

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

Read at the Annual Visitation of the Royal Observatory, 1877, June 2.

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THE Report now presented gives the general history of the Royal Observatory through the period of twelve and a half lunations, comprised between 1876, May 8, and 1877, May 13, and exhibits its condition on the last-mentioned day. No alteration has been made in the arrangement of the heads into which it has, for years past, been found convenient to divide the Report.

I. Buildings and Grounds :—

The fan-roof alluded to in the last Report has been fixed at the entrance to the staircase of the Octagon Room.

In the Transit-Circle Room an alteration has been made in the pitch of the roof-shutters, the fall for water having been found insufficient. The interior of the room has recently been re-painted.

Much inconvenience from wet has been long experienced in the South-East Dome, notwithstanding the care that has always been taken to keep the roof in proper repair. Gutters have now been fixed on the vertical shutter and under the long hinge of the horizontal shutter, to prevent any dripping of water on the instrument.

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The wooden stage for giving access to the light of the Altazimuth Collimating Mark has been used more frequently than in the preceding year. A thorough revision of the galvanic apparatus appears to be necessary.

The scale of equal parts, 16 feet in length, lent by Mr. De La Rue for determination of the distortion of the Photoheliographs of the Transit of Venus, has been taken down from the roof of the Octagon Room, and is now deposited in the Great Shed.

The portable buildings for the Transit of Venus, which at the date of the last Report were left at Simons Town, have been returned to England; but it has not been thought necessary to preserve their flat walls; the roofs and the mechanism have been separated, and are lodged in the Reserved Ground of the Park. I propose to submit to the Lords Commissioners of the Admiralty a request that one of the Transit Huts (now at the South Kensington Museum) be lent to Mr. David Gill, for use in his intended heliometer-observations of Mars at the approaching opposition of that planet, referring to the determination of Solar Parallax.

The buildings and fences are maintained in general good order. Some brick piers which have been used in various astronomical operations are left standing (for the present) upon the grounds. In particular, the two piers used by the Austrian observers of longitude to carry their two forms of transit-instrument are left in place; when it becomes necessary to remove them, their places will be marked (as in preceding instances) by flag-stones with appropriate inscriptions.

The railway through the town of Greenwich is not yet opened for thorough traffic.

II. Moveable Property:—

In our own apparatus, not included among instruments, none but the most insignificant changes have been made. We have nothing lent to us; and nothing lent from the Observatory, except one telescope lent to Col. Tennant for an Eclipse observation in India, which, apparently, has not been returned.

The moveable articles of all kinds are catalogued, and comparison with catalogue is made usually about the time of the Visitation.

The Astronomical instruments used for the Transit of Venus have at length been all returned from the expedition (I believe that they have not yet been fully compared, in details, with their lists); and those which had been borrowed from private contributors have been repaired, where necessary, and returned. Of those which are

the property of the Government, several are lent in different directions ; thus, of the five photoheliographs, one is in daily use in our own photoheliographic observatory, one is at the Cape Observatory, one at the Engineer establishment of Chatham, and one at the South Kensington Museum. The last is accompanied with Equatoreal, Transit, Altazimuth, Clocks, Micrometers, &c. with their appropriate Huts, Chemical Rooms, &c., forming a complete representation of a first-class establishment for observation of the Transit of Venus.

III. Manuscripts :—

One of the daily operations in the Observatory is to take the first step in the arrangement of the manuscripts of every kind which have come before us in the course of the day. This is followed at convenient intervals by other steps, of which the result is to produce ultimately a series of bound volumes of manuscripts in an accessible and (I trust) an orderly form.

The bound volumes are catalogued, and annual comparison is made with the catalogue. In the comparison lately finished, all the bound manuscripts were found in their places ; there was wanting, however, a packet of papers relating to the Eclipse of 1860, which is lent to Mr. Ranyard for his assistance in drawing up the Report on that and other eclipses, and which I hope will shortly be returned.

IV. Library :—

I regard it as desirable for various reasons, (among which is, the instruction of all persons scientifically connected with the Observatory,) that for all subjects bearing upon the operations of the Observatory, the Library should be kept up to a condition well representing the present state of science. Our pursuits have ramified into more numerous branches than formerly (for instance into telegraphy, photography, spectroscopy), and in each of them literature has become more extensive ; and in consequence our purchases of books have become larger than heretofore. Still they are not very large, and are small in comparison with the number of books presented to us.

The principal part of the presents consists of meteorological observations and academical transactions. And these, though it may be permitted to doubt their value (at least those of the first class), must be preserved, on the bare chance of

ultimate reference. Our library accommodation will in a few years be somewhat distressed; and it is not easy to see how it can be extended.

The usual comparison of books with their Catalogue has lately been made, and all are found.

V. Astronomical Instruments :—

The Transit-Circle has required comparatively few repairs during the past year. In December last it was found that the Western pivot had "fired," the Y having been cut probably by a particle of sand, which might have got into the bearing when the instrument was raised. Under Mr. Simms' direction, the roughness was carefully burnished down; and a re-determination of the form of the pivots has been made. A discordance in the results depending on the direction in which the instrument was turned was ultimately traced to instability of the ghost-apparatus; and when this had been remedied and the excentricity of the dot reduced to a small quantity, the residual errors were found to be much smaller than in any previous determinations. Though some approach to law appeared to be indicated in these residuals, there was reason for suspecting that this was a result of periodic error in the micrometer-screw of the seven-feet telescope. To test this point another determination was made, by three complete sets of measures; the seven-feet telescope being shifted through a space corresponding to half a revolution of the micrometer, between each pair of the three sets. The result shows conclusively that there is no sensible deviation from circularity in the form of the pivots, the residuals being obviously casual errors of observation, and nowhere amounting to $0''.5$, whilst the majority are under $0''.1$.

A new determination of the coefficient of flexure was made on 1877, April 21, with an atmospheric temperature considerably higher than on the last two or three occasions. The result, however, only differs by $0''.01$ from the value formerly found.

The Sidereal Standard Clock, after considerable irregularity of rate, finally stopped on January 2. It was cleaned by Messrs. E. Dent & Co., and subsequently the driving weight was slightly increased; since then the rate has been remarkably steady.

The plate-glass-cover of the Chronograph barrel was accidentally broken a short time ago. This has been restored, the instrument having sustained no injury.

The Altazimuth is in good working order, the only trouble experienced being a deficiency of illumination of one of the microscopes of the horizontal-circle. In

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December last, while the instrument was being adjusted, one of the zenith-distance levels was accidentally cracked, and was not replaced by Mr. Simms till the end of March, some difficulty having been experienced in making a new level of suitable curvature. To relieve the lower bearing of the vertical axis more effectually from the weight of the instrument a more powerful lever-counterpoise has been applied by Mr. Simms, with very beneficial results as regards the azimuthal motion of the instrument.

The Sheepshanks and Shuckburgh Equatorials are available for observation of occasional phenomena, though the position of the North Dome, in which the latter instrument is placed, is extremely unfavourable.

The increasing stiffness of motion of the Great Equatorial has led to a thorough examination of its bearings, which are peculiarly liable to suffer, from the circumstance that the motion is almost exclusively confined to a comparatively small arc, and that the instrument rests in one position during long periods of cloudy weather. From this cause, apparently, the upper pivot had worn considerably on one side, whilst the pivots of the friction-rollers had "fired" to such an extent that their action was greatly impeded. The latter were turned afresh in the lathe by Mr. Simms, but nothing was done to the upper pivot, as an error in its form has comparatively little effect on the movement of the Equatorial. The motion of the instrument is now very free, and indeed leaves little to be desired.

The spiral springs connected with the screws for giving slow motion in R.A. and N.P.D. have been removed, as their action was found to be somewhat uncertain; the screws now turn in dead-fittings, with provision for tightening the bearings as may be required.

The apparatus for removing the object-glass from its cell, and separating the lenses by screw-motion, for the purpose of cleaning, has been made by Mr. Simms, and is perfectly successful in its action.

For the convenience of the observer in working with the Spectroscope, the steps on the travelling frame of the observing-chair and the semi-circular platform round the Southern side of the Great Equatorial have been extended.

The Spectroscope is in good working order. Since the date of the last Report provision has been made for illuminating the wires (for observations of stellar spectra); and the Collimator object-glass has been mounted in gimbals, which allow of its being tilted sufficiently to correct the astigmatism of the prisms. This plan has been found perfectly successful.

A large Direct-vision Spectroscope has been quite recently made by Mr. Hilger on a new plan, in which either great dispersion or great purity of spectrum is obtained by the use of "Half-prisms," according as the incident-pencil falls first on the

perpendicular or on the oblique face. In this Spectroscope either one or two half-prisms can be used at pleasure, according to the dispersion required, and there is facility for increasing the train to three or four half-prisms, though the dispersion with two only is nearly double of that given by the large ten-prism Spectroscope. The definition in this form of Spectroscope appears to be very fine.

The Sprengel air-pump has been fixed to the iron casting forming the North support of the Equatoreal, where it is at the same time more firmly mounted and less exposed to accidental injury. Some repairs have, however, been required during the past year.

In view of the application of the Great Equatoreal to stellar photography it has been proposed to correct the object-glass for the actinic rays, by a doublet composed of a convex flint lens cemented to a concave crown, and placed at a short distance within the principal focus of the refractor. No definite step, however, has yet been taken for this purpose.

The Photoheliograph has been lately cleaned by Mr. Dallmeyer, and is now in excellent order. A position-micrometer, for measuring the positions and areas of Sun-spots and faculæ on the heliograms, has been made by Mr. Simms, and used regularly from the beginning of the year.

The micrometer used for the Transit of Venus photographs has been packed in its box, in readiness for another occasion.

VI. Astronomical Observations:—

The regular subjects of observation with the Transit-Circle continue to be as in past years, the Moon, Sun, and large planets, with clock-stars and stars for determination of azimuth-error and zenith-point; and, as opportunity offers, stars from our Working-Catalogue, special attention having been directed during the past year to the completion of the tale of observations for each star in the new Nine-Year Catalogue, which closes with the year 1876. In the case of the Fundamental Stars, efforts are directed rather to obtaining a series extending over many hours than to multiplying the individual observations, which are already sufficiently numerous to eliminate casual errors. Though the application of this principle materially increases the labour of the observer and limits the number of individual observations, it has long been held to be

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necessary where fundamental positions are to be obtained, and no pains have been spared to carry it into effect. As an independent check on the level-error and form of the pivots, both clock-stars and azimuth-stars have been observed in right ascension by reflexion as opportunity offered.

Comparatively few observations have been obtained of the Minor planets, the daily ephemerides given in the Berliner Jahrbuch having been reduced considerably in number. Those inserted principally refer to recently-discovered planets, which are for the most part too faint for observation with the Transit-Circle.

With the Altazimuth, the Moon and two stars for instrumental error have been observed, as well as the Collimator, on every day when the Moon was visible. Determinations of her diameter, both in zenith-distance and azimuth, have been made whenever practicable, and a considerable number of observations of this important element have been accumulated since the date of the last Report.

The following is a statement of the number of observations made from 1876, May 8, to 1877, May 13:—

With the Transit-Circle :

Transits, the separate limbs being counted as separate observations	3,748
Pairs of observations of the nearly vertical wires of the	
Collimators	300
Reciprocal observations of the nearly vertical wires of the	
Collimators	345
Reflexion-observations of the central wire	332
Circle-observations, each requiring a separate reading of the six	
microscope-micrometers	3,274
Reflexion-observations of the zenith-distance wire (included in	
the number of circle-observations)	336
Reflexion-observations of stars (similarly included)	428

With the Reflex-Zenith-Tube :

Pairs of observations of γ Draconis, the instrument being reversed	
between the observations	33
Single observations	10

With the Altazimuth :

Azimuths of the Moon and Stars	772
Azimuths of the Collimating-mark	262
Zenith-distances of the Moon	399
Zenith-distances of the Collimating-mark	262

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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	.	.	.	.	.	.	.	.	.	4			
”	”									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	.	.	3
”	”									between 2 ^h and 3 ^h	.	.	6

The following comparison shows the number of places of the Moon observed with the Transit-Circle and Altazimuth respectively :—

With the Transit-Circle, 85, or 6·8 per lunation.

With the Altazimuth, 172, or 13·8 per lunation.

The following is the number of measures of the Moon's diameter :—

With the Transit-Circle, 3 in R.A., 5 in N.P.D.

With the Altazimuth, 13 in Azimuth, 51 in Zenith-distance.

The observations of occultations of stars by the Moon have been 7 in number; namely, 5 disappearances and 2 re-appearances. Of Jupiter's satellites, 6 phenomena have been observed. The instruments usually employed for these phenomena, sometimes simultaneously, are the Great Equatoreal, the Sheepshanks Equatoreal, and the Altazimuth.

One set of observations of Comet II. 1877 (Winnecke's) and comparison stars was made with the Great Equatoreal. The weather has been singularly unfavourable for the observations of the comets of the present year, which, combined with their inconvenient position, has prevented any regular work on these objects. Besides which, observations in the early morning hours cause a serious interference with the regular work of the Observatory.

VII. Reduction of Astronomical Observations :—

On May 13 the reductions were in the following state :—

For Meridional Transit Observations :

Observed transits are corrected for instrumental errors, and

clock-times of transit over the true meridian are prepared, to . 1877, May 5

Clock errors and rates are applied, and apparent right-ascensions

from observation are formed, to May 4

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Reductions of apparent places of stars to mean places on January 1 are prepared, to	May 4
The two last-mentioned elements are combined, to form mean R. A. 1877, January 1, of stars, from daily observation, to .	May 4
Mean solar times of observation of Sun, Moon, and Planets, are prepared, to	May 4
Corrections for defective illumination of the limbs of Moon and Planets are prepared, to	May 4

The Personal Equations in observation of transits during the year 1876 have been investigated; there appears to be no sensible change among the principal observers since 1875.

For Meridional Circle Observations:

Means of readings of microscope-micrometers are taken, and corrections are applied for reading of telescope-micrometer, error of graduation, flexure, inclination of wire, and zenith- point, in order to form apparent zenith-distances, to 1877,	May 6
True geocentric north polar distances are formed by application of refraction, parallax, and colatitude, to	May 6
Reductions of apparent N. P. D. of stars, given by daily observa- tions, to mean N. P. D. 1877, January 1, are applied, to .	May 1
Corrections are applied for defective illumination of limbs of Moon and Planets, to	May 6

The corrections for R—D, the error of assumed co-latitude, and the position of the Ecliptic, have been computed for 1876, and the computations of the geocentric and heliocentric errors of the planetary tables are commenced. The result of the R—D investigation is almost identical with that obtained last year. The co-latitude for 1876 is $38^{\circ}.31'.21''52$; that for 1875 (which was not ready at the date of the last Report) is $38^{\circ}.31'.21''34$.

Though the period of nine years is rather long for our new combined Catalogue, I have decided to include the observations from the beginning of 1868 to the end of 1876, as the places of many of the stars would otherwise have been insufficiently determined. In order to avoid any error from the length of the period comprised, especially in the case of circumpolar stars, the results will be corrected for secular variation of the precession in the interval from the epoch 1872.

The preparation of the Nine-Year Catalogue is steadily advancing. The reduction of the observations in each year to the mean epoch is nearly completed, whilst the Precessions and Star-Constants in R. A. and N. P. D. are computed in duplicate and examined. The Secular Variations are well advanced, and the heavy work of pre-

paring the copy for press will soon be commenced. It is intended to have the Catalogue completed in time to be attached as an Appendix to the volume of Greenwich Observations for 1876. The Nine-Year Catalogue will contain more than 2,250 stars (a considerable number being circumpolar) nearly all of which have been observed at least three times in each element.

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

The following is the state of reduction of the Altazimuth observations :—

For azimuths, true azimuths are formed by combination of mean of microscopes, correction for level, collimation, and azimuth-zero, to	1877, April 13
For zenith-distances, true Greenwich zenith-distances, corrected for refraction and parallax, are formed, to	May 13
Corresponding tabular azimuths and zenith-distances are formed, to	April 13
Apparent errors of Moon's tabular R. A. and tabular N. P. D. are computed, to	April 13
Apparent errors of Moon's tabular Longitude and Ecliptic N. P. D. are computed, to	April 13

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

VIII. Spectroscopic and Photographic Observations :—

During the past year the Sun's chromosphere has been examined with the Spectroscope on 57 days (on 5 of these through part of the circumference only); prominences were seen on 39 days, or about 75 per cent. of the whole number of days. From the tendency to formation of cloud in the day-time, opportunities of examining the Sun's limb are however rather rare, and the observations are hardly sufficient to give reliable data on the comparative frequency of prominences.

At the end of May. 1876, spectroscopic determinations of the Sun's rotation were made by observations of the relative displacement of the Fraunhofer lines at the east and west limbs respectively. The results are in close agreement with the value of the rotation found from observations of Sun-spots. A similar determination has also been made in the case of Jupiter, with equally satisfactory results.

Ninety-one measures have been made of the displacement of the F line in the spectra of 25 stars as compared with hydrogen, and 91 measures of the displacement

of the *b* lines in the spectra of 17 stars as compared with magnesium. Unfortunately a few measures made on March 17 and April 4 are liable to a small uncertainty, from the circumstance that the pointer was illuminated for the observation of the stellar spectrum, but not for that of the comparison spectrum. As a check on the validity of the general results, 10 measures have been made of the displacement of the F line and 8 of that of the *b* lines in the spectrum of Venus as compared with hydrogen and magnesium respectively, and 5 measures of the F line and 26 of the *b* lines as compared with the sky-spectrum. The results, both for the eastern and western elongations, give a motion of the same sign as the calculated value, though rather larger in amount. Eleven observations of the F line and 12 of the *b* lines in the spectrum of the Moon agree with theory in showing no sensible displacement. The observations of displacement have been made, as far as possible, with different dispersive powers, ranging from $1\frac{1}{2}$ to 6 prisms.

With the single-prism Spectroscope, Saturn, Neptune, and Venus have been examined, as well as variable stars, interesting changes in the relative intensity of the absorption-bands having been noticed in the case of some of the latter. These observations, however, need confirmation. Unfortunately the news of the discovery of the temporary star in Cygnus was not communicated to me till the star had declined greatly in brightness; and as the Great Equatoreal had then been dismantled for the repair of the pivots, no spectroscopic results could be obtained.

With reference to the question of displacement of the F line in stars, measures have been made of the position and breadth of the corresponding hydrogen line under varying conditions of pressure, the result being conclusive as to the fixity of the centre of the line when its breadth increases with increase of pressure. It would appear to follow from this that the displacement of the F line, in cases where its breadth is considerable, cannot be due to the greater pressure in the star's atmosphere. In these observations much trouble was occasioned by the intrusion of two spectra of a different character, which frequently obliterated the usual four bright lines of hydrogen. The origin of these anomalous appearances has not been distinctly traced, though a determination has been made of the positions of the bright lines in one of the intruding spectra. The hydrogen spectrum has also been examined with varying intensity of spark, with a view to the determination of the effect of increased temperature. These investigations are still occupying our attention during periods of cloudy weather.

Photographs of the Sun have been taken on 140 days, and of these 239 have been preserved. The photographs show a complete absence of spots on 57 days, and on 29 of these there are neither spots nor faculæ.

Since the date of the last Report a few photographs of Jupiter and α and β Lyræ have been taken with the Great Equatoreal, mainly to test the applicability of Kennett's gelatine dry-plates to this class of work. Comparatively little attention,

however, has been directed to stellar photography, pending the introduction of the proposed doublet for actinic correction of the object-glass.

IX. Reduction of Spectroscopic and Photographic Observations :—

All observations with the Spectroscope have been completely reduced; the measures of lines in the spectra of elements being converted into corresponding wave-lengths, and the observations of displacement of lines in the spectra of stars being reduced so as to exhibit the concluded motion in miles per second, after applying a correction for the earth's motion.

As regards the Photographic Reductions :—

The areas of Sun-spots and faculæ have been measured in duplicate, and the measures reduced to millionths of the Sun's visible hemisphere, up to the end of 1876. Since the new photograph-micrometer was brought into use in January last, considerable progress has been made with the measurement of positions of spots and faculæ, a much heavier work than the evaluation of the areas. Up to the present time the distances from the centre of the Sun's disk and the position-angles have been measured in duplicate for all spots and faculæ on 100 photographs from 1873, June 1, to 1873, October 9. As the number of spots is much smaller in the subsequent years the progress will now be much more rapid.

X. Magnetical and Meteorological Instruments :—

The Magnetical and Meteorological Instruments in use at the present time are the same as those described in the last Report. They comprise all which are necessary for the fundamental eye-observations and the continuous self-formed register of the following phenomena :—The three magnetic elements and earth-currents, barometric pressure, force and speed of wind, rain, temperatures of air (at different elevations) and evaporation, ozone, and solar radiation; with maximum and minimum thermometers at the Observatory and in the waters of the Thames at Poplar, and thermometers deep-sunk in the earth. Besides these, which are adapted for reading every day, there are the magnetic deflexion-instrument, the dip-instrument, and atmospheric electrometers, to be observed occasionally. All are in good working order.

The driving-chronometers of the barrels of Declination, Horizontal Force, Vertical Force, and Barometer and Thermometers, have been slightly altered for diminution of play in the driving-arm. The screw of the relieving apparatus of the dip-instrument, and the clamp of the theodolite, have been repaired. The suspension of the Upper Declination-Magnet has been so changed that, in raising the magnet-carrier, no alteration is made in the free length of the suspension-skein or in the nature of its attachment as regards horizontal torsion. The brass bar, occasionally suspended for observations of torsion, is now so loaded that its weight is precisely equal to that of the magnet with its collimator.

The Standard Barometer has lately been compared with the Kew Standard; the difference of their readings was exceedingly small.

The new Standard Thermometer (mentioned in the two last Reports) has been compared with the old Standard, by the intermediation of eight thermometers which had been compared with both. No sensible difference was found.

An Electrometer on Sir William Thomson's plan, for continuous photographic registration of atmospheric electricity, has been received from Mr. White of Glasgow; it is not yet mounted.

XI. Magnetical and Meteorological Observations :—

It will perhaps suffice to say that all the instruments mentioned under the last head have been in full and continuous use, forming the most complete record that we have been able to devise of all the magnetic and meteorological phenomena which appeared to be fit subjects of observation. I may however specify that the eye-observations for zeros are taken several times each day, that stars are observed with the declination-theodolite about twice a month, that absolute measure of Horizontal Magnetic Force is made (by deflexion) once a month, and dips are taken two or three times a week.

XII. Reduction of Magnetical and Meteorological Observations :—

Absolute magnetic declinations in eye-observations are reduced to the end of 1876; eye-observations of the Horizontal-Force-Magnet to the present time; and eye-observations of the Vertical-Force-Magnet to the end of 1875. The time-scales for Declination, Horizontal Force, and Earth Currents, are complete to the end of 1876; those for Vertical Force to the end of 1875. Values of the ordinates of new base-lines for the Declination and Horizontal Force are formed, but the lines are not yet laid down, for 1876. No progress has been made in

reading out the hourly ordinates for 1876. The results of this section, as compared with those shown in preceding Reports, are slightly in arrear. The Dips are reduced to the last observation; the absolute measures of Horizontal Force to the end of 1876. No step is taken in reduction of the Earth-current observations.

On examining the monthly values of Vertical Force in each year since the mounting of the Vertical Force Magnetometer (which has now been in use for twelve years), it is remarked, that the value for each December is less than that for the preceding January by about $\frac{1}{100}$ part of the whole; a quantity vastly greater than the change deduced from the combination of Dip and Absolute Horizontal Force. This is undoubtedly produced by gradual diminution of the power of the Magnet; it is supported by the increase in the time of horizontal vibration.

The following are the principal results for magnetic elements in the year 1876:—

Approximate mean westerly declination	. . .	19°. 8'.
Mean horizontal force		{ 3·898 (in English units). 1·797 (in Metric units).
Mean dip		{ 67°. 39'. 38" (by 9-inch needles). 67. 40. 50 (by 6-inch needles). 67. 42. 7 (by 3-inch needles).

I have it in contemplation, when our staff shall be relieved from the great meteorological reductions, to collect and discuss the photographic magnetic records since 1865, in the same form as those printed in the Philosophical Transactions for preceding years to 1863 (1864 being an interrupted year). For all years except 1865, 1866, 1867, the principal part of the work is already done.

The mean temperature of the year 1876 was $50^{\circ}\cdot 1$, being $0^{\circ}\cdot 7$ above the average of the preceding 35 years; the months of greatest deviation were May, July, and December, their temperatures being respectively $3^{\circ}\cdot 5$ below, $3^{\circ}\cdot 7$ above, and $4^{\circ}\cdot 0$ above, the average. The absolute temperature was seven times above 90° , the highest being $94^{\circ}\cdot 0$ on July 17. The lowest was $17^{\circ}\cdot 4$ on January 8.

The mean daily motion of the air was 291 miles, being 13 miles greater than the average. In February and March, the movements were 54 miles and 113 miles above the average. The greatest day's motion was 869 miles on March 15; the least was 49 miles on February 11.

The vane of Osler's anemometer made, in the year 1876, rather more than one complete revolution in the positive direction N, E, S, W, N.

The observations on the pluviometer mounted in the "Royalist" at Poplar (the ship to which our Thames-thermometers are attached), at the elevation of 17 feet

above the river, appear to show that the amount of rain collected there is the same as that on the ground-level at the Royal Observatory in the months of June, July, and August, but less in all other months of the year. The aggregate for the year is nearly the same as that of the rain collected on the roof of the Octagon Room.

The computation of the photographic records of the barometer from 1854 to 1873 has so far advanced that we can assert positively that there is no trace of lunar tide in the atmosphere; but that there is a strongly marked semidiurnal solar tide, accompanied with a smaller diurnal tide. We are at present engaged in comparing the barometrical measures with the directions of the wind.

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

The printing of the Astronomical part of the volume for 1875 is complete; with the exception of the Photographic and Spectroscopic observations, and the Introduction. As Appendix of astronomical character, I propose to attach, but at the end of the Volume, the first part of Numerical Lunar Theory (already printed), including the general theory, extensive numerical developments of certain functions of the moon's co-ordinates, and the theory of Symbolical Variations.

The Magnetical and Meteorological Results are printed for 1875, excepting only the Introduction, which has been sent to the Printer. The Magnetic part contains detailed observations of one magnetic storm; mean diurnal inequalities of terrestrial magnetic forces; dips; and measures of absolute horizontal force. The Meteorological part contains daily results of the observations mentioned under Section XI.

I propose to attach to the Volume, as usual, the Report upon Chronometers on Competitive Trial, 1876, and last year's Annual Report to the Board of Visitors.

For the year 1876, the manuscript of the three principal astronomical sections (Meridional Transits, Meridional Zenith Distances, and Altazimuth Observations) has been transmitted to H. M. Stationery Office or their Printer; and a few proof sheets have been received.

The extent of printing contemplated for the volumes 1875 and 1876 is as follows:—

Of the Volume, including everything	300 copies.
Separate copies of the Astronomical Results	150 „
Separate copies of the Magnetical and Meteorological Results	250 „
Separate copies of the Report on Chronometers	650 „
Separate copies of the Report to the Board of Visitors	650 „
Separate copies of the Numerical Lunar Theory	250 „

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With the separate copies of the Astronomical Results, it may perhaps be desirable to circulate copies of the Astronomical Introduction; a work which might almost be adopted as a practical text-book for observatories of the Greenwich class.

The Nine-Year Catalogue of stars will, I trust, be ready for attachment to the Volume for 1876. Experience has taught us that the ordinary number (250) of separate copies of Star-Catalogues is not quite sufficient; and I propose to print in this instance 650 copies, namely 300 for the Volume and 350 for separate distribution or sale.

In the course of the year, I trust that the results of the extensive discussion of the Temperatures and Barometric Pressures derived from the photographic registers, 1848 to 1868 and 1854 to 1873 respectively, will be printed. This work will perhaps be too large to be treated as Appendix to the Greenwich Observations; in that case it must be issued as a smaller separate volume.

By a late arrangement, under the sanction of the Lords Commissioners of Her Majesty's Treasury, the distribution of the volumes is in future to be made on the responsibility of the Astronomer Royal. It is not intended in this to curtail materially the distribution which has been made by other channels, but to place it under an officer who is known to the Government. The general rule of distribution is, to present the entire Volume to Observatories, Libraries, Scientific Academies, and other institutions of permanent character; the separate copies of Results to private observers or amateur astronomers. Some copies are sold by H. M. Stationery Office.

Observations of small planets are sent every quarter to the Paris Observatory, and other observations occasionally to the Royal Astronomical Society. There is no extensive wish for separate magnetic observations, but general magnetic results are in great demand, especially for mining operations, and to meet this a map of magnetic declination is furnished to the newspaper called the "Colliery Guardian." Daily meteorological results are supplied to M. Le Verrier, to the War Department at Washington, to the Registrar General, and to the Meteorological Office, and are made more quickly accessible to the public by newspapers and by affiche on the Observatory Walls.

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

We have now under our care 191 chronometers. Of these 34 are box-chronometers, the property of chronometer-makers, and placed here for the annual competitive trial. The others (113 box-chronometers, 26 pocket-chronometers, and 18 deck-watches) are

the property of the Government, either returned from service for examination and repair, or awaiting orders for issue to ships of the Royal Navy.

The general rules for rating are these. Chronometers on competitive trial, and occasionally other chronometers (especially when a weekly rate exhibits irregularities) are compared every day with a clock sympathetic with the Mean Solar Standard Clock. Other chronometers are compared once a week. No comparisons are made in artificially depressed temperature, but every chronometer is tried in a temperature raised nearly to 100° Fahrenheit; Government chronometers at least during three weeks, competitive chronometers twice during periods of four weeks each. Competitive chronometers are also rated in four different magnetic positions. (It may be worth mention that more than a thousand chronometers have passed under my review, and that only one of these has indubitably shown signs of sensitiveness to external magnetism.) Every weekly rate is inspected by myself.

The supplementary compensation, to which allusion was made in the last two Reports, has now been repeatedly tried, and I think I may say that in the makers' hands it is successful. We do not doubt that chronometers are delivered to us by the makers in a better state of compensation than formerly. For the convenience of makers, it was judged prudent in the competitive trial now advancing, not to insist on the application of this apparatus to every trial-chronometer, but to intimate that the Government would be unwilling to purchase chronometers not fitted with it. More than three-fourths of the chronometers now on trial are furnished with the new supplement.

The accuracy of chronometers continues to improve, but very slowly, and not uniformly. The "trial-number," exhibiting the errors of the chronometers on the 1876 trial, referred to our usual test of the mean of the irregularities of the first six, is lower than that of any year except 1873. The first chronometer is a fine one, only surpassed in 1873.

The automatic drop of the Greenwich time-ball has failed only on 7 days when the ball was not raised on account of high wind, and on 3 days from accident. The Deal time-ball failed, on 6 days from high wind, and on 15 days from error in the telegraphic connexion; on 6 days the assistance of the attendant was required (on account of the feebleness of the current) to work the relay by which the dropping-current is created. The Lombard Street Clock has been placed under a new contract, and its action is imperfect to this extent, that it does not return signals to us. It is under the contemplation of the Telegraph Department of the General Post Office to place this clock in their general system of telegraphic time-signals, and to relieve the Observatory from all further care of it. The Westminster Clock, from some neglect of the agent of the chronometer-maker, has not fully maintained its character; it has sometimes been more than 3^s in error.

Time-signals, originating at the Royal Observatory, and dispersed without sensible loss of time by the "Chronofer" of the General Post Office, are distributed, I believe with perfect accuracy, through every part of the kingdom.

In the last summer, several German gentlemen, introduced by Professor Theodor von Oppolzer, were engaged for many weeks in the time-observations and the telegraphic observations necessary for determining the longitudes of Vienna and Berlin, connected also in some measure with Munich and Paris. Under sanction of the Treasury, a temporary Observatory was provided on the Magnetic Ground. No results, I believe, were accepted by the observers, unless good transits were obtained at both ends of the line under treatment, with perfect communication on the telegraphic wire. The final results of the operation have not yet reached me.

XV. Personal Establishment :—

The establishment remains in the same position as at the last Report.

Mr. Christie is Chief and Confidential Assistant, and in my absence is invested with the fullest powers over all departments.

In the Astronomical Department ;—

Mr. Dunkin superintends the Supernumerary Computers, especially those who are employed on the reduction of transit-observations and on the more advanced computations ; aiding also in the management of those who are in great measure employed under other Assistants. At the present time, Mr. Dunkin also superintends the extensive calculations for the Nine-Year-Catalogue. In recognition of Mr. Dunkin's high standing and his close confinement to the work of computations, he is entirely relieved from active observations.

Mr. Lynn is charged with the care of the Altazimuth and the reduction of observations made with it ; he is usually assisted by one Supernumerary in the Observatory, and occasionally by one residing at a distance.

Mr. Criswick has every part of the duties connected with the management of chronometers and time-signals, the care of Stationery, and the Quarterly Accounts of the Observatory. He is aided by one Supernumerary.

Mr. Downing usually communicates with H. M. Stationery Office, and is charged with the care of the Library and Manuscripts, and the distribution of Printed Observations, &c.

Mr. Thackeray's special duty is attention to the Chronograph and to Meridional Zenith-Distances. He is assisted by one Supernumerary.

The ordinary astronomical observations are made, as far as possible, by the four gentlemen last mentioned.

The Supernumeraries, to whom allusion is made above, are young men, whose terms of employment are entirely at my discretion, and whose remuneration is varied from time to time. They are encouraged to learn the methods of observation; and, when observations are unusually pressing, they are frequently able to relieve the regular Assistants and to give efficient assistance to the Observatory.

In the Magnetical and Meteorological Department;—

Mr. Ellis and Mr. Nash, as Senior and Junior Assistants, superintend every part; as regards attention to the buildings, management of the instruments, observations, and reductions.

Four young men are at present attached to this Department. The future diminution of this staff is contingent on the termination of the Meteorological, and possibly the Magnetic, Reductions to which I have alluded.

In the Spectroscopic and Photographic Department;—

Mr. Maunder continues to control this department; one Supernumerary is subordinate to him. From the nature of his employments, in which the South East Equatoreal is used,—sometimes with sidereal and sometimes with solar rate of motion, sometimes furnished with plain eyepieces and sometimes with spectroscope,—he becomes in fact the superintendent of that instrument.

Other attached servants of the Observatory are the gate-porter, the watchman, and the labourer. These are recognized in the annual provision made by Government. There is however also an unrecognized Clerk of Works (a skilled carpenter); and some carpenters or other workmen are almost always employed.

Work of every kind,—observational, scientific, practical,—is every day recorded in sheets or books, which are submitted periodically to my examination.

XVI. Extraneous Work:—

First, as regards the operations for the Transit of Venus:—

The computing staff under Captain Tupman has by degrees been reduced to two junior computers within the Observatory; and one or two computers external to the observatory, who are employed on large groups of systematic calculations, for which they are remunerated by tariff. The principal part of the calculations remaining at

the last Report was that applying to the determination of the geographical longitudes of fundamental stations. At the moment of my writing, the last of these (the longitude of Observatory Bay, Kerguelen,) is not absolutely finished ; but I trust that it will be so before my presentation of this Report ; and then I shall be in position to offer the first determination of correction to parallax from eye-observations of the Transit.

The method of determining the geographical longitude of the principal station in each group by vertical transits of the Moon has been found very successful at Honolulu and Rodriguez. For stations in high south latitude, horizontal transits are preferable ; for Kerguelen, as I have mentioned, the work is not quite completed. (It will be remembered that the longitude of Mokattam, the principal Egyptian station, was determined by telegraph.) The corrections to the Moon's tabular places have been determined with much care from meridional observations at the principal European observatories.

The differences of longitude, or the relations of clock-times, within the groups of stations, are ascertained.

These calculations must be followed by the preparation of the factors of errors of various elements. Little progress is made in these ; the work will not be heavy.

No further advance is made in the photographic reductions. The work is large, but it is simple, and will not be oppressive.

Second, as regards the Numerical Lunar Theory :—

In the algebraical theory an alteration has been made, by the substitution of the equation of radial forces for the equation of vis viva. Nearly all the numbers had been computed, and the additional numerical operation was small.

The numerical calculations of the factors of symbolical variations are advancing ; and the computations of the perturbing side of the equations, with due attention to the terms requiring extension of decimals, are in progress.

The numerical errors to which I alluded in the last Report are corrected ; and I do not think that any systematic error now remains.

With the view of preserving, against the ordinary chances of destruction or abandonment, a work which is already one of considerable magnitude, I have prepared and have printed as Appendix to the Greenwich Observations, (with additional copies as for a separate work,) the ordinary Equations of Lunar Disturbance, the novel theory of Symbolical Variations, and the Numerical Developments of the quantities on the first side of the Equations. The last of these will ultimately require some additions for the terms whose magnitude is increased (in algebraical development).

The work is perhaps somewhat larger than I anticipated, and the regularity of its progress has been disturbed by very frequent interruptions of my own attention,

occasioned chiefly by annoying occupations on the Transit of Venus. I trust that it will in future go on in a more orderly and more rapid way.

XVII.—General Remarks :—

The subject which, I think, must first present itself to the mind of any one who has traced the history of the Observatory, is the increase in the number and the fullness of our occupations.

Of these, one in particular (Altazimuth-observations of the Moon) has originated with myself; others, from the suggestions of the Board of Visitors, or from the obvious demands of the scientific world.

This increase is felt even in our buildings and grounds; every corner of every room is or will shortly be occupied; and the form of the ground almost forbids extension.

The printing of the steps of the reductions of observations (which originated with myself, more than forty years ago) naturally increased the labour within the Observatory, as well as the expenses without it. This printing, however, must never be abandoned. But there is another part, of which the policy still appears to me somewhat doubtful, namely the printing in extenso of every figure of original observations; it being remarked that the originals or extracts are always open to astronomers. I brought the question of suppressing these before the Board of Visitors many years ago; but the opinions of astronomers (I cite in particular the honoured name of M. Biot and that of Mr. Johnson) were so strongly adverse to it, that I laid aside all further thoughts of it; and I do not even now profess to entertain a decided opinion.

The three points, however, to which I have alluded (the extent of scientific occupations, the enlargement of buildings, and the amount of printing,) must before long engage the attention of the Visitors.

G. B. AIRY.

*Royal Observatory, Greenwich,
1877, May 14.*
