dip and deflexion observations made in the Magnetic Pavilion are completely reduced.

The principal results for the magnetic elements for 1904 are as follows :—

| | |
|---|---|
| Mean declination - - - | 16° 15′·0 West. |
| Mean horizontal force - - | 4·0166 (in British units).<br>1·8520 (in Metric units). |
| Mean dip (with 3-inch needles) - | 66° 57′ 11″. |

These results depend on observations in the Magnetic Pavilion and are free from any disturbing effect of iron in the Observatory buildings.

In 1904 there were no days of great magnetic disturbance and 8 of lesser disturbance. Traces of the photographic curves for these days will be published in the annual volume. The calculation of diurnal inequalities from five typical quiet days in each month, selected in concert with M. Moureaux and Dr. Chree, has been continued.

of 197 plates from $12^h$ to $24^h$ of R.A. and from $0^h$ to $8^h$ have been made, and copies distributed to about 50 observatories and representative institutions. Another batch of reproductions from 20 plates will be made and distributed before the issue of this report. As soon as Zones 65°, 66°, and 67°, containing 232 plates, are completed, the three Zones 68°, 69°, and 70° will be taken in hand, beginning at R.A. $12^h$. Positives and satisfactory trial prints of 48 fields in these Zones between $12^h$ and $18^h$ have been obtained, and there remain 6 fields which it is proposed to re-photograph.

III. Spectroscopic and Heliographic Observations :—

No observations have been made with the spectroscope during the year.

In the year ending 1905 May 10, photographs of the Sun have been taken on 242 days with the Thompson Photoheliograph. The Dallmeyer Photoheliograph was also used on three of these days. Of the photographs taken, 507 have been selected for preservation, besides 31 with double images of the Sun for the determination of zero of position angles. Supplementary photographs have been received from India to 1905 March 11, and from Mauritius to 1904 September 29.

For the year ending 1904 December 31, Greenwich photographs have been selected for measurement on 209 days, and photographs from India and Mauritius (to fill up the gaps in the series) on 151 days, making a total of 360 days out of 366 on which photographs are at present available. Photographs were taken in Mauritius for three of the six days yet unrepresented, and will no doubt be received in due course.

The measurement and reduction of the photographs are completed for 1904, with the exception of 7 days, for which photographs from Mauritius have only just come to hand or are still required. The Greenwich photographs for 1905 are measured to March 14, and those from India to January 28.

The solar activity has shown a great increase during the year ending 1905 May 10, and the Sun has not been free from spots on a single day during that period. The mean daily spotted area for 1904 was more than half as great again as that for 1903, and early in the present year a number of exceptionally large groups were observed. The group which was seen first on the east limb on 1905 January 28 had a greater total area than any other group which has been photographed at the Royal Observatory.

The measures of areas and positions of sunspots on photographs lent from the Harvard College Observatory, Cambridge, U.S.A., and the Melbourne Observatory

some years ago, in order to fill the gaps in the Greenwich series of solar photographs for the years 1874–77, are prepared for press, and when these are printed the sun-spot ledgers from 1874 to 1885 can be completed without delay. From 1886 onwards the spot-ledgers have been given annually in the Heliographic Results.

IV. Magnetic Observations :—

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

The regular determinations of magnetic declination, horizontal force and dip have been made with the new declinometer, the Gibson deflexion instrument, and the Airy dip circle mounted in the Magnetic Pavilion.

The magnetic reductions for 1904 are completed to the following stages :—

The eye observations of the declination and horizontal and vertical force magnets are completely reduced, and the hourly ordinates of the photographic registers are read off and tabulated. 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 declination, dip and deflexion observations made in the Magnetic Pavilion are completely reduced.

The principal results for the magnetic elements for 1904 are as follows :—

| | |
|---|---|
| Mean declination - - - | 16° 15′·0 West. |
| Mean horizontal force - - | 4·0166 (in British units).<br>1·8520 (in Metric units). |
| Mean dip (with 3-inch needles) - | 66° 57′ 11″. |

These results depend on observations in the Magnetic Pavilion and are free from any disturbing effect of iron in the Observatory buildings.

In 1904 there were no days of great magnetic disturbance and 8 of lesser disturbance. Traces of the photographic curves for these days will be published in the annual volume. The calculation of diurnal inequalities from five typical quiet days in each month, selected in concert with M. Moureaux and Dr. Chree, has been continued.

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. Cloud observations in connection with the international balloon ascents have been made with a Fineman nephoscope.

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 time-scales are laid down, and the hourly ordinates are read out and completely reduced to the end of 1904 for the dry and wet bulb thermometers and the barometer. The table of principal changes of the wind is complete for 1904.

The mean temperature for the year 1904 was 49°·8, or 0°·3 above the average for the 50 years 1841–90.

During the twelve months ending 1905 April 30 the highest temperature in the shade (recorded on the open stand in the Magnetic Pavilion enclosure) was 91°·0, on August 4. On the same day the highest temperature in the Stevenson screen in the Magnetic Pavilion enclosure was 89°·5, and in the Observatory Grounds 89°·7.

The lowest temperature of the air recorded in the year was 19°·5, on January 1. During the winter there were 39 days on which the temperature fell below 32°·0, being 17 less than theaverage number.

The mean daily horizontal movement of the air in the year ending 1905 April 30, was 280 miles, which is 2 miles below the average of the preceding 37 years. The greatest recorded daily movement was 867 miles, on November 9, and the least 49 miles, on December 22. The greatest recorded pressure of the wind was 23·5 lbs. on the square foot, on March 12, and the greatest hourly velocity 45 miles,onDecember 30.

During the year 1904 Osler's anemometer showed an excess of 21 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 12 months ending 1905 April 30, by the Campbell-Stokes instrument, was 1,486 out of 4,457 hours during which the Sun was above the horizon, so that the mean proportion of sunshine for the year was 0·333, constant sunshine being represented by 1.

The rainfall for the year ending 1905 April 30 was 20·21 inches, being 4·33 inches less than the average of the 50 years 1841–90. The number of rainy days was 153. This small rainfall may be contrasted with the heavy rainfall of 35·42 inches in the corresponding period last year. The most striking contrast is obtained by comparing the rainfall for the year commencing 1903 March 1, which was over 37 inches, with that for the year commencing 1904 March 1, which was less than 17½ inches. This dry period of 12 months was followed by a heavy rainfall in 1905 March, which exceeded 3½ inches, and is the greatest amount recorded in March since 1851.

VI.—Printing and Distribution of Greenwich Publications :—

The copies of the volume for 1901 were distributed in July 1904, and those of the volume for 1902, in April 1905.

The printing of the volume for 1903 is completed with the exception of the Introduction.

The printing of the volume for 1904 has been commenced.

The copies of Volume I. of the Astrographic Catalogue, Greenwich Section, were distributed in July. The printing of Volume II., which will complete the Greenwich Section, is nearly half finished.

The printing of the Paris–Greenwich longitude determination, 1902, is practically complete. The Killorglin longitude is the only determination which still requires to be printed to complete the Volume of Longitude Determinations, which will contain the determinations Paris–Greenwich made in 1888, 1892 and 1902, of Greenwich–Waterville–Canso–Montreal made in 1892, and of Greenwich–Killorglin made in 1898.

The printing of the re-reduced Groombridge Catalogue is nearly finished, except the Introduction, which is ready for the printers. The printing of the Ledgers of the separate observations, reduced to 1810·0 (226 pp.), and of the Catalogue of Mean Places for 1810·0 (108 pp.), is finished, and that of the determination of proper

motions by comparison with modern Greenwich observations, is completed to $22^h$ of R.A. (184 pp.).

VII.—Chronometers, Time Signals, and Miscellaneous:—

The number of Government marine chronometers and deck-watches now being tested at the Observatory is 571, viz., 399 box chronometers, 42 pocket chronometers, and 130 deck-watches.

In the year ending 1905 May 10, the average daily number of chronometers and deck-watches being rated was 686; the total number received was 1,734, the total number issued was 1,691, and the number sent for repair 735. These include 32 box chronometers, 2 pocket chronometers, and 3 deck-watches for the Indian Government.

For the annual trial of chronometers, which lasted 29 weeks, with a range of temperature from 41° to 104°, 67 chronometers were sent in. During the trial 24 were rejected because the difference between one week's rate and the next exceeded 12 seconds. Of the remaining 43 chronometers, 10 were purchased for the Navy, and 9 for the Indian Government. The performance was about the same as in recent years, 16 chronometers having trial numbers less than 30, as against 19 last year and 13 the year before.

A competitive trial of pocket chronometers took place concurrently with the trial of box chronometers, and under the same conditions as regards length of trial and temperature, trials in positions as for deck-watches being included. Only 1 of the 11 pocket chronometers sent in came up to the standard for purchase.

For the annual trial of deck-watches, lasting 16 weeks and including trials in the oven and in positions, 224 watches were entered, of which 128 were classified, and of these 19 were purchased for the Navy. Among the watches classified were 44 with centre-seconds dials, of which 7 were purchased. There were 76 "Karrusel" or "Tourbillon" watches classified, of which 13 were purchased. The performance of the deck-watches is very satisfactory, and shows a marked improvement on that of any previous year.

It is noteworthy that the performance of the watches compares well with that of the box chronometers in this year's trial, as tested by the trial numbers $a + 2b$, though it is to be remarked that the chronometer trial is rather more severe, the

temperature having been from 41°·2 to 104°·0 for the chronometers and ·6 to 90°·7 for the watches. The following is a comparison of the trial a + 2b (omitting the part due to tests in position for the watches) for the eters and deck watches, respectively, in the trials 1904–5, the watches having rranged for this comparison in order of a + 2b :—

*Average Trial Numbers a + 2b.*

| Nos. | 1–5 | 6–10 | 11–15 | 16–20 | 21–25 | 26–30 |
|---|---|---|---|---|---|---|
| onometers | 16·8 | 21·3 | 24·9 | 30·8 | 33·7 | 35·2 |
| k-watches | 17·6 | 24·8 | 29·3 | 33·1 | 35·2 | 37·0 |

nay be added that the values of the trial numbers a + 2b for the watches respectively first and fourth are actually smaller than those standing rely first and second in the chronometer trial.

next trial of watches will commence on August 5.

Greenwich time-ball was not raised on five days during the year, owing to nce of the wind. On all other days it was dropped correctly.

Greenwich time signal at 13h was 0s·4 late on three days (all Sundays), , June 19, and December 18. On all other days the error of the signal was n this.

e automatic drop of the Deal time-ball failed on 8 days owing to interruptions telegraphic communications. On 5 days the ball was not raised owing to the e of the wind. On February 16 the ball was dropped 12s·5 early owing to a gnal on the line just before the Greenwich signal.

e return signal from Devonport failed on 35 days (of which 9 were Sundays), uld not be observed on 10 days owing to interruptions by telegraph signals. pparent error of the clock signal (after daily correction of the clock by aid of a gnal from Greenwich, on the plan described in the Report for 1885) did not 0s·2 on 90 per cent. of the 319 days of observation, and did not exceed 0s·5 on cent. On 9 occasions it exceeded 0s·5, but never exceeded 1s·0. The average r the year was ± 0s·10.

ie return signal from Portsmouth failed on 65 days (of which 42 were Sundays), uld not be observed on 14 days owing to the interruption by telegraph signals. pparent error of the clock (corrected in the same manner as the Devonport did not exceed 0s·2 on 84 per cent. of the 285 days of observation, did not

exceed $0^s \cdot 5$ on 97 per cent., and exceeded $1^s \cdot 0$ on two occasions. The average error for the year was $\pm 0^s \cdot 17$.

The automatic signals from the Westminster clock have been received much more regularly during this year. On 6 days the signal failed, and on 4 other days it was interrupted by telegraph signals. An improvement is also shown in the performance of the clock. Its apparent error was not greater than $0^s \cdot 5$ on 33 per cent. of the days of observation, not greater than $1^s \cdot 0$ on 58 per cent., not greater than $2^s \cdot 0$ on 87 per cent., not greater than $3^s \cdot 0$ on 98 per cent., and exceeded $3^s \cdot 0$ on only 4 occasions.

Provision has been made in the Navy Estimates for the observation of the total Solar Eclipse of 1905 August 30 by a party of three observers on the coast of Tunis, where the weather conditions are promising. It is proposed to take photographs of the corona for detail and extension with the Thompson 9 in. coronagraph, the 13 in. astrographic refractor, and the 4 in. Dallmeyer rapid rectilinear lens, and also photographs of the spectrum with the two spectroscopes lent by Major Hills, R.E., as in 1900 and 1901.

On the invitation of the Canadian Government, Mr. Maunder is joining their expedition to Labrador to observe the eclipse at the other end of the track, taking the Dallmeyer 4 in. coronagraph and a 4 in. rapid rectilinear lens for photographs of the corona, as in Mauritius in 1901.

VIII.—Personal Establishment:—

There have been no changes in the staff of the Observatory during the year.

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

Chief Assistants—Mr. Cowell, Mr. Dyson.

Assistants—Mr. Bryant, Mr. Crommelin, Mr. Hollis, Mr. Lewis, Mr. Maunder, Mr. Thackeray.

Clerical Assistant—Mr. Outhwaite.

Established Computer (Higher Grade)—Mr. Davidson.

Established Computers—Mr. Bowyer, Mr. Burkett, Mr. Edney, Mr. Evans, Mr. Furner, Mr. Melotte, Mr. Stevens, Mr. Storey, Mr. Witchell, and one vacancy.

Mr. Dyson and Mr. Cowell have the general superintendence of all the work of the Observatory. Mr. Maunder is charged with the heliographic photography

and reductions. Mr. Lewis has charge of the clocks, time signals, and chronometers, and of the 28-inch equatorial. Mr. Thackeray superintends the meridian work and miscellaneous astronomical computations, and this year has been specially engaged in the re-reduction of Groombridge's observations. Mr. Hollis superintends the photographic mapping of the heavens, the measurement of the plates, and computations for the Astrographic Catalogue. He also has charge of the reductions of the longitude determinations. Mr. Crommelin has charge of the altazimuth and of the observations of occultations. Mr. Bryant superintends the magnetic and meteorological observations and reductions. Mr. Outhwaite acts as responsible accountant officer, has charge of the library, manuscripts, and stores, and conducts the official and general correspondence. Mr. Davidson has charge of the Thompson equatorial and the measurement of the photographs taken with it. In particular, he has this year been employed on the measurement of the photographs of Eros taken in the opposition of 1900–1 for the determination of the Solar parallax. Mr. Bowyer, Mr. Edney, and Mr. Furner assist Mr. Lewis, Mr. Bryant, and Mr. Crommelin, respectively. Mr. Witchell and Mr. Storey, under Mr. Thackeray's direction, undertake respectively the reduction of the meridian zenith distances observed with the transit circle and with the reflex zenith tube, and of the transit observations with the transit circle. Mr. Melotte and Mr. Stevens are engaged alternate weeks, under Mr. Hollis' direction, in the reproduction of the enlarged prints of the astrographic chart. At other times Mr. Melotte assists in the measurement and reduction of the Thompson photographs, and Mr. Stevens in the astrographic work. Mr. Evans also assists Mr. Hollis in the measurement and reduction of the astrographic plates. Mr. Burkett assists Mr. Outhwaite.

The number of Supernumerary Computers at present employed in the Observatory is 30; of these, 13 are attached to the Astronomical Branch, 3 to the Chronometer and Time Signal Branch, 6 to the Astrographic Branch including the Thompson equatorial measures and reductions, 3 to the Heliographic Branch, 4 to the Magnetic and Meteorological Branch, and 1 to the Clerical Branch.

A foreman of works, with 2 carpenters and 2 labourers; a foreman mechanic, with 2 assistants; a gate-porter, 2 messengers, a watchman, a gardener, a labourer, and a charwoman are also attached to the Observatory.

The whole number of persons employed at the Observatory is 64.

W. H. M. CHRISTIE.

Royal Observatory, Greenwich,
1905, May 30.