REPORT

OF

THE ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1887, *June* 4.

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The present Report refers to the period of twelve months from 1886 May 21, to 1887 May 20, and exhibits the state of the Observatory on the last-named day.

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

The extension of the two Computing Rooms, to which reference was made in the last Report, has been sanctioned by the Admiralty, and provision for the work has been made in the estimates. Detailed plans have been prepared in which it is arranged that the Quadrant Passage should be included in the Lower Computing Room, and that the Upper Computing Room should extend over the Safe Room, with a central opening and spiral staircase to establish ready communication between the two rooms. Above the extended portion of the Upper Computing Room, a dome 18 feet in diameter is to be erected, in which it is proposed to mount the Cooke 6-inch equatoreal, the photo-heliograph tube being attached to the same mounting. The combined instrument will be carried on a pier to be built on the top of the old Quadrant Pier, which appears to be sufficiently firm for the purpose, and will command a complete view of the Sun throughout the day—an important consideration, as the work of the photoheliograph in its present position is seriously interfered with by trees and the Lassell dome. The 6-inch Cooke refractor will be available for occultations, phenomena of Jupiter's satellites, and other occasional observations. It may be anticipated that the concentration of the astronomical establishment thus effected will prove of great advantage.

Arrangements have been made for warming the South-east dome in damp weather by means of heated air passing through a large grating under the instrument from the stove in the Chronometer Room, which has been shifted to a suitable position.

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A photographic dark room has been fitted up on the staircase-landing of the South-east dome.

A lathe, with a set of chucks and turning tools, has been procured and set up in the basement of the Lassell building.

Four portable pneumatic fire-engines have been supplied to the Observatory by direction of the Admiralty.

As regards moveable instruments, three transits, an altazimuth, a photo-heliograph, and two clocks (Dent 1916 and 2013) are still at the Cape Observatory, a photoheliograph and the mountings of two others (without the tubes) are at South Kensington; a photoheliograph tube is in India; a transit, an altazimuth and a 6-inch equatoreal (Simms No. 2) have been lent for exhibition at Bethnal Green Museum, an altazimuth has been transferred to the Royal Naval College, and the Lee 6-inch equatoreal to the Hong Kong Observatory, the Hodgson 6-inch object glass is still in the hands of the Elder Brethren of the Trinity House for photometric experiments, and a clock with zinc and steel pendulum (Dent 2011) has been lent to the Kew Observatory.

The two Simms equatoreals, part of the mounting of the Corbett equatoreal, a photoheliograph and two photoheliograph mountings, two 4-inch detached telescopes (Simms Nos. 1 and 2), and part of the single prism spectroscope were lent for use in the Eclipse expedition to Grenada last August. Mr. Turner proposes to use the telescope of the Simms equatoreal No. 1 and a small portable equatoreal mounting for the observation of the Total Solar Eclipse of August next in Russia.

The micrometer used for measuring the Transit of Venus (1874) photographs has been lent to Capt. Darwin R.E. for measurement of the eclipse photographs taken by him last August.

The old instruments and apparatus stored in the South-east lower room have been thoroughly overhauled by Mr. Lewis, and those that appeared to be merely of historical interest have been transferred to Library 4, under the Altazimuth dome. The remainder are now disposed so as to be readily available for use.

The annual comparison of the books and manuscripts in the Library and Record Room with the catalogue has been made. Two of the books missing last year have been found on the shelves, but the third (a small octavo book) and two others are missing.

A copy of Maskelyne's printed observations has been lent to Dr. Auwers.

II. Astronomical Observations :—

Transit Circle.—No change of importance has been made in this instrument beyond the renovation of the recording micrometer apparatus, which was much worn by constant use since 1873. The collimator object glasses have been tested by Mr. Simms and pronounced to be excellent.

The Personal Equation Instrument has not been much used in the past year, partly owing to pressure of other work, and partly because it seemed expedient, before undertaking an extensive series of observations, to make arrangements for registering the end as well as the beginning of the contacts made by the instrument. With this object a small chronograph by Krille, made many years ago for mechanical registration, has, after some delay, been adapted by Messrs. E. Dent & Co. for electric registration of make and break contacts.

The regular subjects of observation with the transit-circle are the Sun, Moon, planets and fundamental stars, with other stars from a working catalogue. On the conclusion of the observations for the Ten-Year Catalogue at the end of 1886, a new list of some 3,000 stars was prepared to include all the stars in Groombridge's Catalogue and in the Harvard Photometry, which had not been observed at Greenwich since 1867. The Annual Catalogue of stars observed in 1886 contains about 1,665 stars.

The observations for the Ten-Year Catalogue, epoch 1880, were concluded at the end of 1886, special efforts being made in the latter part of the year to make the Catalogue as far as possible complete to the sixth magnitude inclusive. It is estimated that the Catalogue will contain about 4,000 stars, all of which, with very few accidental exceptions, have been observed at least three times in R.A. and N.P.D., the total number of observations being about 40,000 in each element.

The following statement shows the number of observations made with the Transit Circle in the twelve months ending 1887 May 20 :—

Transits, the separate limbs being counted as separate observations	6366
Determinations of collimation error	304
Determinations of level error	410
Circle observations	5983
Determinations of nadir point (included in the number of circle observations)	385
Reflexion-observations of stars (similarly included)	602

About 400 transits (included in the above number) have been observed with the reversion-prism, to determine personality depending on the direction of motion.

As regards the computations :—

The transits are completely reduced (so as to exhibit mean R.A. 1887 Jan. 1) to May 13, means of wires and of limbs being taken to May 19.

The investigation of personal equations in eye-and-ear transits, as well as in chronographic, has been completed for the year 1886. The results accord well with those found in the previous year. The practice of observing two clock-stars on each night by the eye-and-ear method has been maintained.

The circle observations are completely reduced (so as to exhibit mean N.P.D. 1887 Jan. 1) to May 14, means of microscopes being taken and micrometer equivalents entered to May 18.

The correction for discordance between the nadir observation and the mean of results from reflexion observations of north and south stars is $+0''\cdot09$. As there are considerable fluctuations in the individual months, no correction has been applied since the introduction of the new steel microscope-micrometer screws at the beginning of 1886.

Five determinations of the astronomical flexure of the transit-circle have been made since the last Report, the resulting values being $-0''\cdot16, +0''\cdot13, -0''\cdot15, -0''\cdot17$ and $-0''\cdot13$. It is clear that the flexure is very small, and, as in previous years since 1879, it has been considered better not to apply any correction for flexure, as distinct from the R – D correction.

The correction for R – D, the error of assumed colatitude, and the position of the ecliptic, have been investigated for 1886. The geocentric and heliocentric errors for the planetary results 1886 are computed, and the ledgers of mean R.A. and N.P.D. of stars for 1886 are prepared.

The value of the correction for discordance between reflexion and direct observations of stars for 1886 is accordant with the values for 1883, 1884, and 1885, being $+0''\cdot006 + 0''\cdot731$ Sin Z.D. It is to be remarked that the constant term (which is very small) has changed sign and become much smaller numerically in 1886 in correspondence with the alteration in the difference between the adopted and observed values of the nadir correction, the adopted value being that found from the observations of the preceding year, except in 1886, when no correction was applied.

The value found for the colatitude from the observations of 1886 is $38°.31'.22''\cdot03$, differing by $0''\cdot13$ from the assumed value; the correction to the tabular obliquity of the ecliptic is $+0''\cdot65$; and the discordance between the results from the summer and winter solstices is $-0''\cdot25$, indicating that the mean of the observed distances from the pole to the ecliptic is too great by $+0''\cdot12$.

The mean error of the Moon's tabular place (computed from Hansen's lunar tables, with Professor Newcomb's corrections) is $+0^s\cdot029$ in R.A. and $+0''\cdot34$ in longitude as deduced from 97 meridian observations in 1886. The mean error in tabular N.P.D. is $-0''\cdot66$, which would appear to agree with the observations of the Sun in indicating that the mean of the observed N.P.D.'s is too great.

As regards the computations for the Ten-Year Catalogue, a large amount of preparatory work has been done in the application of corrections to the observations as printed to reduce them to a homogeneous system, and some progress has been made in the formation of the catalogue results. The proper motions actually used have been thoroughly revised for every observation in the period 1877-1886, and corrections applied where, as occasionally happened, different proper motions had been used in the same year. A comparison has been made of the R.A.'s of clock-stars as observed

in the last ten years and as computed from the Nine-Year Catalogue, epoch 1872, with Auwers' recently published proper motions, the result of which is to show that the Greenwich observations are better represented by these than by the proper motions in use hitherto, and it has therefore been decided to adopt Auwers' proper motions throughout. Preparations have accordingly been made for reducing the observations in the Ten-Year Catalogue to the epoch 1880, with Auwers' proper motions wherever available. In regard to the R − D correction, the mean of the determinations for the four years 1883–1886 (which are very accordant) has been adopted for the whole period included in the Ten-Year Catalogue, the reflexion observations in these four years having a large range in zenith distance, consequent on the alteration in the mounting of the collimators. The constant term in the R − D correction of each year, which may be taken as representing residual nadir correction for the year, has however been retained. Corrections for reduction to the mean formula for R − D and for index error of the thermometer (in the period 1877 January 1 to 1879 April 3) have been applied to all the annual means throughout the years 1877 to 1886. The corrected annual results for R.A. and N.P.D. have been entered in the catalogue sheets for the first two hours of R.A. (327 stars), and the precessions and secular variations have been computed. The mean R.A. and N.P.D. 1880 (corrected for reduction to Auwers' proper motions) have been formed for the first hour of R.A. (178 stars.)

The results for level and azimuth errors of the transit-circle since its erection have been collected, and monthly and yearly means have been taken. These have been discussed by Mr. Turner in a paper communicated to the Royal Astronomical Society.

It has appeared doubtful whether the reading of the exterior thermometer placed near the north wall of the transit-circle room represents the true temperature of the external air as affecting the refraction for the Sun and other southern objects in the daytime. A discussion of simultaneous readings of the exterior, front court, and meteorological standard thermometers, which is being made by Mr. Thackeray, shows systematic differences between the first and last at the time of observation of the Sun, the mean monthly excess of the meteorological standard over the exterior thermometer for the ten years 1877–1886 ranging from $+0^{\circ}\cdot7$ in December to $+2^{\circ}\cdot1$ in May and August and $+2^{\circ}\cdot6$ in September. The reading of the front court thermometer (which is at a distance from any building) appears to agree closely with that of the meteorological standard, and it has been adopted, from the beginning of this year, in computing refractions for the Sun, Moon, planets and stars south of the zenith observed in the daytime, the exterior thermometer being still used for northern stars as probably representing better the temperature of the air on the north side of the transit-circle. The systematic differences in thermometer readings have a sensible effect on the position of the ecliptic as deduced from observations of the Sun, the discordance in the results between the summer and winter solstices found when the readings of the

exterior thermometer are used being rendered insensible when corrections are applied to reduce to the reading of the meteorological standard thermometer.

Altazimuth.—The total number of observations of various kinds made in the twelve months ending 1887 May 20 is as follows, the observations of the Moon having been as usual restricted to the first and last quarters in each lunation :—

Azimuths of the Moon and stars	356
Azimuths of the azimuth mark	208
Azimuths of the collimating mark	242
Zenith distances of the Moon	181
Zenith distances of the collimating mark	240

The altazimuth observations are completely reduced to March 31, so as to exhibit errors of Moon's tabular R.A., N.P.D., longitude, and ecliptic N.P.D., and the manuscript for the printer has been prepared to the same date.

The following table shows the number of days on which complete observations of the Moon were obtained with the transit-circle and altazimuth respectively :—

Moon's Time of Meridian Passage.	Transit-circle.	Altazimuth.
1^h to 2^h mean solar time . . .	0	6
2^h to 3^h ,, . . .	0	13
3^h to 4^h ,, . . .	5	10
4^h to 5^h ,, . . .	8	12
5^h to 6^h ,, . . .	8	13
6^h to 9^h ,, . . .	21	6
9^h to 12^h ,, . . .	27	—
12^h to 15^h ,, . . .	17	—
15^h to 18^h ,, . . .	13	4
18^h to 19^h ,, . . .	8	8
19^h to 20^h ,, . . .	5	8
20^h to 21^h ,, . . .	1	6
21^h to 22^h ,, . . .	0	6
22^h to 23^h ,, . . .	0	2

The whole number of places of the Moon observed with the transit-circle is 113 or 9·4 per lunation, and with the altazimuth 94 or 7·8 per lunation.

The Moon's diameter has been measured with the transit-circle 3 times in R.A. and 12 times in N.P.D.

The following is a statement of the number of observations made with the altazimuth reversion-prism in the year ending 1886 May 20, for determination of personality depending on the apparent direction of motion :—

	Moon.		Stars.	
	Chronographic.	E. & E.	Chronographic.	E. & E.
Double transits	177	110	252	108
Nights of observation	16	7	17	13

Clocks and Chronograph.—Several auxiliary clocks which had not been cleaned for many years have been cleaned recently. The sidereal standard and mean solar clocks and the chronograph are in good order.

Reflex Zenith Tube.—The observations of zenith distance of γ Draconis have been resumed, and 33 double observations have been made since the date of the last report. The results of the transits observed in the years 1883 to 1885, made for determination of the temperature correction, have been collected and the value of an interval of the wires has been tabulated for different temperatures and different scale-readings for focus. The discussion is not yet quite completed.

Equatoreals.—Various additions have been made to the Lassell equatoreal with a view to making it available for astronomical photography and for general use. A delicate slow motion in R.A. (with differential wheels) and a firm N.P.D. clamping arm with fine motion in N.P.D. have been applied, the steadiness and general usefulness of the telescope being greatly increased by these additions. The Corbett $6\frac{1}{2}$-inch refractor has been mounted below the tube of the reflector and parallel to it to serve as a directing telescope in taking photographs and also for observation of occasional phenomena. A camera to take circular plates $8\frac{1}{4}$ inches in diameter (giving a field 1° 58′ in diameter) has been mounted at the principal focus of the Lassell mirror and some trial photographs of the Moon, Procyon, Regulus, γ Leonis, and Præsepe, have been taken.

The construction of the new 28-inch refractor has been delayed by difficulty in obtaining the discs of glass. Messrs. Chance are engaged in removing a bunch of fine veins from the flint glass disc, and have every hope of being able very shortly to report the disc practically perfect; and M. Feil's successor has successfully moulded a crown disc from which he believes that he has removed all defects. Meanwhile I have settled the details of the special tube and other mechanical parts with Mr. Grubb, and he has made considerable progress with its construction, so that when the object glass is completed it will be mounted without delay.

The South-east and Sheepshanks equatoreals are in good order. Some trouble has been experienced with the water supply for the driving clock of the former instrument, and an alteration in the arrangements for maintaining the pressure has been made at the Kent Waterworks, since which the working has been found quite satisfactory.

The Cooke 6-inch equatoreal is being mounted in the South ground for trial of the instrument before erecting it in the new dome to be constructed over the Computing Rooms, and also for photographic experiments with the photoheliograph (which is to be attached to the same mounting), as to the practicability of using curved plates for stellar photography and other questions which have been raised at the Paris Conference on astronomical photography.

During the past 12 months, 29 occultations of stars by the Moon (17 disappearances and 12 reappearances) and 12 phenomena of Jupiter's satellites have been observed with one or more of the equatoreals or with the altazimuth. The occultations are completely reduced to 1887 January 12, and the phenomena of Jupiter's satellites to the end of 1886. Comets have been observed with the Sheepshanks Equatoreal on 25 nights during the year ending 1887 May 20, viz., Comet *e* 1886 on two nights, Comet *f* 1886 on twelve nights, Comet *b* 1887 on nine nights, Comet *c* 1887 on one night, and Comet *d* 1887 on one night. All the observations of comets have been completely reduced.

III. Spectroscopic and Photographic Observations :—

The chromosphere and solar prominences have been observed with the half-prism spectroscope on two days only. We have for the present reluctantly discontinued the spectroscopic observation of the Sun, as it is not possible under existing circumstances to secure a sufficient number of observations to serve any useful purpose.

For determination of the motions of stars in the line of sight, 206 measures have been made of the displacement of the F line in the spectra of 26 stars, and 20 measures of the *b* lines in eight stars, besides comparisons with lines in the spectrum of the Moon made in the course of the night's observations of star motions, or of the sky on the following morning, as a check on the general accuracy of the results. The observations of Sirius since the date of the last Report, indicate that the apparent displacement of the F line (which was originally towards the red and subsequently towards the blue) is now insensible. The displacement of the F line in the spectrum of Algol has been measured as frequently as possible during the winter months, in order to ascertain if any evidence could be obtained of rapid orbital motion such as would result from the hypothesis of the variability of Algol being caused by the transits of a large satellite. A sufficient number of observations has not yet been obtained to allow a definite conclusion to be formed, but as far as the observations go

there are indications of a variation of the motion in the line of sight corresponding to orbital motion, having the same period as that of the star's variability. The spectrum of Comet *f* 1886 (Barnard) was examined with the half-prism spectroscope on one night.

The spectroscopic observations are less numerous than usual, owing to various causes. Mr. Maunder was absent on the Eclipse Expedition to the West Indies in the autumn, whilst Mr. Nash has, through pressure of work in the Magnetical and Meteorological Department, been unable to take part in these observations. Also since February 16 the South-east equatoreal has been devoted to experiments in astronomical photography, and the spectroscope has consequently been out of use.

A photographic corrector, consisting of a concave crown and convex flint lens (in contact), placed about 30 inches within the focus, has been applied to the telescope of the South-east equatoreal to correct the chromatic aberration of the object glass for the photographic rays without alteration of the focal length. A Dallmeyer doublet (formerly used in the photoheliograph) has been employed to enlarge the primary image about $7\frac{1}{2}$ times, so as to give on the photographic plate an image on a scale of about 0·45 in. to one minute of arc, or 15 inches to the Sun's diameter. A number of trial photographs of Castor, γ Virginis, Venus, Jupiter and Saturn have been obtained. The photographs of the double stars appear to be susceptible of very accurate measurement, and several of the photographs of Jupiter show the four satellites, the belts and the red spot. A photograph of γ Virginis, showing the components widely separated, has also been taken at the primary focus, the Dallmeyer enlarging doublet having been removed. It is intended also to use the photographic corrector with the Dallmeyer doublet to obtain photographs on a large scale of sun-spots, craters on the Moon, and other objects of small angular dimensions. The field of view with the photographic corrector is necessarily very restricted.

The spectroscopic observations of all kinds are completely reduced to the present time.

In the twelve months ending 1887 May 20, photographs of the Sun have been taken at Greenwich on 215 days, and of these 421 have been selected for preservation, besides 16 photographs with double images of the Sun for determination of zero of position.

For the year 1886 Greenwich photographs are available on 199 days, and photographs from India and Mauritius filling up the gaps in the series, on 164 days, making a total of 363 days out of 365 on which photographs have been measured, the record being thus practically complete for 1886.

The areas of both spots and faculæ have continued to decline through 1886 and 1887, the Sun being free from spots on 61 days in the year 1886. In the period of 150 days from 1886 October 30 to 1887 April 17 on which photographs are at present available, there were 73 days on which no spots were visible on the Sun. Since

April 17 there has been a revival of activity. As in 1885, the mean spotted area of the northern hemisphere has been much smaller than that of the southern.

As regards the photographic reductions :—

The Greenwich photographs have been measured in duplicate as far as 1887 April 28, and the measures have been completely reduced so as to exhibit heliographic longitudes and latitudes of spots and areas of spots and faculæ.

The photographs from India and Mauritius have been received from the Solar Physics Committee as far as March 10 and February 20 respectively, and these have all been measured, and the measures completely reduced.

In order to facilitate the discussion of the changes from day to day in a spot-group, and the recognition of those regions of the Sun where spots form most frequently, a form has been prepared for use in which the areas and positions of the spots of a group are to be collected for the several days on which the group was visible, and the area and mean longitude and latitude of the group formed. In these ledgers of spot-groups it is proposed to print, in addition to the area on the Sun's surface, the projected area as measured (uncorrected for foreshortening), as it is not improbable that changes in the earth's magnetism and other terrestial effects of the Sun's action may have relation to the projection of the solar spotted area on the plane perpendicular to the line of sight rather than to the actual area of the spots on the Sun's surface. All the numbers have been entered in the Ledgers of Spot-groups for 1886.

The discussion of probable error and personality in measurements of areas and positions of spots and faculæ on solar photographs, mentioned in the last report, is printed in the volume of Greenwich Observations for 1885.

A set of solar photographs was lent to the Glasgow Photographic Exhibition last year, and another set to the Potsdam Photographic Exhibition.

IV. Magnetical Observations :—

The observations have been continued on the same lines as in former years, changes in the magnetic declination, horizontal force and vertical force being continuously recorded by photography and the absolute values of magnetic declination, horizontal force and dip being determined from time to time by eye-observation. Earth currents in two directions nearly at right angles to each other are also photographically registered. For these last the ordinates have hitherto been measured on an arbitrary scale, and it appeared desirable to obtain the data for expressing this in terms of the accepted electrical units. The authorities of the Post Office Telegraphs have courteously given every assistance in regard to the requisite electrical measurements, and an electrical balance for measuring resistance, a standard cell and a galvanometer of the Post Office pattern have been procured under their auspices. In

October last Mr. H. R. Kempe of the Post Office Telegraphs made some measures of the resistances of the earth current wires, but the conditions were not then favourable for insulation. Subsequently the wires were damaged in the snowstorm of December 26-27 last, and were temporarily repaired on January 25. It is believed that they are now restored to their normal condition, and arrangements are being made to obtain the value of the difference of electric potential between the two earth-plates on each line corresponding to a given length of ordinate on the photographic register. An experimental set of measures of resistance has been taken recently.

The Richard thermograph has been regularly used to obtain a continuous record of the temperature of the magnet-basement, its indications being checked by eye-observations several times a day.

As regards the magnetic reductions, the eye-observations of the upper declination magnet and of the horizontal and vertical force magnets are completely reduced to the end of 1886. The time scales for declination, horizontal force, and vertical force are complete to the end of 1886, and the base-line values, deduced from the eye-observations, are entered on the photographic sheets.

The hourly ordinates of the photographic curves are read out to the end of 1886 for all three magnets, and the daily and hourly means are taken for horizontal and vertical force. The time scales for the earth currents are laid down to the end of 1886. The dip observations are completely reduced to the present time, and the deflexion observations for absolute measure of horizontal force to the end of 1886. The temperature of the magnet basement at every hour has been read off from the sheets of the Richard thermograph to the end of 1886.

In order to complete the determination of the temperature corrections of the horizontal and vertical force magnets further experiments were made last summer, when a much higher temperature of the basement could be obtained than on the previous occasions. The range of mean daily temperature in the summer experiments was from 67° to 79° whilst in the other cases it was from about 48° to 62°. The temperature correction of the vertical force magnet is the same at the high temperature as at the low, but that for the horizontal force appears to be slightly greater in the summer experiments, indicating that the correction increases numerically with the temperature.

The following are the principal results for magnetic elements for 1886 :—

Approximate mean declination . .	17° 55′ West
Mean horizontal force . .	3·9379 (in British units) 1·8157 (in Metric units)
Mean Dip	67° 26′ 38″ (by 9-inch needles) 67° 26′ 45″ (by 6-inch needles) 67° 27′ 40″ (by 3-inch needles)

In the year 1886 there were only four days of great magnetic disturbance, but there were also a number of other days of lesser disturbance for which tracings of the photographic curves will be published, as well as tracings of the registers on four typical quiet days. Mr. A. J. S. Adams of the Post Office Telegraphs made an examination last October of the magnetic photographs in regard to the accuracy of the lithographic plates given in the Greenwich observations, and satisfied himself as to their fidelity.

A specimen set of magnetic and meteorological photographic registers and specimen solar photographs were lent to the Glasgow photographic exhibition last year. All have been returned in good condition.

The declination and horizontal force magnets were thrown into vibration by the earthquake shock of February 23, the extent of vibration being 20′ in declination and 0·004 of the whole horizontal force in that element. The motion commenced at $5^h\ 37^m{\cdot}6$ Greenwich civil time, and a second double disturbance of much smaller amplitude (possibly accidental) was registered from $7^h\ 39^m$ to about $7^h\ 57^m$. At the request of M. Mascart, a copy of the photograph has been sent to him for discussion with other records of the earthquake which he is collecting. In view of the importance of the study of earthquakes, it appears desirable that a suitable seismograph should be procured for the Observatory.

V. Meteorological Observations :—

The continuous registers of barometer, dry and wet bulb thermometers, direction, pressure, and velocity of wind, rain, sunshine, and atmospheric electricity have been maintained with the usual regularity.

The record of temperature of the air and of evaporation has been continued throughout 1886 with the old as well as with the new photographic thermometer apparatus, in order to obtain satisfactory comparisons between the indications of the two instruments at different seasons of the year. From the beginning of this year the register with the old apparatus has been discontinued, though it has been used occasionally when the new instrument was out of use, as on some days in March (the new wet bulb thermometer having been accidently broken) and since May 13, when the clock of the new thermograph, after repeated stoppages, was sent to Mr. Kullberg for thorough repair.

A Stevenson screen, with dry and wet bulb and maximum and minimum thermometers, has been mounted near the stand carrying the standard thermometers, and regular readings have been taken since January 21 for comparison of the two sets of thermometers.

The readings of the thermometers on the roof of the Magnet House have been continued, and a comparison with those of the standard thermometers for the year

1886 shows that the diurnal range of temperature is generally greater for the latter, except during the three winter months. The differences between the two thermometers, due to difference of exposure, frequently amount to several degrees.

The new sunshine recorder of Professor Stokes's improved pattern was brought into use at the beginning of 1887, the record with the Campbell instrument being, however, still continued for purposes of comparison.

Experiments were made last summer with the new thermograph and the standard thermometer stand to determine how far it is necessary to screen the thermometer-bulbs from possible effect of radiation from neighbouring objects. The boards placed on the north and south sides of the thermograph were alternately removed and replaced a number of times on five days of nearly uninterrupted sunshine specially selected as likely to be favourable for radiation effects. The mean excess of recorded temperature with the boards off was for the several days $+0°{\cdot}1$, $-0°{\cdot}2$, $0°{\cdot}0$, $+0°{\cdot}2$ and $+0°{\cdot}1$ respectively, from which it may be concluded that there is no sensible effect of radiation with the boards off, and they were accordingly removed in December. As regards the standard thermometers, the circular board fixed in 1878 to screen the bulbs from ground radiation was alternately removed and replaced a number of times on four selected days, and the results for mean excess of reading with the board off were $-0°{\cdot}3$, $+0°{\cdot}1$, $-0°{\cdot}3$ and $+0°{\cdot}1$, indicating that in this case also there is no sensible radiation from the heated ground.

The meteorological reductions are in the following state:—The observations of barometer, thermometers, anemometers, rain-gauges, and sunshine recorders (corrected, where necessary, for instrumental error) are reduced up to the present time. On the photographic sheets all the time-scales are laid down to the end of 1886. The hourly ordinates are read out for the dry and wet bulb thermometers (old apparatus) to the end of 1886, and for the dry bulb of the new thermograph to April 1886. The hourly ordinates for the electrometer are also read out to the end of 1886, and the table of principal changes of direction of the wind for 1886 has been prepared.

The mean temperature of the year 1886 was $48°{\cdot}7$, being $0°{\cdot}6$ below the average of the preceding forty-five years. The highest air temperature in the shade was $89°{\cdot}8$ on July 6, and the lowest, $16°{\cdot}5$, on January 7. The mean monthly temperature in 1886 was below the average in January, February ($6°{\cdot}0$), March, June and December, and above the average in September, October and November. In the period of 156 days from 1886 December 16 to 1887 May 20 the mean temperature was $3°{\cdot}1$ below the average of twenty years, the daily temperature being below the average on 115 days.

The mean daily motion of the air in 1886 was 291 miles, being 7 miles above the average of the preceding nineteen years. The greatest daily motion was 857 miles on December 8, and the least, 56 miles, on October 8. The recorded pressures in 1886, exceeding 20 lbs. on the square foot, were $27{\cdot}6$ lbs. on March 31, and $23{\cdot}5$ lbs. on December 9.

During the year 1886 Osler's anemometer showed an excess of about 17 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 by Campbell's sunshine instrument during 1886 was 1,228, which is about twenty hours above the average of the preceding nine years. The aggregate number of hours during which the Sun was above the horizon was 4,454, so that the mean proportion of sunshine for the year was 0·276, constant sunshine being represented by 1.

The rainfall in 1886 was 24·2 inches, being 0·5 inch below the average of the preceding forty-five years.

Provision has been made in the estimates for the current year for the discussion of the photographic registers of barometer for the years 1874–1876, and of thermometers (dry and wet bulb) 1869–1876, referred to in the Report for 1883. The work will be taken in hand at once.

VI. Printing and Distribution of Greenwich publications :—

The volume of Greenwich Observations, 1884, and the separate copies of the Results were distributed last October after considerable delay at the binder's.

The whole of the volume for 1885 has been passed for press.

As regards the volume for 1886, the proof sheets of the whole of the altazimuth section have been revised, and the proof sheets of the Spectroscopic Results, of the Transits to March 13, and of the Meridian Zenith Distances to March 9 have been received. The MSS. of the Transits to August 31 and of the Meridian Zenith Distances to December 31 are in the printers' hands.

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

The number of chronometers now being tested at the Observatory is 225, and of these 170 (126 box-chronometers, 19 pocket-chronometers, and 25 deck-watches) belong to the Navy, 52 box-chronometers are the property of various chronometer makers, who have sent them for the special competitive trial, and 3 deck-watches have been placed here for trial by Messrs. E. Dent & Co., with a view to the selection of 2 of them to be transferred to the Navy in exchange for some old chronometers.

The first seven chronometers in the competitive trial of 1886 were exceptionally good, the first chronometer being superior to any we have previously had on trial, except the first in 1882.

As mentioned in the last Report, the time of commencement of the annual trial of chronometers has been altered to the first Saturday in July, so that the trial may terminate at a time more convenient for the financial arrangements of the Admiralty.

But as it is desired to increase the stock of Navy chronometers without delay, a supplementary trial (for which 52 chronometers have been entered) was commenced on March 5, the rating to terminate on June 18, just before the commencement of the ordinary annual trial.

For the annual trial of deck-watches, which commenced last November, 15 watches were entered, and of these 9 were purchased for the Navy, the first three being classed "A," or equal, in performance, to an average box-chronometer.

A supplementary trial took place in February and March, for which 9 deck-watches were entered, and of these 7 were purchased for the Navy, the first two being classed "A."

The watches in each trial were rated for a period of 9 weeks, viz., 2 weeks (dial up) in the room at a temperature of 50° to 55°, 4 weeks in four different positions in the oven (dial up, pendant up, pendant right, pendant left, arranged symmetrically) at a temperature of about 80°, and 3 weeks (dial up) in the room. When the period of rating in any position was less than a week, weekly rates were inferred from the rate for the period by simple proportion.

In order to compare the performances of the several watches, "trial numbers," representing deviations in weekly rates, have been formed on the same general principles as for the chronometer trials. The trials in different positions introduce, however, a new element, and an arbitrary weight must be assigned to them in combining them with the trials "dial up." It has been considered that when the watch is worn in the pocket the pendant will generally be "up," and that not more than one-third of the deviation "pendant right" or "pendant left" is likely to have practical effect.

Putting a = Difference between greatest and least weekly rates "dial up,"
b = Greatest difference between one week and the next "dial up,"
c = Difference between weekly rates "pendant up" and "dial up,"
d = " " " "pendant right" and "dial up,"
e = " " " "pendant left" and "dial up,"

the quantity $c + \frac{d}{3} + \frac{e}{3}$ may be taken as the measure of the deviation in weekly rate due to positions in ordinary wear. Half weight has been given to this quantity in combining it with the trial number "dial up" $(a + 2b)$, on the assumption that the deck-watch would be usually lying "dial up" and that it would not be carried in the pocket more than eight hours a day on the average. Thus the quantity $a + 2b + \frac{1}{2}(c + \frac{d}{3} + \frac{e}{3})$, has been adopted as the trial number for deck-watches. It has been

arranged that for the future all pocket chronometers and deck-watches rated at the Observatory after repair shall be tested in positions.

The following is a statement of the trials of chronometers and deck-watches for purchase from the beginning of 1886 to the present time :—

Annual trial of 37 chronometers for the Navy .	from 1886 Jan. 9 to 1886 July 24.
Trial of 15 deck-watches for the Navy . . .	„ 1886 Feb. 15 „ 1886 March 6.
Trial of 2 chronometers for the Navy . . .	„ 1886 July 10 „ 1886 Nov. 6.
Trial of 8 chronometers for the Indian Government	„ 1886 Sept. 1 „ 1886 Sept. 31.
Trial of 4 deck-watches for the Indian Government	„ 1886 Sept. 1 „ 1886 Sept. 31.
Trial of 15 deck-watches for the Navy . . .	„ 1886 Nov. 27 „ 1887 Jan. 22.
Supplementary trial of 9 deck-watches for the Navy	„ 1887 Feb. 5 „ 1887 April 2.
Supplementary trial of 52 chronometers for the Navy	„ 1887 March 5 „ 1887 June 18.
Trial of 3 deck-watches for the Navy. . . .	„ 1887 May 16 „ 1887 July 18.

In addition to the above, 3 chronometers have been tested for the Indian Government after being repaired.

The temperature of the chronometer oven has been successfully regulated by Mr. Kullberg's automatic apparatus to the temperature of about 80° for the trials of deck-watches as well as to the higher temperature at which chronometers are tested.

In June and July last year, Mr. Lewis spent several days at the Admiralty in comparing the chronometer books kept there with those of the Observatory, and after some trouble a complete accordance was finally secured.

The automatic drop of the Greenwich time-ball failed on one day only during the past twelve months. On three days the ball was not raised on account of the violence of the wind, and on five days on account of accumulation of snow on the mast.

As regards the Deal time-ball, there have been twelve cases of failure owing to interruption of the telegraphic connections, and on three days the violence of the wind prevented the raising of the ball. For fourteen days after the snow storm of December 26-27, no signals were sent to or received from the Deal time-ball tower, telegraphic communication being interrupted. There have been four cases of failure of the 1 PM. signal to the Post Office Telegraphs.

The arrangements for hourly time-signals at Devonport to be given by a local clock, corrected daily by the help of a time-signal at Greenwich at 10 A.M., have been

carried out under Captain Wharton's directions, and a return signal from Devonport (serving as a test of the accuracy with which the local clock was corrected) has been regularly received at Greenwich (at $13^h\ 0^m\ 39^s$ G.C.T.) since November 22, with the exception of 36 days following the snowstorm of December 26–27, when there was interruption of the telegraphic communication with the west of England, and of 23 days when no return signal was received. The failures occurred for the most part on Sundays. The plan appears to answer well, and it seems desirable that apparatus should be provided by the Government to enable the Committee of Lloyd's to establish hourly signals at the Lizard on the same system.

The new contact apparatus of the Westminster clock was brought into action on 1886 May 22, and the automatic signals from the clock have been received regularly from that date, except on three days following the snowstorm of December 26–27. The error of the clock was insensible on 25 per cent. of the days of observation, 1^s on 40 per cent., 2^s on 22 per cent., 3^s on 11 per cent., and 4^s on 2 per cent. On one day the signal was 15^s late and on another day 10^s late.

A suggestion has been made that in view of the importance of the connection of the British and Continental surveys, the telegraphic difference of longitude between Greenwich and Paris, which was originally determined with great care in 1854, should be confirmed in order to complete the network of telegraphic longitudes which have been determined of late years by continental astronomers. It seems desirable that Greenwich Observatory, which, under Sir G. B. Airy's direction, took such an active part in utilizing the telegraph for the determination of longitude should now assist in completing the cycle. The necessary exchange of observers and signals could conveniently be carried out in the summer of next year, when the French geodetists will, I understand, be prepared for their share of the work.

VIII. Personal Establishment :—

The staff of Assistants remains the same as at the date of the last Report. Provision has been made in the Navy Estimates for the appointment of a Clerk for office work, as recommended by the Board of Visitors at the last Visitation, but I have not received any official communication from the Admiralty on the subject. The following is a list of the Assistants, the names in each class being arranged in alphabetical order :—

Mr. Turner, Chief Assistant ;

Mr. Criswick, Mr. Downing, Mr. Ellis, and Mr. Maunder, First-class Assistants ;

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

Mr. Turner has the general superintendence of all the work of the Observatory, with full power to act during my absence. Mr. Criswick takes charge of the transit reductions and miscellaneous astronomical computations. Mr. Downing superintends the altazimuth and equatoreal computations, and has the care of the library and manuscripts. Mr. Thackeray is charged with the circle and zenith-tube reductions, and with the reading out of the chronographic transits. Mr. Lewis superintends the time department, including chronometers, and takes charge of the money accounts and stores. Mr. Maunder and Mr. Hollis have the charge of all the spectroscopic and photographic observations and reductions. In the magnetical and meteorological branch Mr. Ellis superintends the whole of the work, assisted by Mr. Nash, who is specially charged with the meteorological reductions and instrumental adjustments.

There are at the present time eight computers attached to the astronomical branch, one to the spectroscopic and photographic, and four to the magnetical and meteorological.

A gate-porter, a watchman, a gardener, and a foreman of works, with two carpenters and a labourer, complete the establishment.

It may be mentioned here that Mr. Turner and Mr. Maunder took part in the observation of the total solar eclipse of August last at Grenada, West Indies, and that Mr. Charles Chambers, Jun., spent a fortnight at the Observatory last September in making himself acquainted with the method of observing with the transit-circle, and of reducing the observations.

IX. General Remarks :—

As the result of an International Congress on Astronomical Photography held at Paris in April on the invitation of the French Academy of Sciences, at which 56 representative astronomers from all parts of the world were present, a scheme has been approved for the formation of a photographic map of the heavens by the concerted action of a number of observatories in both hemispheres. This scheme provides for two series of photographs, the one intended to contain all stars down to the 14th magnitude inclusive, and the other, taken with short exposure, specially designed to give accurate positions of brighter stars down to the 11th magnitude, so that it may be possible to form an extensive catalogue of reference-stars for the first series, and thus to give the means of accurately determining the position of any star on the photographic map down to the 14th magnitude. The instruments with which this work is to be jointly carried out are to be photographic refractors of $0^{m}{\cdot}33$ (13 inches) aperture and $3^{m}{\cdot}43$ ($11^{ft.}\ 3^{in.}$) focal length, and the Directors of the following ten observatories have already announced that they are prepared to take part in the enterprise :—Algiers, Bordeaux, Paris, Toulouse, and Vienna in the northern

hemisphere; La Plata, Melbourne, Rio de Janeiro, Santiago da Chile, and Sydney in the southern hemisphere. It seems fitting that Greenwich should take its share in a scheme which will in a few years so greatly extend our knowledge of the places of the fixed stars, and thus serve to carry out one of the principal objects for which the Astronomer Royal was appointed.

On a review of the work of the past twelve months, it will be found that the activity of the Observatory has increased in various directions. The number of meridian observations is much larger than usual; additions have been made to the work of the magnetical and meteorological branch; there have been continuous trials of chronometers and deck-watches (requiring special arrangements in each case), which have made large demands on my own time, as well as on that of Mr. Turner and of Mr. Lewis. Extraneous work in connection with the Navy has also absorbed a good deal of time that would otherwise have been free for scientific investigations. Questions connected with gun-directors, mirrors for electric search-lights, and binoculars for the Navy have continued to engage our attention, and since the date of the last Report 510 telescopes and 35 binoculars for the Navy have been sent to the Observatory for examination, whilst it is to be presumed that a further supply of 500 binoculars, now on order, will be forwarded here to be tested in due course.

Whilst it seems desirable that such directly utilitarian work should be undertaken at the Observatory, as being the only existing Government establishment where it can be done efficiently, I feel it necessary to point out that the existing staff is inadequate for these extraneous duties in addition to the well-defined work for which the Observatory is primarily maintained. By great efforts, which can hardly be sustained for an indefinite period, the current reductions have been kept up, notwithstanding the large number of observations obtained in the last twelve months, but the ulterior discussions which are required to maintain the character of the Observatory as a scientific institution are falling further and further behind. Amongst other matters which I should wish to take up, if leisure could be found, I may mention the determination of proper motions of stars from the observations made at Greenwich since Sir G. B. Airy's appointment in 1835, an investigation which appears to come within the terms of the Royal Warrant directing the Astronomer Royal "to rectify the tables of the motions of the heavens and the places of the fixed stars."

The appointment of a clerk, which has presumably received the sanction of the Admiralty, will, when it is made, provide for the increase of office-work which has taken place of late years in regard to chronometers, accounts, stores, stationery, printing, &c., and if the maintenance of the telegraph wires, batteries, &c., for communication of time-signals were undertaken by the Post Office Telegraphs as part of the distribution of time to the public, there would be some further relief. But to enable me to give time to extraneous questions referred to the Astronomer Royal by the Government, it appears necessary that the Chief Assistant and I should

be relieved of certain mechanical work which might be entrusted to computers, and that further responsibility should be delegated to the Assistants. Proceeding on the lines which have been laid down by my predecessor, I believe that the maximum of efficiency at the minimum of cost would be attained if an increase of work were met by an increase in the staff of computers, with due recognition of the position of two or three senior computers, and of the increased responsibility of the Assistants.

W. H. M. CHRISTIE.

ROYAL OBSERVATORY, GREENWICH,
1887 *May* 21.