REPORT

OF

THE ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1881, *June* 4.

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The present Report refers to the period of twelve and a half lunations between the New Moon of 1880, May 9, and the Full Moon of 1881, May 13, and exhibits the state of the Observatory on 1881, May 13.

I. Buildings and Grounds:—

The erection of the proposed new Library, the site for which had been cleared last year, has been sanctioned by the Government, and the work will be carried out under the superintendence of the Director of Works to the Admiralty. The building is to consist of a room of one storey, 50 by 18 feet, with galleries at mid-height. To make room for the new Library, the fire-hydrant near the Magnetic Observatory has been moved a short distance. (It may here be mentioned that the fire-hose is periodically tested, and all the members of the staff are practised in its use.)

Some trouble has been occasioned by the intrusion of water into the Magnetic Basement, the source of which has not been perfectly traced.

Halley's ancient tombstone, after its removal from Lee Churchyard (where it has been replaced by a new stone with a fac-simile of the inscription), had been placed in the South Ground, where it has been lying for several years. It has now been carefully restored, and mounted on the east wall of the lobby of the North Dome.

The new line of underground telegraph-wires has been completed by the officers of the General Post Office. The new route is down Croom's Hill, joining the ordinary Post Office wires at the corner of London Street, instead of through the Circus and Circus Street as heretofore. The result of this change, at least as regards the earth-current-wires, and probably as regards the other wires, has not been satisfactory. Allusion will be made, in a following section, to the difficulties which have been introduced. The telegraphic authorities of the General Post Office have been engaged in the search for the causes of the abnormal indications, but have hitherto found no fault in the wires. I am proceeding to change the earth-plates.

II. Moveable Property :—

The only changes to record are in the disposition of the Transit of Venus instruments. Of these, three transits (to two of which, portable iron stands have been fitted by Mr. Simms), one altazimuth, and three clocks, have been sent to Mr. Gill at the Cape of Good Hope, for determination of the Cape longitude. The disposal of the other instruments remains the same as at the date of the last report :—A transit, an altazimuth, an equatoreal, and a photoheliograph, are at South Kensington ; a photoheliograph is at the Cape of Good Hope ; and another (telescopic part only) is in India ; a photoheliograph and an equatoreal (the "Naylor") are mounted here for daily use ; and the remaining instruments, viz., one transit, three altazimuths, three equatoreals, and one photoheliograph, together with eight detached telescopes, are in our hands. In view of the Transit of Venus next year, the Corbett telescope has been adapted to the equatoreal mounting of one of the photoheliographs, and erected for trial in the South Ground.

III. Manuscripts :—

To accommodate our increasing store of manuscripts, new shelves have been placed in the Lower Record room.

The missing book of Zenith Points of the Altazimuth has not been found. It appears to have been lost at the binder's. The Bradley manuscripts lent to Dr. Auwers for many years have been returned.

The usual comparison of the manuscripts with the Catalogue has been made, and all the catalogued manuscripts have been found.

IV. Library :—

The increase in the number of books has caused serious inconvenience, through the pressure on our present limited space ; and a more commodious library is urgently needed. The cataloguing of the library, which had fallen into arrear owing to the long delay in the appointment of an Assistant, has now been completed, and everything is in its normal condition. It has, however, not been possible to find room for all the books in due sequence on the shelves, and they have been temporarily arranged as well as the space at our disposal permits. A new section of " Astronomical Physics " would appear to be desirable.

We have many duplicates, especially of Modern Serial Transactions, which it will be necessary to banish from the library.

The library has been compared with the Catalogue, as usual, and all the books have been found.

V. Astronomical Instruments :—

The Transit-Circle is in good working order. The only change to record is an alteration in the positions of the indexes of the microscope-micrometers, which are now placed so as to be fully illuminated by the central lamp.

New determinations of the flexure have been made on 1880, July 22 and December 6, and 1881, May 2, and May 10. The values found are $+0''{\cdot}04$, $+0''{\cdot}20$, $+0''{\cdot}13$, and $+\ 0''{\cdot}18$, confirming the change of sign remarked in 1879. No correction for flexure has been applied to the observations.

The wires of the North Collimator have been renewed, having been accidentally broken.

The alterations in the Sidereal Standard Clock referred to in the last report have been carried out, and it is now used to regulate, on Jones's principle, another clock placed near it in the magnetic basement. This clock in turn drives the Sidereal Relay, and, through its intermediation, registers seconds on the chronograph, and drives the system of sympathetic Sidereal clocks. For this purpose a toothed wheel has been fitted on the escape-wheel-arbor of the Sidereal Standard, giving 2-seconds'

contacts by means of a pair of springs. After some difficulty occasioned by the shortness of the contact, which was met by the use of longer springs, the system has been brought into operation. The springs formerly acted on by the pendulum have been removed. As the action of the toothed wheel on the contact-springs now takes place after the impulse has been given to the pallet, and while the pendulum is quite free from the train, it is expected that the springs will not have any effect on the rate of the clock, such as was found with the former arrangement. These alterations were carried out by Messrs. E. Dent and Co., between 1880, September, and 1881, April; the clock "Hardy" being used in place of the Sidereal Standard during the interval.

The clock "Hardy" and the other clocks are in good order.

The Chronograph has been cleaned and is in excellent state.

The Altazimuth is in an efficient state. A metal cover, to protect the horizontal circle from dust, has been applied; and to it have been attached the illuminators for the microscopes. The object-glass has been cleaned, and the horizontal wires have been renewed, having been accidentally broken in trying to remove a piece of dirt which had lodged on them. The division-errors of the horizontal circle (recently re-graduated) have been determined for every 5°, and interpolated for every 1°. Corrections for division-error are now applied to the readings of both the vertical and horizontal circles, though the quantities are small.

The new Azimuth-mark, upon the parapet of the Naval College, is found to be perfectly satisfactory as regards both steadiness and visibility.

All the Thermometers in use with the Transit-Circle and Altazimuth have been lately compared with the Standard. In only one case is there any appreciable change of index-error.

The South-East Equatoreal is in good order. The contact springs at the upper pivot continue to give trouble, sometimes from failure of insulation in damp weather, and sometimes through interruption of contact from occasional dirt.

The Half-prism Spectroscope and the Single-prism Spectroscope have received some trifling repairs and alterations.

The Sheepshanks and Shuckburgh Equatoreals are in working order.

The Photoheliograph is in an efficient state.

The "Naylor" Equatoreal, mounted in the South Ground, had become very rusty during the winter. It has now been cleaned, and is in excellent order.

All the instruments have suffered from the congealing of the oil during the severe weather of the past winter, and very thorough cleaning of all the moving parts has been necessary.

VI. Astronomical Observations :—

The subjects of observation with the Transit-Circle remain the same as in past years. The Moon is observed at every opportunity, and the Sun and Planets on every week-day, except when they transit between 15^h. and 18^h. The Minor Planets are observed whenever they transit before 13^h., the arrangement by which these observations were intermitted during the second half of the lunation having been recently modified, so that these objects are now observed continuously in entire independence of the observations at Paris. In consequence of the paucity of ephemerides, for Minor Planets which are sufficiently bright to be observed with our Meridian instrument, the number of these observations is so small as to make the relief obtained by the former convention with the Paris Observatory hardly necessary. As regards observations of stars, the rule is—to observe clock-stars extending over as many hours as possible, circumpolar stars, stars by reflexion (occasionally in R. A., and every day in N. P. D.), and stars from the Working Catalogue. To the latter have been recently added, at the request of Dr. Auwers, the stars in his list of Fundamental Stars for Zone Observations, which had not been previously observed with the Greenwich Transit-Circle. The Annual Catalogue of Stars observed in 1880 consists of about 1,300 stars. The Altazimuth is entirely devoted to observations of the Moon, with stars, collimator, and azimuth mark, for determination of instrumental errors.

The following is a statement of the number of observations made between 1880, May 9, and 1881, May 13 :—

With the Transit-Circle :

Transits, the separate limbs being counted as separate observations	4100
Pairs of observations of the nearly vertical wires of the Collimators	297
Reciprocal observations of the nearly vertical wires of the Collimators	359

Reflexion-observations of the central wire . . .	317
Circle-observations, each requiring a separate reading of the six microscope-micrometers	4129
Reflexion-observations of the zenith-distance wire (included in the number of circle-observations)	315
Reflexion-observations of stars (similarly included) . .	466

With the Reflex-Zenith-Tube:

Pairs of observations of γ Draconis, the instrument being reversed between the observations	38
Single observations	1

With the Altazimuth:

Azimuths of the Moon and Stars	833
Azimuths of the Azimuth-mark	364
Azimuths of the Collimating-mark	298
Zenith-distances of the Moon	421
Zenith-distances of the Collimating-mark . . .	344

The number of observations of the Moon near to her conjunction with the Sun is:—

On days when the Moon passed the meridian

		between 21^h and 22^h	Mean Solar Time .	5
„	„	between 22^h and 23^h	„ .	2
„	„	between 23^h and 24^h	„ .	0
„	„	between 0^h and 1^h	„ .	0
„	„	between 1^h and 2^h	„ .	4
„	„	between 2^h and 3^h	„ .	7

The whole number of places of the Moon observed was—

With the Transit-Circle, 98, or 7·8 per lunation.
With the Altazimuth, 197, or 15·8 per lunation.

The Moon's diameter has been measured—

With the Transit-Circle, twice in R.A., 14 times in N.P.D.
With the Altazimuth, 11 times in Azimuth, 25 times in Z.D.

Fifteen occultations of stars by the Moon (11 disappearances and 4 reappearances), and 47 phenomena of Jupiter's satellites, have been observed in the interval from 1880, May 9, to 1881, May 13. The instruments used in these observations

(simultaneously when practicable) are the South-East Equatoreal, the Sheepshanks Equatoreal, the Naylor Equatoreal, and the Altazimuth. When the object is low, the Airy prism eye-piece is used.

The Solar Eclipse of 1880, December 31, was well observed. The first contact was observed by four observers and the last contact by two. During the Eclipse the following observations were made with the South-East Equatoreal:—10 differences of N. P. D. of N. and S. cusps, 10 differences of R. A. of p and f cusps, 13 differences of N. P. D. of S. limbs of Sun and Moon, 11 differences of N. P. D. of p and f cusps, and 12 differences of R. A. of p and f cusps.

VII. Reduction of Astronomical Observations:—

The following Report exhibits the various stages of Reductions on May 13:—

For Meridional Transits:

Clock-times of transit over the true meridian after all corrections for instrumental errors, &c. are prepared to . .	1881, May 8
Clock-errors and rates are determined, and corrections are applied to form apparent right-ascensions from observation, to	May 7
Star-reductions are computed and applied to the apparent right-ascensions of stars, so as to exhibit the mean right-ascensions on 1881, January 1, to	May 7
For transits of the Sun, Moon, and Planets, mean solar times are prepared to	May 7
Corrections for defective illumination are computed and applied to	May 7

The Personal Equations in observations of transits during the year 1880 have been investigated.

For Meridional Circle-Observations:

The means of micrometer-readings are taken, and the usual corrections are applied, forming apparent zenith-distances, to	1881, May 8
Refraction, parallax, and co-latitude are applied to . .	May 8
Star-reductions are computed and applied so as to form mean N. P. D. for 1881, January 1, to	May 8
Corrections for defective illumination are computed and applied to	May 8

The corrections for R—D, the error of assumed co-latitude, and the position of the ecliptic have been investigated for 1880. The R—D correction is $+0''{\cdot}07 + 0''{\cdot}54 \text{ Sin } z \,.\, \text{Cos}^2 \,.\, z$, slightly larger than in the preceding year. The result for co-latitude is 38°. 31′. 21″·89, almost identical with the assumed value. The correction to the obliquity of the ecliptic is $-0''{\cdot}08$, and the discordance between the results from the summer and winter solstices is $-0''{\cdot}03$.

The Planetary Results are complete, as far as the exhibition of geocentric errors, to the end of 1880.

The observations of γ Draconis are completely reduced to the end of 1880.

The Altazimuth-observations are reduced to the following stages:—

For azimuths, true azimuths are formed by combination of mean of microscopes, correction for level, collimation, and azimuth-zero, to	1881, March 28
For zenith-distances, true Greenwich zenith-distances, corrected for refraction, are formed to	March 28
Corresponding tabular azimuths and zenith-distances are formed to	March 28
Apparent errors of Moon's tabular R. A. and N. P. D. are computed to	March 28
Apparent errors of Moon's tabular Longitude and Ecliptic N. P. D. are computed to	March 28

The observations of the Azimuth-Mark are more consistent than I could have expected, and its position appears to be quite steady. The azimuth of the mark has been determined for each lunation from the observations on those days on which both stars and mark have been observed. As the azimuth has remained sensibly unchanged throughout the whole period of observation since last July, it is now judged better to take the mean result as the adopted azimuth; and by means of this, a zero of azimuth, to be combined with that deduced from stars, is derived from the daily observation of the mark. The observations of a low star for zero of azimuth have been omitted since the beginning of 1881; the mark, in combination with a high star, appearing to give all that is necessary for this purpose.

The error of the Moon's tabular longitude (Hansen's) appears to be again increasing.

The observations of Occultations of Stars by the Moon are completely reduced to March 16.

The computations for the observations of the Solar Eclipse are nearly completed. These have been exceptionally heavy, from the circumstance that the Sun was very low (86°. 14′. Z.D. at the last observation), and that it has therefore been necessary to compute the refraction with great accuracy, involving the calculation of the zenith distance for every observation. And besides this, eighty-six separate computations of the tabular R. A. and N. P. D. of cusps have been required.

VIII. Spectroscopic and Photographic Observations :—

The Sun's chromosphere has been examined with the Half-prism Spectroscope on 29 days during the period to which this Report refers; and on every occasion prominences were seen. In the spectrum of a prominence seen on 1880, November 22, 21 bright lines were observed. On seven days a detailed examination of the whole spectrum of the chromosphere was made at 24 points of the Sun's limb. Fourteen Sun-spots have been examined on 20 days, with reference to the broadening of the lines in their spectra. The results confirm the remark that some of the lines of iron are broadened in some spots, whilst others are broadened in other spots. Displacements of some of the lines of iron towards the red, and of others towards the blue, have also been noted in the case of one spot. A remarkable spectrum of a Sun-spot showing 17 strong black lines or bands, each as broad as b_1, in the Solar spectrum, was observed on 1880, November 27 and 29. These bands, to which there is nothing corresponding in the Solar spectrum (except some very faint lines), have also been subsequently remarked in the spectra of several spots.

For the determination of motions of Stars in the line of sight, 168 measures have been made of the displacement of the F line in the spectra of 43 stars, 87 of the b_1 line in 27 stars, and 8 of the b_4 line in 4 of these stars. Of these 70 stars, 16 had not previously been examined, and the total number of stars of which the motions have been spectroscopically determined is now 91. In the case of six of the stars observed in the last year, a dispersive power equivalent to that given by sixteen prisms of 60° has been used. Ten measures have been made of the relative displacement of the F and b lines in the spectra of the east and west limbs of Jupiter.

Comet 1880 d (Hartwig's), and the Aurora of 1881, January 31, have been spectroscopically examined.

Between 1880, May 9, and 1881, May 13, photographs of the Sun were taken on 149 days, and of these 284 have been selected for preservation. There are only 8 days out of 149 days on which the Sun's disk was observed to be free from spots, whilst in the preceding year there was a complete absence of spots on 64 days out of 145.

IX. Reduction of Spectroscopic and Photographic Observations:—

The Spectroscopic Observations of all kinds mentioned in the preceding section have been completely reduced to 1881, May 6.

As regards the Photographic Reductions:

The photographs have been measured in duplicate, and the measures entered, to	1881, March 30
The areas of spots and faculæ have been completely reduced, so as to exhibit areas in millionths of the Sun's visible surface, to	March 3
The Radius of the Sun, Correction for Zero of Position-Circle, and Heliographic Elements, have been computed to	March 3
Distances from the Sun's Center and Position-Angles of Spots and Faculæ, corrected for distortion and refraction, have been formed to	March 3
Heliographic Longitudes and Latitudes of Spots have been computed to	March 3

The Mean Areas of Spots and Faculæ, and the Mean Heliographic Latitude of Spots have been computed for each rotation to 1881, March 3.

Owing to the great increase in the number of the spots, it has been thought advisable to limit the work by measuring only one of the photographs taken on each day, instead of two as formerly. And, since the beginning of this year, it has been found necessary to group the spots for purposes of measurement instead of measuring every individual spot.

X. Magnetical and Meteorological Instruments:—

The alterations of the photographic cylinders of the magnetical and meteorological instruments, which were in contemplation at the time of the last Report, so as to

make their time-scales the same in extent and in position on the record-sheets, have been to a great extent carried out. In the case of the Declination and Horizontal Force magnets, two reflecting prisms with convex cylindrical front surfaces have been mounted by Mr. Simms above the registering cylinder, which has been lowered so that each prism receives the light from the magnet opposite to it. By this arrangement the traces of both magnets fall (as regards time-scale) on the same part of the sheet. The cylindrical lenses formerly used have been removed, being replaced by the cylindrical surface of the prism. The new arrangement is found to be perfectly satisfactory, and Mr. Simms is proceeding with a similar change in the case of the Earth-Current apparatus and of the Vertical Force and Barometer registers. No alteration has yet been made in the Thermometer cylinder.

A modification has been made in the system of determining the time-scales, by the substitution of hourly breaks in the register, for the photographed hour-lines. The break at each hour is made automatically by a slight alteration in the apparatus hitherto used for registering the hour-lines. The time-scales for the Declination, Horizontal Force, Vertical Force, Barometer, and Electrometer are now laid down in this way.

The Magnetic instruments were all cleaned by Mr. Dover as usual at the beginning of this year. New suspension threads have been applied to the Lower Declination and Horizontal-Force magnets.

The unsatisfactory state of the Earth-Current register has been already noticed. After the change mentioned in a preceding Section, it was soon found that the indications of the Earth-Current wires were disturbed by a continual series of petty fluctuations which almost completely masked the proper features of earth-currents. By cutting off the communications with those parts of our wires called the North Kent East Line and the Ladywell Line (thus sacrificing one-third of our effective terrestrial span), these disturbances were checked; but there remains a periodical disturbance at every hour, which entirely destroys the value and credit of the results. It seems not impossible that something may depend on imperfection of earth-communication. If this fault cannot be removed, I should propose to return to our original system of independent wires (formerly to Croydon and Dartford).

The Thomson Electrometer is in good order. Of late, however, there has been a small fluctuation in the zero indicated by the spot of light when earth-connexion is made. The cause of this has not been clearly ascertained.

The new pressure plate of Osler's Anemometer has worked well. The limiting pressure of 50 lbs. on the square foot was twice exceeded during the snow-storm of 1881, January 18.

The thermometers in ordinary use have been compared with the Standard.

The Police-Ship "Royalist" has not been again moored in the river, and the series of observations of temperature of the Thames is thus terminated.

XI. Magnetical and Meteorological Observations:—

In addition to the continuous record of magnetical and meteorological changes given by the self-registering instruments, eye-observations are made periodically for determination of absolute values and of base-lines. The scale-readings of the three magnetometers and of barometer and thermometers are taken four times a day, magnetic dips are observed two or three times a week, and the absolute measure of Horizontal Magnetic Force is made (by deflexion) once a month.

The photographic records of the measures of Magnetic Earth-Currents, in two directions upon the earth's surface nearly at right angles to each other, are maintained with the same regularity as those of the ordinary magnetic forces; and are preserved in readiness for reference or publication when need may require. While writing this Report, I learn from Professor Förster of Berlin, that an extensive confederacy is organized, principally in Germany, for register of the earth-currents at several stations. This will make it even more necessary than it now is, to remove every fault in our Photographic Register of Earth-Currents.

XII. Reduction of Magnetical and Meteorological Observations:—

The theodolite readings of the Upper Declination-Magnet, giving absolute declinations, and the eye-observations of Horizontal and Vertical Force Magnets, are reduced to the end of 1880. These determinations give the zeros for the ordinates of the photographic curves.

The time-scales for the Declination and Horizontal and Vertical Force are complete to the end of 1880; the base-line values are formed, and new base-lines are laid down on the photographic sheets. The hourly ordinates of the photographic curves are read out to the end of 1880, and the hourly and monthly means are taken for nearly the whole of the year. The time-scales for the Earth-Currents are not yet laid down. The Dip-observations are reduced to the present time, and the Deflexion-determinations of absolute Horizontal Force to the end of 1880.

The following are the principal results for magnetic elements in the year 1880 :—

Approximate mean westerly declination . .	18°. 32′.
Mean horizontal force	3·912 (in English units). 1·804 (in Metric units).
Mean dip	67° 34′ 55″ (by 9-inch needles). 67. 35. 53 (by 6-inch needles). 67. 36. 3 (by 3-inch needles).

In respect of Diurnal Inequalities of Magnetic Horizontal Force and its Direction, though all measures are ready, the curves are not yet actually formed. In the last Report I adverted to the usual character of these curves. Assuming it to be certain that they originate from the Sun's power, not immediately, but mediately through his action on the earth, it appears to me (as I suggested long ago) that they are the effects of the attraction of the red end or north end of the needle by the heated portions of our globe, especially by the heated sea, whose effect appears to predominate greatly over that of the land. I do not say that everything is thus made perfectly clear, but I think that the leading phænomena may be thus explained. And this is almost necessarily the way of beginning a science.

As regards the Meteorological results:—The eye-observations of barometer, thermometers, anemometer, and rain-gauges, are corrected, where necessary, for instrumental errors; and a summary of results is communicated weekly to the Registrar-General for publication. On the photographic sheets, time-scales are laid down, and hourly ordinates from the curves are read out, to the end of 1880, for the barometer and thermometers; and the hourly and monthly means are taken for the greater part of the year. For the Electrometer, the hourly ordinates are read out, and hourly and monthly means are taken, nearly to the end of 1880.

The mean temperature of the year 1880 was 49°·4, being 0°·1 above the average of the preceding 39 years. The highest temperature was 87°·5 on May 26, and the lowest 17°·2 on January 27. The mean temperature was below the average, 5°·3 in January, and 4°·0 in October, and above the average, 2°·4 in February, 2°·7 in March, 2°·6 in September, and 3°·4 in December; in other months the mean temperature differed little from the average.

Part of the month of January last, 1881, was, as regards cold, especially severe. The mean temperature of the period, January 12 to 26 (15 days), was only 24°·2, or 14°·7 below the average; the temperature fell below 20° on 10 days and rose above the freezing point only on 3 days. The highest temperature in this period

was 35°·3; the lowest 12°·7. On January 18 there was a very severe snow-storm, with violent easterly gale.

The mean daily motion of the air in 1880 was 281 miles, being 2 miles greater than the average. In January the mean daily motion was 147 miles below the average, in September 68 below the average and in November 61 above the average. The greatest daily motion was 954 miles on March 2, and the least 33 miles on January 29.

The vane of Osler's Anemometer made, in the year 1880, nineteen complete revolutions in the positive direction N, E, S, W, N.

The number of hours of bright sunshine, recorded with Campbell's Sunshine Instrument, during 1880, was 1214, which is about the same as the average of the four years for which we have a record.

The discussion of the Electrometer results for the year 1879 shows that the potential of the atmosphere is usually positive; that it is least in summer and greatest in winter, and especially in the colder weather of winter. There is also a definite diurnal inequality, having double maxima and minima, the maxima, on the average of the year, occurring at about 8^h. a.m. and p.m., and the minima at about 3^h. a.m. and p.m. In character the diurnal curve has a resemblance to the barometric curve, but the points of maxima and minima precede those of the barometric curve by about two hours. On days of magnetic disturbance, when aurora is visible, nothing unusual is remarked in the electrometer indications. Excepting thunder storms, the greatest disturbances are experienced in showery weather, and are probably local disturbances only.

A rough reduction of the observations of the Thames thermometers was in contemplation, but has not yet been carried out.

The Magnetical and Meteorological Reductions are now in a much more forward state than they have been in for several years past, and it is hoped that they will not again fall behind.

XIII. Printing and Distribution of the Volume of Greenwich Observations:—

The volume for 1878 was printed and distributed last autumn, and the volume for 1879 was passed for press at the beginning of March, but no copies have yet

been received from the binders. An Appendix to this volume contains a description of the Greenwich Time-Signal System originally drawn up for "Nature" by Mr. Ellis.

As regards the volume for 1880, the transits are printed to June 19, meridian zenith-distances to May 14, azimuths with the altazimuth to September 12, zenith-distances to September 23, and the comparison of tabular and observed azimuths and zenith-distances to June 12. The whole of the Photographic Results and the greater part of the Spectroscopic Results for 1880 have been printed.

Of the entire volume, including everything emanating from the Observatory, 300 copies are printed. Of each of the subordinate parts, Results of Astronomical Observations, Results of Magnetical and Meteorological Observations, and Results of Spectroscopic and Photographic Observations, 250 additional copies are printed; and of the Reports on Trial Chronometers and Reports to the Board of Visitors, 650 additional copies.

A great advance has been made in the printing of the Greenwich Observations since the last Report, and my thanks are due to the Queen's Printers for the arrangements which they have made to accelerate the rate of printing.

XIV. Chronometers, Time-Signals, Regulation of External Clocks, Operations for Longitude:—

The number of chronometers now in our hands is 237. Of these, 43 belong to various chronometer-makers, who have placed them here for the annual competitive trial; and the remaining 194 (134 box-chronometers, 35 pocket-chronometers, and 25 deck-watches) are the property of the Government. Of the 43 competitive chronometers, 13 are fitted with my supplementary compensation, and one has a palladium spring. The chronometers of all classes are ordinarily rated once a week, the competitive chronometers once a day. Every chronometer is tested in a temperature approaching to 100° Fahrenheit for one or more periods of three or four weeks each. And every competitive chronometer is rated several days in positions corresponding to the four cardinal magnetic directions.

In addition to those above mentioned, 15 chronometers have been placed here on trial for the Chinese Government.

The first six chronometers in the competitive trial of 1880 were on the average, as inferred from the "trial numbers," slightly inferior to those of 1879, there being

in particular no one chronometer of remarkable excellence. In the first few years after the strict and systematic examination of competitive chronometers, beginning with 1856, the accuracy of chronometers was greatly increased. For many years past it has been nearly stationary. I interpret this as showing that the effects of bad workmanship are almost eliminated, and that future improvement must be sought in change of some points of construction. One which occurs to me (I mention it principally as a specimen of departure from customary forms) is this. The impact of the escape-wheel upon the pallet of the balance-axis takes place very near to that axis, and must produce considerable friction, though of short duration. I proposed to the late Mr. Charles Frodsham to meet this by use of a broader pallet and a lighter impact of longer duration. The decease of that accomplished horologist prevented the completion of the trials which he had commenced for carrying out my suggestion. Other variations of the established form might be worthy of trial.

The Greenwich Time-ball has been regularly dropped automatically at 1^h on every day throughout the year, with the exception of 6 days when the violence of the wind made it imprudent to raise the ball, and 8 days when the severe frost of last winter prevented its being raised; and of one day when there was accidental failure.

The Deal ball was not raised (on account of high wind) on 10 days. It was not dropped (through failure in the telegraphic connexion) on 7 days, and was erroneously dropped about 5^s too soon by telegraph signals on one day; and on another day it was not dropped at 1^h owing to telegraph signals continuing up to 1^h; on one day the current was too weak to release the trigger. On every other day the ball has been dropped automatically at 1^h.

As regards the Westminster Clock, its errors have been under 1^s on 31 per cent. of the days of observation, between 1^s and 2^s on 47 per cent., between 2^s and 3^s on 18 per cent., and between 3^s and 4^s on 4 per cent.

The distribution of time-signals to all parts of the country continues to be made on the same system as in late years, by means of the Chronopher at the Central Office of the Post Office Telegraphs. In connexion with this system, I would express the hope that the proposal to establish an hourly signal at the Start Point will be borne in mind.

Last autumn a telegraphic determination of the longitude of Leiden was made with great care by M. M. Bakhuyzen. The interchange of signals between Green-

wich and Leiden occupied nearly four months. I may here remark that the American extension of longitude carried out under Commander Green, U.S.N., to which reference was made in the last Report, will be most useful for the Transit of Venus in 1882. Cannot a British officer be found to complete the operations for Australia and New Zealand? I lament that this has not been done. Mr. Gill has undertaken the necessary work for the Cape.

XV. Personal Establishment:—

The staff is at present constituted as follows:—

Mr. Christie, Chief Assistant.

In the Astronomical Department:

Mr. Dunkin, Superintendent of Computers, especially of those engaged in the Transit-reductions and in the miscellaneous computations.

Mr. Criswick, superintending the Time-department, and having also charge of the stationery and money accounts.

Mr. Downing, Superintendent of the Altazimuth.

Mr. Thackeray, principally employed on the Library and manuscripts.

Mr. Lewis, superintending the Circle-reductions and the work of the chronograph.

There are at present seven Computers attached to the Astronomical Department.

In the Spectroscopic and Photographic Department:

Mr. Maunder, Superintendent, assisted by one computer.

In the Magnetical and Meteorological Department:

Mr. Ellis, Superintendent.

Mr. Nash, Assistant.

Four computers are employed in this Department.

The vacancy in the Astronomical Department, caused by the retirement of Mr. Lynn in 1880, January, was filled up at the end of last January by the appointment of Mr. Lewis.

A gate-porter, a watchman, and a labourer, form part of the establishment; and a clerk of works, with several carpenters, are regularly employed in the Observatory.

XVI. Extraneous Work:—

First, in reference to the Transits of Venus.

Captain (now Colonel) Tupman continued his labours (gratuitously) on the reduction and preparation for press of every branch of all the observations of the Transit of 1874, till the autumn of last year, when for private reasons and change of residence he resigned the work to me. And I cannot sufficiently acknowledge the skill and completeness with which this vast mass of calculations was effected, and the excellent order in which they were left. The portions applying to the Hawaiian and Egyptian groups had been printed: those relating to the Rodriguez group and the greater part of the Kerguelen group—and in a less perfect degree the limited work of New Zealand—were prepared for press in conformity with Colonel Tupman's views.

When I examined the printed sheets, I judged that, though it had perhaps been well to exhibit in detail the Hawaiian calculations as a specimen of every stage of reductions, yet it would be unnecessary to print the other observations in the same detail; and that it would be right generally to adopt the principle which I had laid down in my paper of 1875, January 19 (in the *Monthly Notices* of the Royal Astronomical Society), greatly limiting the extent of detailed publication, without omitting anything essential. This principle has been carried out; and the printing of all Sections of the observations, with specimens of the Printed Forms employed, and remarks on the Photographic operations, is very nearly completed. An Introduction is begun in manuscript.

A change of system like that here described, requiring very close attention from myself, interrupting and interrupted by the daily business of an office already fully charged, has—unfortunately for me—occupied almost every moment which I desired to devote to an astronomical subject in which I take very deep interest.

I am in correspondence with the Commission which is entrusted with the arrangements for observation of the Transit of 1882.

Secondly, on the Lunar Theory.

The great fundamental calculations have been repeated and extended; and I trust that they may be accepted as sufficient for their portion of the theory. These have been effected by computers. The subsequent parts must (from the nature of the work) belong entirely to myself. I have examined and altered some parts of the theory, and have attached notes in preparation for further work. But I have been sadly interrupted by other occupations of my time, which I trust may soon terminate.

Attention has been given to some matters of the Cape Observatory (which fall within my prescribed duties), and to other business at the request of the Admiralty; but to nothing that requires special notice.

XVII. General Remarks :—

The present meeting may afford a fitting opportunity for the expression of my views on the general objects of the Observatory, and on the duties which they impose on all who are actively concerned in its conduct. Assuming as beyond dispute that these ought to be carried out in a spirit, liberal in itself and honorable to the nation, I proceed to state my opinion on the line of action which they suggest.

The object prescribed to the Observatory is the promotion of "Astronomy and Navigation." And, since the abolition of the Board of Longitude, the second of these objects (which historically gave rise to the introduction of the first) presses upon the directors of the Observatory much more strongly than before. Considering then the claims of Astronomy as bearing on Navigation, and our responsibilities in reference to them, we find that those responsibilities are by no means narrow. Whatever the rest of the scientific world may do or may not do, we are responsible for determinations of the fundamental elements of Sidereal, Solar, and especially Lunar, Astronomy, with the highest accuracy that modern skill can secure. The same apparatus of instruments and of mathematical treatment which fix the places of fundamental stars will apply to those of other stars; the same which apply to the Sun will apply to planets and comets (not unconnected with solar theory, by virtue of perturbation) and even to satellites. And we could hardly consider ourselves as discharging our duty to the more educated portion of the nation, or as maintaining our proper position in the world, if we did not include in our operations these latter offshoots of the first-mentioned objects.

But new astronomical subjects have arisen of which no one dreamed when our constitution was first fixed. The first of these was the measures of double stars. But this, though important as ever, has almost disappeared from our view when occupied with Solar and Spectroscopic Physics. I yield to no one in the interest which I take in these subjects, and in the admiration with which I regard the positive conclusions and the problematic suggestions which are founded on them. But I still point out that these are not parts of our original system, and their connexion with the Greenwich Observatory is at any time liable to question.

I now advert to the general subject of Navigation. And first I remark that Magnetism, in its ordinary and nautical form, is indisputably a proper subject for the Observatory. But within the present century there have arisen :—the accurate examination of magnetic irregularities, the partial reduction of daily irregularities to practical laws (still wanting theoretical explanation), and the establishment of the simultaneous co-existence of occasional disturbances covering the whole surface of the earth. Connected with these is the observation of magnetic currents through the terrestrial soil, registered at Greenwich for many years past, and now attracting

attention on the Continent. Perhaps no branch of physics bears the same prospective importance as these. Yet I conceive that their continued study in this Observatory requires special authorisation.

The original views in making Astronomy contributory to Navigation were limited to observations of the Moon. But in the latter part of the last century, the possibility of making chronometers subservient to the determination of longitude (a subject to which the late Board of Longitude gave good attention, and to which the Government has always offered liberal rewards) was proved, and in the present century the improvement has been very great. This has been effected by our Hydrographical Office (mainly through the action of the Observatory), partly by specific rewards, partly by careful attention to the accuracy of every chronometer purchased. And the practical value of the chronometric-system has been very greatly increased by taking advantage of the galvanic distribution of time-currents, and by the galvanic exhibition of ball-drops and other signals. There can be no doubt that all the agencies involved in this system are well employed, and that they are a legitimate part of the Observatory duty, as originally contemplated.

Still I remark that the observatory-operations bearing on chronometric navigation are not carried out to the extent which I could desire. It is known to all persons familiar with chronometers, that rates of the chronometers, obtained while the ships are actually in voyage, would possess remarkable value. We possess the power of giving facility for obtaining these, to a large part of our mercantile navy, by exhibiting a time-signal at every hour, at Deal (where the necessary apparatus already exists) and on the Start Point. I have several times brought this proposal, as regards the Start, before the Government, but unsuccessfully. But I should have done wrong if I had omitted, in this general survey of the duties of the Observatory, to state my continued conviction that this is a proper and very desirable addition to the other points of assistance which we can give to Navigation.

Next,—closely connected, however, with the subject of Navigation,—is the knowledge of the longitudes of distant ports, as referred to the Greenwich Observatory. And I approach this subject with grief. We have entirely abandoned the longitudes of the Atlantic, which have been cleared away, before our eyes, by the scientific enterprise of another nation. The Pacific, bearing those vast and important colonies, almost entirely British, is equally neglected; though so much is ready that the mission of a single officer would quickly establish all. The same aspiring nation, which has mastered the Atlantic, is now bent (as I understand) on adding to its scientific dominion the Pacific. I think this is not honorable to our nation.

There remains another subject, which occupies no small part of the force of the Observatory, and which I am unable to connect with either of the two great divisions to which I have alluded—the subject of Meteorology. It is exceedingly popular in the country, perhaps because it requires little of expense or of science.

It is also pursued at many foreign observatories, where vast numbers of observations are produced without attempt at classification or reduction. We at least are not amenable to this accusation; and may appeal to our reduction of more than twenty years' collected observations as giving matter of permanent interest to the more scientific meteorologist, and even to the geologist. Still I call attention to the fact that this is a subject which, though introduced mainly by myself, I regard as foreign to the original "Astronomy and Navigation" of the Observatory.

There is still a matter for consideration, not in our observations, but in the mechanism by which they are made available to the world—I mean our printing. I have repeatedly expressed my opinion that the extent of our printing is far too great: not in the full exhibition of reductions, but in the minute details of individual observations. There are printed every year more than 7,000 transits or circle readings, each consisting of 6 or 7 individual readings, of which only the mean is useful. I do not believe that, since the year 1835 at least, any person in the world except ourselves has actually taken a mean. As each reading contains 3 or 4 figures, there are printed in each year something like 150,000 useless figures. Reliance must be placed somewhere on the skill and fidelity of the observer, and (considering the severity with which every figure of transit-wire and of circle-microscope, and of their means, is examined here), this reliance may be placed at least as well on the means as on the originals. I have reason to think that the bulky volume, of nearly 900 pages, might be reduced to about $\frac{3}{5}$ of its present size by omitting those originals.

I would submit for the consideration of the Board whether it might not be advantageous that they should hold a special Meeting to consider the subjects which I have indicated. The length of time at an ordinary Visitation, and the circumstances under which the Board meets, are not sufficiently favourable for the discussion of broad questions of Observatory policy.

G. B. AIRY.

Royal Observatory, Greenwich,
1881, *May* 20.