

REPORT
OF
THE ASTRONOMER ROYAL
TO THE
BOARD OF VISITORS
OF THE
ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1880, June 5.

A

1881GOAMM..41I...1A

REPORT OF THE ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1880, June 5.

THE dates of the Annual Reports have usually been made to depend on the limits, or on the middles, of lunations. On the present occasion the New Moon of 1880, May 9, appeared to be the most convenient day; and the entire period of the Report, extending from the New Moon of 1879, May 20, to that of 1880, May 9, is somewhat shorter than has been usual.

I. Buildings and Grounds :—

The Visitors will have remarked, in the upper part of the wall which divides the Front Court from the North Terrace, a circular hole. This has been made in order to allow a clear view from the Altazimuth of a mark which I have been permitted, by the courtesy of the Governor of the Royal Naval College, to fix upon the parapet of the south-east building of the College. I shall again advert to the object of this mark.

Since the serious attack of dry rot in the Octagon Room, which was met, and I trust conquered, as described in the last Report, there has been no further appearance of that dangerous invasion. But a leak in the leadwork (Sir Christopher Wren's, I believe,) above the south window of the same room caused some alarm. After repair of the leak I have taken down the upper woodwork of the window,

Q 1564. 650.—5/80. Wt. 3034.

A 2

and I propose to keep the pannel open for drying and ventilation until I can be confident that there is no fear of appearance of fungus.

I stated in the last Report that steps had been taken for the erection of a new Library near the Magnetic Observatory. The Admiralty, on final consideration of the estimates, decided not to proceed with the work; and they have repeated that decision in the present year. In the meantime the space has been cleared (which, in consequence of the necessity of removing some offices, was a more troublesome work than was anticipated), and I am confident that the Visitors will recognize that the state and general appearance of the Observatory Grounds are much improved. The space will admit of the erection of a building 50 by 20 feet; and I propose to erect here a room of one story, but with galleries at mid-height, so that there would never be need to use a ladder. Among other changes occurring in this clearance, I have removed the Electrometer Mast (a source of some expense and some danger); the perfect success of Sir William Thomson's Electrometer rendering all further apparatus for the same purpose unnecessary: and have changed the position of the well and pump used for draining the Magnetic Basement. The demand for additional library-room becomes more and more pressing.

The subterranean telegraph-wires through the Park, connecting the Royal Observatory with the wires of the South-Eastern Railway, have lately become partially inefficient. The authorities of the General Post Office have been engaged in restoration of the wires; and, in furtherance of the same object, they are considering the adoption of a new line through the streets of Greenwich.

II. Moveable Property:—

Omitting matters of the most insignificant kind, our moveables are generally in the same state as at the last Report.

Our Detached Telescopes (eight in number) are in our own custody. In regard to the instruments employed on the Transit of Venus Expedition of 1874, the present disposal of all is known. I will enumerate only those which are not absolutely in our own hands, or which are in constant employ here:—"Transits," one at South Kensington. "Altazimuths," one at South Kensington. "Equatoreals," one at South Kensington; one has lately been mounted in open air in our South Ground, protected by a proper covering, for occasional astronomical use. "Photoheliographs," one established here for daily use; one at South Kensington; one at the Cape of Good Hope; one sent (telescopic part only) to India. "Transit Huts," one at Ascension

Island; no others returned. "Altazimuth Huts," one not returned. "Equatoreal Huts," one at South Kensington; one not returned; two, roofs only returned; one slightly altered for Mr. Oppolzer; one lent to Major Tupman. "Photoheliograph Huts," one at South Kensington; one sent to Cape of Good Hope; two, roof of hut and dark house returned; one not returned.

III. Manuscripts:—

Our store of manuscripts—observations, calculations, and correspondence—continues to increase at its usual rate; but no extraordinary addition has been made.

The retardation in the more confidential parts of the business of the Observatory, arising from the long-continued illness and final retirement of an able Assistant, has (among other things) prevented us from thoroughly examining the stored manuscripts. It has, however, been incidentally discovered that a collection of Zenith Points of the Altazimuth is missing. It has not been entered in any of our Catalogues; and this circumstance induces me to hope that it may have been bound up with other papers. I am, however, preparing a search in another direction. Besides this defect we know at present of no other, except the papers (cited in former Reports) lent to Dr. Auwers.

(The usual comparison with the Catalogue has at length been made, and all the catalogued manuscripts are found.)

IV. Library:—

No change has been made in plan, but in some departments the number of books has increased rapidly. Fundamental Astronomy advances slowly; Magnetism is almost stationary; Geodesy progresses; Photography and Spectroscopy increase very fast; and Meteorology the most rapidly of all. The Transactions of Foreign Academies increase in number.

This is owing, I imagine, to the general scientific activity, both of Academicians and of private men of science, in most foreign countries; and to the facilities given for transmission, by the courtesy of Publishers and by the extension of Book Post.

Our purchases have been few.

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

V. Astronomical Instruments:—

The Transit-Circle is in excellent order. Two of the transit-wires which had been accidentally broken have been renewed, and the instrument has been kept in thorough repair.

New determinations of the flexure made on 1880, April 6 and May 6, confirm the change of sign remarked last year. The observations of April 6 give $+0''.19$, and those of May 6 $+0''.04$, for the value of the horizontal astronomical flexure. As the quantities are small, it has been judged better not to apply any correction for flexure. The errors of the 5' divisions in use for observations of Polaris and λ Ursæ Minoris have been determined, as the precessional motion had carried the former star on to a new division, whilst the old correction had been inadvertently used. The change in the correction is only $-0''.10$ for Polaris and $+0''.02$ for Polaris S.P.

The Transit-Circle Barometer has been shifted to the north side of the room, to avoid the risk of exposure to the Sun; and a barometer by Horne and Thornthwaite has been mounted in the Altazimuth Dome in place of the old barometer by Simms.

The Sidereal Standard Clock has not needed any repairs during the past year. Its rate has been reduced to a very small quantity by means of the sliding rate-adjuster. Experiments in applying a 2-seconds galvanic current to regulate a clock, which should give seconds' signals on the Chronograph, have been made during the last year, and, after various alterations in the regulating and regulated clocks, the results appear to be perfectly successful. It is proposed ultimately to make use of the Sidereal Standard as the regulating clock, but no alteration has yet been made in it.

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

The Chronograph was cleaned last autumn, and is in excellent condition.

The horizontal circle of the Altazimuth has been regraduated by Mr. Simms, the divisions having been nearly rubbed out in course of years; and improved compound object-glasses, with adjustment for focus, have been supplied to the reading microscopes. Two supplementary microscopes have been mounted for examination of the division-errors of the horizontal circle and of the errors of the micrometer-screws. The instrument is now in thorough working order.

An Azimuth-Mark has been fixed on the parapet of the Royal Naval College at a distance of about 1700 feet, for check on the Zero of Azimuth. It consists of

(7)

a stout tube let into a cubical block of stone, and carrying a silvered plane reflector. Its illumination is not yet quite satisfactory; and since, at the distance of the mark, 1 inch corresponds to 10'', there would be a difficulty in using the reflection of sunlight from a convex glass.

The Sheepshanks and Shuckburgh Equatorials are in their usual state.

The South-East Equatorial is in very good order. New contact springs (of electrum) and insulated rings have been fixed at the upper pivot; and for those at the declination axis a cable of wires led through a hole in the pivot has been substituted. It is hoped that no further trouble will be experienced from failure in the insulation.

A small camera has been applied to the Half-prism Spectroscope, for photographing spectra of Sun-spots, prominences, &c.; and a slide for spark-apparatus and reflector has been adapted to the slit of the Single-prism Spectroscope.

The Photoheliograph is in good working order.

The "Naylor" Equatorial, one of those returned from the Transit of Venus Expedition, has been mounted for occasional use in the South Ground, where it is protected by a water-proof cloth. A comet eye-piece with diagonal bars has been applied to it.

Many years ago a double-image micrometer, in which the images were formed by the double refraction of a sphere of quartz, was prepared by Mr. Dollond for Captain Smyth, R.N. Adopting the same principle on a larger scale, I have had constructed by Mr. Hilger a micrometer with double refraction of a sphere of Iceland spar. Marks have been prepared for examination of the scale, but I have not yet had opportunity of trying it.

VI. Astronomical Observations :—

The Sun, Moon, Planets, and Fundamental Stars are the regular subjects of observation on the meridian; special attention being devoted to the Moon, which is also observed at every available opportunity with the Altazimuth. Other stars are observed from a Working Catalogue of about 2500 stars, with which good progress has been made in the past year, though a large number of stars still remain for observation. About 1100 stars were observed in 1879.

(8)

The number of observations made between 1879, May 20, and 1880, May 9, is as follows :—

With the Transit-Circle :

Transits, the separate limbs being counted as separate observations	4164
Pairs of observations of the nearly vertical wires of the Collimators	296
Reciprocal observations of the nearly vertical wires of the Collimators	356
Reflexion-observations of the central wire	313
Circle-observations, each requiring a separate reading of the six microscope-micrometers	3953
Reflexion-observations of the zenith-distance wire (included in the number of circle-observations)	302
Reflexion-observations of stars (similarly included)	426

With the Reflex-Zenith-Tube :

Pairs of observations of γ Draconis, the instrument being reversed between the observations	23
Single observations	1

With the Altazimuth :

Azimuths of the Moon and Stars	713
Azimuths of the Collimating-mark	196
Zenith-distances of the Moon	352
Zenith-distances of the Collimating-mark	200

The observations with the Altazimuth were interrupted from March 8 to April 13, during the alterations of the instrument. They refer, therefore, to a period of eleven lunations only.

The number of complete 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 .	1
„	„ between 22 ^h and 23 ^h „	1
„	„ between 23 ^h and 24 ^h „	0
„	„ between 0 ^h and 1 ^h „	0
„	„ between 1 ^h and 2 ^h „	2
„	„ between 2 ^h and 3 ^h „	3

(9)

The whole number of places of the Moon observed was—

With the Transit-Circle, 99, or 8·3 per lunation.

With the Altazimuth, 154, or 14·0 per lunation.

The Moon's diameter has been measured—

With the Transit-Circle, twice in R.A., 10 times in N.P.D.

With the Altazimuth, 13 times in Azimuth, 40 times in Z.D.

Thirteen occultations of stars by the Moon (11 disappearances and 2 reappearances), and 30 phenomena of Jupiter's satellites, have been observed since the date of the last Report. The instruments usually employed for these phenomena are the South-East Equatoreal, the Sheepshanks Equatoreal, and the Altazimuth. When practicable they are used simultaneously by different observers.

A set of micrometer-measures of the outer satellite of Mars, and several sets of measures of the satellites of Saturn, were obtained last autumn with the South-East Equatoreal; and a few drawings of Mars and Jupiter were made near the time of opposition.

The exceptionally bad weather of the past summer has seriously interfered with the observations, a whole month's observations of the Sun being lost in July.

VII. Reduction of Astronomical Observations :—

The following Report exhibits the various stages of Reductions on May 9 :—

For Meridional Transits :

Clock-times of transit over the true meridian after all corrections for instrumental errors, &c. are prepared, to	1880, May 2
Clock-errors and rates are determined, and corrections are applied to form apparent right-ascensions from observation, to	May 1
Star-reductions are computed and applied to the apparent right-ascensions of stars, so as to exhibit the mean right-ascensions on 1880, January 1, to	May 1
For transits of the Sun, Moon, and Planets, mean solar times are prepared, to	May 1
Corrections for defective illumination are computed and applied to	May 1

B

The Personal Equations in observations of transits during the year 1879 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 1880, May 1
 Refraction, parallax, and co-latitude, are applied to . . . May 1
 Star-reductions are computed and applied so as to form mean
 N. P. D. for 1880, January 1, to . . . April 18
 Corrections for defective illumination are computed and
 applied to . . . May 1

The corrections for R—D, the error of assumed co-latitude, and the position of the ecliptic, have been computed for 1879. The R—D correction for 1879 is somewhat smaller than in the preceding year. The result for co-latitude is $38^{\circ}.31'.21''.88$, almost identical with the assumed value. The correction to the obliquity of the ecliptic adopted in the Nautical Almanac is $+0''.01$, and the discordance between the results from the summer and the winter solstices is $+0''.43$, agreeing closely with the value found last year.

The Planetary Results are complete, as far as the exhibition of geocentric errors, to the end of 1879.

The observations of γ Draconis with the Reflex-Zenith-Tube are completely reduced to the present time.

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 . . . 1880, March 8
 For zenith-distances, true Greenwich zenith-distances, corrected
 for refraction, are formed, to . . . March 8
 Corresponding tabular azimuths and zenith-distances are
 formed, to . . . March 8
 Apparent errors of Moon's tabular R. A. and N. P. D. are
 computed, to . . . March 8
 Apparent errors of Moon's tabular Longitude and Ecliptic
 N. P. D. are computed, to . . . March 8

There are no observations with the Altazimuth between March 8 and April 13.

A discussion has been made of all the determinations of Moon's diameter from observations with the Altazimuth by the various observers from 1864 to 1878. The results show that there are large personalities in the measure of diameter, both horizontal and vertical; and under these circumstances it has been decided to use for each observer the horizontal and vertical diameters deduced from his own observations.

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

VIII. Spectroscopic and Photographic Observations :—

The Sun's chromosphere has been examined on 37 days during the period to which this Report refers; and on 34 days prominences were seen. Whenever practicable, the appearance of the prominences as seen on each of the chromospheric lines has been recorded, and on four days a detailed examination of the whole spectrum of the chromosphere was made at 24 points of the Sun's limb. Three Sun-spots have been examined with reference to the broadening of lines in their spectra, and 15 photographs have been taken of the spectra of three Sun-spots.

As regards the Spectroscopic determination of Star-motions, 113 measures have been made of the displacement of the F line in the spectra of 29 stars, 44 of the b_1 line in 19 stars, and 6 of the b_4 line in 3 stars. Of these 51 stars, 21 had not previously been examined. In the case of three of the stars a dispersive power equivalent to that given by fifteen prisms of 60° was used. The stars are taken from a working list of 150 stars, which may eventually be extended to include all stars down to the fourth magnitude, and it is expected that in course of time the motions of about 300 stars may be spectroscopically determined.

The spectra of Comets *c* (Swift's) and *d* (Palisa's) 1879, and of the Red Spot on Jupiter, have been examined, but no certain results were obtained.

Between 1879, May 20, and 1880, May 9, photographs of the Sun were taken on 145 days, and of these 270 have been selected for preservation. The photographs show a complete absence of spots on 64 days out of 145, whilst in the preceding year there was a similar absence of spots on 121 days out of 150. The epoch of minimum appears to have occurred about the beginning of 1879, and since last October the outbreak of spots has been very marked.

IX. Reduction of Spectroscopic and Photographic Observations :—

The Spectroscopic Observations of all kinds mentioned in the preceding section have been completely reduced to the present time.

As regards the Photographic Reductions :

The photographs have been measured in duplicate, and the
measures entered, to 1880, April 27
The areas of spots and faculæ have been completely reduced,
so as to exhibit areas in millionths of the Sun's visible
surface, to 1879, Dec. 31
The Radius of the Sun, Correction for Zero of Position-Circle,
and Heliographic Elements have been computed, to . . . 1880, April 15
Distances from the Sun's Center and Position-Angles of Spots
and Faculæ, corrected for distortion and refraction, have
been formed, to 1879, Dec. 31
Heliographic Longitudes and Latitudes of Spots have been
computed, to 1879, Dec. 31

The Mean Areas of Spots and Faculæ for each rotation of the Sun from 1873, July 11, to 1879, December 27, and the Mean Heliographic Latitude of Spots for each rotation from 1874, April 16, to 1879, December 27, have been computed.

Various spectroscopic and photographic results are communicated to the Committee on Solar Physics, with whom we are in friendly communication.

X. Magnetical and Meteorological Instruments :—

There are no important changes to record under this head.

The Dip-instrument was thoroughly cleaned by Mr. Dover at the beginning of this year. The values found for the dip since the cleaning were at first somewhat smaller than before, but afterwards more satisfactory results were obtained, and they have been since confirmed by observations with another instrument lent by Mr. Dover. The iron stand of the Naylor Equatoreal, which is mounted in the South Ground not far from the Dip House, appears not to have any appreciable influence on the Dip and Deflexion instruments. The suspension threads of the

Lower Declination and Horizontal-Force Magnets gave way on last Visitation-Day, 1879, June 7, and were renewed on June 9. The time of vibration of the Vertical-Force-Magnet in the horizontal plane has been re-determined. No great change in the value appears to have occurred since the last determination. Enamelled glass scales, used in eye-view by the mirrors attached to the magnets, have been provided for the Horizontal-Force and Vertical-Force Magnets in substitution for the cardboard scales.

The Earth-Current registers are still far from satisfactory, owing to abnormal disturbances. As already mentioned, the Earth-Current Wires (in common with all our telegraphic wires exterior to the Observatory) are in process of renewal.

The Thomson Electrometer is in excellent order. In the warm weather of summer, and in winter when much artificial heat is used in the basement, the photographs have been unsatisfactory, but we are endeavouring to remedy this by cutting off all communication with air from the basement. In the winter the register was frequently interrupted by the freezing of the water in the exit-pipe. A basin (with cesspool) has been recently constructed to carry off the water discharged from this pipe.

The action of the photographic barometer appears to have been improved by the slight changes mentioned in the last Report, and small movements are in many cases excellently shown.

A new pressure-plate with springs has been applied by Mr. Browning to Osler's Anemometer, and it is proposed to make such modification as will give a scale extending to 50 lbs. pressure on the square foot. Other parts of the instrument have also been renewed. An arrangement for slow motion of the barrel, which was much wanted in adjusting the recording paper, has been fitted to Robinson's Anemometer.

It is in contemplation to alter the photographic cylinders of the magnetometers, barometer, thermometers, and earth-current apparatus, so as to make the time-scales of all the Magnetical and Meteorological instruments the same.

The radiation thermometers were shifted at the end of January to a more open position in the South Ground.

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

Since last October the Police-Ship "Royalist" has been laid up in dock, having been injured by a collision, and the observations of temperature of the Thames have been interrupted in consequence.

XI. Magnetical and Meteorological Observations:—

All the instruments mentioned in the last section have been kept in constant use, giving a continuous record of magnetic changes, earth-currents, electricity, temperature, barometric pressure, direction, velocity and pressure of the wind, and rain-fall. The photographic registers are supplemented by eye-observations of magnets, thermometers, barometer, and rain-gauges.

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 1879. These determinations give the zeros for the ordinates of the photographic curves.

The time-scales for the Declination, Horizontal and Vertical Force, and Earth-Currents, are complete to the end of 1879, and the base-line values for the Declination and Horizontal Force are formed for 1879, but not yet laid down on the photographic sheets. The Dip-observations are reduced to the present time, and the Deflexion-determinations of absolute Horizontal Force to the end of 1879.

The following are the principal results for magnetic elements in the year 1879:—

Approximate mean westerly declination	. . .	18°. 40'.
Mean horizontal force		{ 3.911 (in English units). 1.803 (in Metric units).
Mean dip		{ [°] 67. ['] 36. ["] 5 (by 9-inch needles). 67. 36. 54 (by 6-inch needles). 67. 37. 47 (by 3-inch needles).

On the application of the Committee on Solar Physics, the separate daily values of the diurnal range of Magnetic Declination for the years 1848 to 1858 have been supplied to Prof. Balfour Stewart.

The Visitors at their last meeting suggested the advantage of preparing a digested account of the magnetical results obtained at the Royal Observatory from 1841 to 1876, similar in some respects to the account of meteorological results

recently published. A beginning was made by preparing the monthly means of diurnal inequality in force and direction through the whole period, and exhibiting their combination in curves. It is known to the Visitors that, in two communications to the Royal Society, I have exhibited numerically and in curves the means of these monthly results (yearly means through all months, and monthly means through all years,) as far as the year 1863. In 1864, observations were interrupted by the work in progress for the Magnetic Basement, so that the reductions now to be made commence with 1865. The monthly results through the whole period being taken as before, the next step, for obtaining exhibitions which the eye and the mind could easily command, was to collect the monthly conclusions into a limited number of groups of years. On inspecting the monthly curves in detail there was no hesitation in fixing upon the following:—First group, 1865 to 1868; Second group, 1869 to 1872; Third group, 1873 to 1876. In each of these, as before, yearly means are taken through all months, and monthly means through all years. The curves in the second group are strikingly larger than those in the first and third; the linear dimensions of the curves of 1870 are fully $\frac{5}{3}$ of those of 1876 in the east-and-west direction, and fully $\frac{7}{3}$ in the north-and-south direction. In the study of the forms of the individual curves; their relations to the hour, the month, the year; their connexion with solar or meteorological facts; the conjectural physico-mechanical causes by which they are produced; there is much to occupy the mind. I regret that, though in contemplation of these curves I have remarked some singular (but imperfect) laws, I have not been able to pursue them. The heavy load on the Observatory, and the limited means (in the present year) of supporting it, will in part explain this.

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 to the end of 1879 for the barometer, and to 1879, August, for the thermometers.

The mean temperature of the year 1879 was $46^{\circ}\cdot1$, being $3^{\circ}\cdot3$ below the average of the preceding 38 years. The highest temperature was $80^{\circ}\cdot6$ on July 30, and the lowest $13^{\circ}\cdot7$ on December 7. The mean temperature was below the average in every month of the year; the months of greatest deviation being January and December, respectively $6^{\circ}\cdot8$ and $7^{\circ}\cdot6$ below the average; the months of April, May, July, and November were each between 4° and 5° below the average.

The mean daily motion of the air in 1879 was 268 miles, being 11 miles less than the average. In July the mean daily motion was 78 miles above the average,

and in December 75 miles below. The greatest daily motion was 705 miles on December 30, and the least 32 miles on October 12.

The vane of Osler's anemometer made, in the year 1879, thirty-one 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 1879, was only 983. At Glynde (near Lewes) the number of hours registered with a similar instrument, erected by the Right Hon. H. Brand, Speaker of the House of Commons, was 1040, being larger than at Greenwich in April, May, and October, and smaller in July. At Mr. Campbell's request and private expense a diagram has been prepared, under the Observatory superintendence, exhibiting the record of sunshine on each day throughout the year 1879.

From various causes the Magnetical and Meteorological Reductions had gradually fallen behind, and an endeavour is now being made to bring them into a more forward state.

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

The volume for 1877 has been distributed, as well as the separate copies of the Introduction and Results.

The printing of the Astronomical part of the volume for 1878 is complete, with the exception of the Planetary Results and the Introduction. The Spectroscopic and Photographic Results for 1878 have been printed, and 250 copies will be distributed separately, instead of being included in the Astronomical Results as heretofore.

The Magnetical Results for 1878 are printed, and the Meteorological Results are in the press.

As regards the volume for 1879, the whole of the manuscript of the three principal sections of the Astronomical part has been in the printer's hands for some months, and two proof sheets have been received. The Spectroscopic and Photographic Results for 1879 have been printed, and it is hoped that the separate copies will shortly be ready for distribution.

For some years, the printing of the Greenwich Observations has been gradually falling more and more into arrear, until it was at last about six months behind its normal state. On my representing the state of the case to the Queen's Printers,

they have courteously made arrangements for accelerating the rate of printing; and, in the last month or two, rapid progress has been made in bringing up the arrears. We hope that eventually the printing of the volume for each year may be completed before the end of the year next following. The separation of the Spectroscopic and Photographic Results from the Astronomical Results will allow of their being printed independently of the Astronomical portion of the volume, and we may thus be enabled to distribute these Results within a few months of the end of the year to which they refer.

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

The number of chronometers now in our hands is 229. Of these, 44 belong to various chronometer-makers, who have placed them here for the annual competitive trial; and the remaining 185 (125 box-chronometers, 32 pocket-chronometers, and 28 deck-watches) are the property of the Government. Of the 44 competitive chronometers, 11 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.

The competitive trial of last year shows a slight improvement on that for 1878 as regards the first six chronometers. The first chronometer is a very good one, only excelled by the first chronometer in 1873.

In connexion with the question of isochronism, observations have been made of the arcs of vibration of the balance in the case of two chronometers, which have been fitted with graduated arcs for the purpose of experiment.

There has been no failure in the automatic drop of the Greenwich Time-ball; on 4 days the ball was not raised on account of high wind. The Deal ball was not dropped at 1^h on 3 days, through failure in the telegraphic connexion; on one day the ball was accidentally dropped about 4^s too soon by telegraph signals, and on another day 9^s too soon; on 29 days the current was weak, and the trigger was released by the attendant without appreciable loss of accuracy.

During the period to which this Report refers, the error of the Westminster Clock exceeded 1^s on 120 days; on 32 of these it was between 2^s and 3^s, on 4 days between 3^s and 4^s, and on 1 day it exceeded 4^s.

c

I have reason to believe that the use of the time-signals, originating at the Royal Observatory, and distributed automatically from the General Post Office, is becoming more and more extensive; and it seems probable that the same system may be adopted by foreign nations. Very lately an examination of our instruments was made on the part of another country, with the view of establishing something similar in one of their maritime cities; and it was intimated that Greenwich time would probably be used as standard. The establishment of time-balls, &c. at foreign ports is increasing.

In the summer of 1879 Commander Green, U.S.N., came over to this country for the purpose of determining telegraphically the longitude of Lisbon, as part of a chain of longitudes extending from South America to Greenwich. A successful interchange of signals was made with Commander Green between Greenwich and Porthcurno on four nights, 1879, June 25 to 29. The results communicated by Commander Green show that the longitude of Lisbon Observatory, as adopted in the Nautical Almanac, requires the large correction of $+8^s.54$.

XV. Personal Establishment :—

The duties of Chief and Confidential Assistant, with general superintendence of the Observatory, especially in my absence, are (as in late years) intrusted to Mr. Christie. On special occasions Mr. Christie also takes observations with any of the instruments; but the observations at night interfere so much with superintendence in the day that it is rarely prudent to require such observations from the Chief Assistant. Mr. Dunkin takes charge of the Supernumerary Computers of the Astronomical Department; maintaining discipline among all, upon whatever work engaged; and closely directing the routine calculations and the operations connected with printing for the Meridional, Altazimuthal, and Equatoreal sections. In consideration of the important work in which Mr. Dunkin is thus engaged, with so much advantage to the Observatory, and also of the extra number of hours of his daily office-work, and of his high standing in the establishment, Mr. Dunkin is entirely relieved from duty of observation. Mr. Criswick, as before, is engaged in the Time-Department, including clocks, chronometers, time-signals to the General Post Office (for national distribution), and time-balls at Greenwich and Deal; and also manages the exhibition of quarterly accounts, and the transactions relating to current stationery. Mr. Lynn, though in feeble health, continued to take charge of the Altazimuth to the beginning of the present year, but increasing want of

strength compelled him to retire in January; the care of the Altazimuth was then transferred to Mr. Downing. With assistance of a supernumerary computer, Mr. Downing maintains also the general regulation of the Library and the Manuscripts, as well as all correspondence with the Government office relating to stationery, and distribution of the printed works originating in the Observatory. Mr. Thackeray, as before, attends to the calculations connected with Meridional Zenith Distances, and manages the Chronograph.

Each Assistant is liable to be required to take astronomical observations on alternate days.

In this, the Astronomical part of our establishment, we have now lost the services of a responsible Assistant for at least seven months, and our system feels the strain. Although by increase of employment of Supernumerary Computers we can maintain routine calculations, and even (but with some risk) routine observations, we cannot thus supply those services that require more matured judgment.

Mr. Ellis and Mr. Nash take charge of the Magnetical and Meteorological Department, and Mr. Maunder that of the Heliographic and Spectroscopic Department.

The number of Supernumerary Computers is usually six in the Astronomical Section, four (at present five) in the Magnetical and Meteorological, and one in the Heliographic and Spectroscopic. These young men are paid at my discretion from a general fund, and are liable to promotion or removal at my judgment.

Four practical officers (clerk of works, gate-porter, labourer, watchman) may be considered as part of our standing establishment.

XVI. Extraneous Work:—

I have first to state the progress of operations in connexion with the Transit of Venus, 1874.

In the month of September 1879 I received through the Admiralty a notification of the Treasury, that a sum which appears sufficient would be allowed for prosecution of the calculations of the Transit of Venus, and that Major Tupman would be permitted to devote his time to that object till the end of June 1880. Major Tupman in consequence, sometimes with the aid of a computer, has laboured at this work, attending daily at the Observatory for several hours, and revising every part of the operations of the Transit Observers. And the result is (taking the stations or station-groups in the order which I propose for publication): the observations and calculations of the Sandwich or Hawaiian group are completed; those of the

D

Egyptian group nearly finished; those of Rodriguez completed; those of Kerguelen nearly finished; and also those (which unfortunately are less important) of New Zealand.

In January of the present year I received through the Admiralty the notification of the Treasury that the printing of the observations and calculations might proceed. It has gone on rather languidly; but I have before me in type 128 pages, including the text and the greater portion of the tabular part of the Honolulu work. I propose to take steps for urging on this printing.

With regard to the Transit of 1882, I have lately placed a Memorandum before the Royal Astronomical Society. From the facility with which the requirements for geographical position are satisfied, and from the rapid and accurate communication of time now given by electric telegraph, the observation of this Transit will be comparatively easy and inexpensive. I have attached greater importance than I did formerly to the elevation of the Sun. For the four principal phases (Ingress accelerated, and retarded; Egress accelerated, and retarded) I propose to rely mainly on: 1st, the Cape Colony; 2nd, the shores of Canada and the United States, Bermuda, and the West India Islands; 3rd, the same as the 2nd; 4th, the eastern shore of Australia, or New Zealand in preference if telegraph-communication be made. I remark that it is highly desirable that steps be taken now for determining by telegraph the longitude of some point of Australia.

I have stated as the general opinion that it will be useless to repeat photographic observations.

Secondly, I have to report on the progress of my own Lunar Theory. The general principle of this is: to adopt for correction the best existing theory; to compute with the severest accuracy the numerical values of the terms produced geometrically by the tabular co-efficients, and also the terms really due to the forces which produce them; and to remove the differences between these by corrections of the tabular co-efficients, for which corrections proper factors are prepared. It was a special object with me to avoid the use of powers of m (a symbol well known to lunar theorists), and to give easy means of computing, not new absolute values, but corrections of existing numerical co-efficients (a principle which I have adopted extensively in other branches of astronomy), and also of computing the effect of small external disturbances or small changes of force. Both these are obtained by my process. The heaviest part of the work is the severe computation to which I have alluded; and this is done entirely by junior computers. The calculations had been carried out in every part to the accuracy of 10^{-7} ; but for securing the degree of accuracy which I proposed it was found necessary to extend many parts to 10^{-8} , and some to 10^{-9} . This has caused a very great addition to the labour, but the work has advanced well, and will, I trust, be finished ere long. While waiting for this, which

is to give the correction to every co-efficient of the ordinary lunar theory, I am employing myself partly in re-arranging the whole work for publication, and in putting calculations in order for that correction of co-efficients; and partly on three ramifications or supplements of the theory, relating to,—the effect of the earth's oblateness,—the effect of change of position of the ecliptic-plane,—and the effect of change of excentricity of the earth's orbit, and Lunar Acceleration. The last of these I have completed to my satisfaction, requiring only an examination of the external factor; the two others are progressing.

The Admiralty have assisted me, on Estimates, with a moderate grant (of amount named by myself), but much of the expense has been private.

XVII. General Remarks :—

After the details into which I have entered as applying to the present state of the Observatory, and after the remarks which I have made in the two Reports last preceding on the question of reduction of Printing (which at some fitting time I would willingly again present to the consideration of the Visitors), and the note in the last Report on the increase of annual expense; I have only to place before the Visitors, but for no immediate expression of opinion, the impression which frequently weighs upon me, as to the ulterior organization of the Observatory. The determination of places of Stars, Sun, Moon, and Planets, was handed down to me from my predecessors; it has in various ways been much extended. The Magnetic and Meteorological observations (the first originating with myself, the second partly with the movement introduced by the Royal Society and partly with myself,) constituted a distinct branch of science, having this property in common with the original astronomical work, that it is incessant and regular. The much later introduction of Photographic and Spectroscopic astronomy, established at the instance of the Board of Visitors, and carried on with vigour and regularity, has created a third department. All these departments appear at present to be working efficiently and well. But I can easily imagine circumstances which would interfere materially with the successful continuation, in one place, of this triplicate series of observations. Though I think this possibility of partial failure worthy the contemplation of the Visitors, yet I do not see any necessity for action of any kind at the present time.

G. B. AIRY.

*Royal Observatory, Greenwich,
1880, May 17.*
