

BUCHANAN

TRANSACTIONS

OF THE

ROYAL SOCIETY

OF

EDINBURGH.

VOL. XLII.

EDINBURGH:

PUBLISHED BY ROBERT GRANT & SON, 107 PRINCES STREET,
AND WILLIAMS & NORGATE, 14 HENRIETTA STREET, COVENT GARDEN, LONDON.

MDCCCCH.

*Abstract of Paper on the Meteorology of Ben Nevis in Clear and in Foggy Weather.**

By J. Y. BUCHANAN, F.R.S.

The publication by the Royal Society of Edinburgh of the hourly observations made at the observatory on the summit of Ben Nevis along with corresponding observations at Fort-William at the sea level is an important contribution to meteorological science. The study of this work reveals at once the important characteristic of the Ben Nevis Observatory. It is situated on a true peak, and that the highest point in the British Islands. Its height above the sea is such that it is usually enveloped in cloud, and its records are for the most part those of an observatory established in the clouds, and in an atmosphere habitually saturated with moisture.

The weather on Ben Nevis falls naturally into three categories: the first includes the days when the mountain is continuously enveloped in fog or cloud; the second, those periods when the mountain is clear of clouds; and the third, periods during which frequent alternations of clear and foggy weather occur. It is apparent that the meteorological conditions of the locality will be best understood by studying the continuously clear weather and the continuously foggy weather, each by itself. It will then be more easy to understand the conditions of mixed weather. When the meteorological observations on Ben Nevis are looked at as physical observations, and the object is to study the physics of the atmosphere, apart from all considerations of weather, then a separation such as that above indicated becomes an obvious preliminary. Had meteorology been first practised in the Tropics it would now be in a more advanced state than it is. The meteorology of Europe, like the tides on its coasts, is the most intricate and involved that can be found anywhere in the world, and it is the worst possible material on which the study could be commenced. Within the Tropics, and round the Poles, the conditions are simple and uninvolved, and the meteorological observations, at least those made within the Tropics, reflect this simplicity. Generally, in the Tropics there are two kinds of weather, indicated by the terms Dry season, Rainy season. In Europe, we have dry seasons and rainy seasons; but, whereas, in the Tropics the dry season occupies completely one-half of the year and the rainy season occupies completely the other half without any mutual interference, our wet and dry seasons alternate as many times in the course of a single day. Here it would seem to be indicated that we should do for ourselves what Nature does for us in the Tropics, and sort out the weather before discussing it.

The prime factor in determining the climate of a place is its Latitude, because this determines the altitude to which the sun rises from day to day and the length of

* *Transactions of the Royal Society of Edinburgh* (1899), vol. xxxix.—Part III. No. 31.

time that it is above the horizon each day. The heating power of the sun on any horizontal portion of the earth's surface varies with the sine of its altitude at the moment. All the elements of climate and weather depend ultimately on this factor, and its variability produces a corresponding variability in the weather. It is only necessary to consult a table of sines to see where the greatest variability is likely to occur. Thus, at the equator the sine of the sun's meridian altitude varies between 0.94 and 1.000, at either of the Tropics between 0.684 and 1.000, in lat. 45° between 0.367 and 0.930, and in the latitude of Ben Nevis ($56^{\circ} 48' N.$) it varies between 0.169 and 0.835. At the equator the sun's heating power at noon only varies by $7\frac{1}{2}$ per cent. of its maximum amount, while at Ben Nevis the variation is 80 per cent.

But the latitude of a place determines not only the intensity of the sun's heat which it receives, it also determines the intensity of the cooling to which it is exposed by radiation into the upper regions of the atmosphere and into space. This goes on all day independently of the sun's heating, but it becomes more apparent after the sun has set, and produces the greater effect the longer is the duration of the night, and this is a function of the latitude. While the altitude which the sun attains measures the heat which it supplies, and the length of the night determines the amount which is lost, both the heat received and that lost at any particular place may be in excess or in default of what it is entitled to, owing to its latitude alone. This is due to secondary actions set up by the primary heating and cooling, whereby one place may receive, in addition to its own, a supply of heat or of cold to which it is not entitled, thereby altering its climate as well as that of the other place which has supplied the heat or cold.

The principal secondary agencies through which the sun works are the atmosphere in its motion, both horizontal and vertical, and in its changes of volume; and the substance of water in its changes of state of aggregation. It cannot be doubted that, considering the Earth as a whole, the nett effect of these secondary agencies is *nil*. Yet their local effect is in many cases very great, as witness the difference in population between Great Britain and places in the same latitude in North America. The waters of the ocean are also a powerful secondary agency in the distribution of the sun's heat.

The published observations were begun on Ben Nevis in 1884, but, to avoid a broken series, the years from 1st January 1885 to 31st December 1897 are here considered.

The principle on which the dates were selected was:—For foggy weather, to take spells of three or more whole days of continuous foggy weather, and *continuous foggy weather* is defined by twenty-four consecutive entries of fog in the log of each day. The supply of foggy days seemed to be so abundant that the minimum length of spell was able to be fixed at three whole days. When it became a question of selecting the spells of clear weather it was necessary to adopt the hour as unit, and twenty-four consecutive hours during which fog was not once entered in the log was adopted as the

specification of the spell of clear weather of minimum duration. It was not possible to enforce the limitation that the twenty-four hours should all belong to the same day. It will be observed that a *clear* day only means twenty-four hours free of fog, and implies nothing with regard to the presence or absence of cloud overhead. Tables I. and II. give complete information as to the dates used.

Summit and Base.—Although observations have been made at the base of the mountain since the observatory on the summit was established, and for the last ten years a first-class observatory has existed at Fort-William, in this paper no account is taken of the observations made at the base. After the meteorology of the summit has been thoroughly studied by itself, and that of the base by itself, there will be greater light for the study of the combined observations and more assurance of the validity of the conclusions arrived at.

Details of Method of Selection.—A list of dates selected from the years 1885–1897 was made. The principle of the selection was, in the case of *foggy* weather, to pick out every block of at least three days of continuous fog; in the case of *clear* weather, to pick out every spell of at least twenty-four hours continuous clear weather. By a spell of *clear* weather is meant one in which *no fog* was logged. The blocks of *foggy weather* vary in length from three days to eleven days; the spells of clear weather vary in length from twenty-four hours to two hundred and eighty-three hours.

The following short table shows a summary of the quantity of material which was available on the principle of selection adopted.

Summary of Material Used.

| Month. | Foggy Weather. | | Clear Weather. | |
|----------------------|----------------|--------------|----------------|---------------|
| | No. of Spells. | No. of Days. | No. of Spells. | No. of Hours. |
| January, | 22 | 86 | 13 | 606 |
| February, | 12 | 54 | 26 | 1,158 |
| March, | 20 | 78 | 27 | 1,335 |
| April, | 16 | 59 | 30 | 1,728 |
| May, | 7 | 27 | 37 | 2,228 |
| June, | 12 | 42 | 46 | 2,895 |
| July, | 11 | 46 | 30 | 1,502 |
| August, | 17 | 58 | 19 | 971 |
| September, | 16 | 79 | 31 | 1,296 |
| October, | 17 | 64 | 21 | 951 |
| November, | 20 | 88 | 19 | 983 |
| December, | 15 | 66 | 14 | 697 |
| Totals, | 185 | 747 | 313 | 16,350 |

From it, it will be seen that 70 per cent. of the clear weather occurs in the months of April, May, and June, and generally there is much more prolonged clear weather in the spring half of the year than in the autumnal half. There is also less continuous

foggy weather in the spring half, there being a well-marked minimum in May. The months of August and especially September are rich in continuous foggy weather, and this accounts for the very bad reputation of the mountain among tourists. The month which figures in our lists with the maximum of foggy spells is November, the maximum of clear spells falls in June.

The distribution of the spells of clear and of foggy weather in the months of different years is worth attention. In January there were no spells of twenty-four hours' clear weather in the six years, 1889 to 1894 (inclusive). In March, May, June, and July, there is one year without a spell of clear weather; in February, April, August, and September, there are two years; in October and November, three; and in December, five years without a spell of clear weather. With regard to the spells of foggy weather of three days and upwards, we find only one year where they were wanting in January. In March, April, September, November, and December, there are two years; in June and August, three years; in February, July, and October, four years; and in May, six years where they were wanting.

Adding up the total number of hours of clear weather and days of foggy weather considered, we find that they make 681 and 747 days respectively, or a total of 1428 days out of 4748 days contained in the thirteen years, or, roughly speaking, one-third. Hence, out of the thirteen years we can make up four years in which the weather was either continuously clear or continuously foggy in the sense of our specification of these classes of weather.

TABLE giving the Number of Minutes after Greenwich Mean Noon when it is Local Apparent Noon at Ben Nevis at Different Dates.

| Date. | Minutes. | Date. | Minutes. | Date. | Minutes. | Date. | Minutes. |
|--------|----------|---------|----------|---------|----------|--------|----------|
| Jan. 1 | 24 | Mar. 30 | 24 | Aug. 18 | 24 | Nov. 2 | 3·7 |
| " 3 | 25 | April 4 | 23 | " 24 | 23 | " 9 | 4 |
| " 5 | 26 | " 7 | 22 | " 27 | 22 | " 17 | 5 |
| " 7 | 27 | " 10 | 21 | " 30 | 21 | " 21 | 6 |
| " 9 | 28 | " 15 | 20 | Sept. 1 | 20 | " 26 | 7 |
| " 12 | 29 | " 18 | 19 | " 4 | 19 | " 28 | 8 |
| " 15 | 30 | " 24 | 18 | " 7 | 18 | " 30 | 9 |
| " 20 | 31 | " 30 | 17 | " 9 | 17 | Dec. 2 | 10 |
| " 24 | 32 | May 15 | 16 | " 12 | 16 | " 4 | 11 |
| " 29 | 33 | " 25 | 17 | " 15 | 15 | " 7 | 12 |
| Feb. 1 | 34 | June 3 | 18 | " 17 | 14 | " 10 | 13 |
| " 11 | 34·5 | " 9 | 19 | " 20 | 13 | " 12 | 14 |
| " 19 | 34 | " 15 | 20 | " 22 | 12 | " 14 | 15 |
| " 27 | 33 | " 21 | 21 | " 25 | 11 | " 16 | 16 |
| Mar. 2 | 32 | " 25 | 22 | " 30 | 10 | " 18 | 17 |
| " 7 | 31 | " 30 | 23 | Oct. 3 | 9 | " 21 | 18 |
| " 10 | 30 | July 2 | 24 | " 5 | 8 | " 23 | 19 |
| " 15 | 29 | " 12 | 25 | " 11 | 7 | " 24 | 20 |
| " 17 | 28 | " 18 | 26 | " 13 | 6 | " 26 | 21 |
| " 20 | 27 | Aug. 1 | 26 | " 19 | 5 | " 28 | 22 |
| " 25 | 26 | " 12 | 25 | " 27 | 4 | " 30 | 23 |
| " 28 | 25 | | | | | | |

Co-ordinates of the Ben Nevis Observatory.—Latitude $56^{\circ} 48'$ North ; Longitude $5^{\circ} 0'$ West of Greenwich. Elevation above the sea 4407 feet or 1343 metres.

Time used in the Observatory.—The observations are made at every hour by a clock showing Greenwich mean time. The mountain lies 5° of longitude west of Greenwich, so that the local mean time of Ben Nevis is twenty minutes earlier than mean time at Greenwich. With the varying values of the equation of time the local apparent time varies from 3.5 to 34.5 minutes earlier than Greenwich mean time. In the first of the accompanying tables (printed on the preceding page) is given, for a number of dates, the number of minutes after Greenwich mean noon when it is local apparent noon at Ben Nevis. It will be seen that at the beginning of November the sun crosses the meridian at only 3.5 minutes after noon by the clock ; while at the beginning of February it does not do so till nearly thirty-five minutes after noon by the clock. Between 15th January and 10th March, 1 P.M. is nearer true local noon than 12 o'clock by the clock.

The second table gives the dates of days of lengths differing by half-an-hour, with the number of days elapsed since the vernal equinox.

Both of these tables are useful in interpreting the observations. The first naturally suggests the question whether at first-class observatories the hours of observation should not be regulated by local apparent time, especially when, as at Ben Nevis, hourly eye readings are made. When self-recording instruments are used, it is as easy to

BEN NEVIS.—*Dates when the Length of the Day is an exact number of Half-hours.*

| Days from vernal equinox. | Diff. | Date. | Length of Day. | Date. | Diff. | Days from vernal equinox. |
|---------------------------|-------|----------|-----------------|---------|-------|---------------------------|
| 93 | 23 | June 21 | 17 h. 32 m. | 21 June | | 93 |
| 70 | 9 | May 29 | 17 hrs. | 14 July | 23 | 116 |
| 61 | 8 | " 20 | $16\frac{1}{2}$ | 23 " | 9 | 125 |
| 53 | 7 | " 12 | 16 | 31 " | 8 | 133 |
| 46 | 8 | " 5 | $15\frac{1}{2}$ | 8 Aug. | 8 | 141 |
| 38 | 6 | April 27 | 15 | 15 " | 7 | 148 |
| 32 | 7 | " 21 | $14\frac{1}{2}$ | 21 " | 6 | 154 |
| 25 | 6 | " 14 | 14 | 28 " | 7 | 161 |
| 19 | 6 | " 8 | $13\frac{1}{2}$ | 4 Sept. | 7 | 168 |
| 13 | 7 | " 2 | 13 | 10 " | 6 | 174 |
| 6 | 6 | Mar. 26 | $12\frac{1}{2}$ | 16 " | 6 | 180 |
| 365 | 6 | " 20 | 12 | 23 " | 7 | 187 |
| 359 | 6 | " 14 | $11\frac{1}{2}$ | 29 " | 6 | 193 |
| 353 | 6 | " 8 | 11 | 5 Oct. | 6 | 199 |
| 347 | 7 | " 2 | $10\frac{1}{2}$ | 11 " | 6 | 205 |
| 340 | 6 | Feb. 23 | 10 | 18 " | 7 | 212 |
| 334 | 6 | " 17 | $9\frac{1}{2}$ | 24 " | 6 | 218 |
| 328 | 7 | " 11 | 9 | 30 " | 6 | 224 |
| 321 | 7 | " 4 | $8\frac{1}{2}$ | 6 Nov. | 7 | 231 |
| 314 | 7 | Jan. 28 | 8 | 13 " | 7 | 238 |
| 307 | 9 | " 21 | $7\frac{1}{2}$ | 21 " | 8 | 246 |
| 298 | 22 | " 12 | 7 | 30 " | 9 | 255 |
| 276 | 21 | Dec. 21 | 6 h. 28 m. | 21 Dec. | 21 | 276 |

take off the values for one time as for another. It is certain that it is apparent time and not any conventional time that rules meteorological phenomena.

Winds.—Only the direction of the wind is given in the tables. In foggy weather the prevailing directions are N., N.W., W., and S.W., the greatest percentage being from the West. In clear weather the prevailing directions are N., S.E., and S., with a maximum at S.E., while calms occur very frequently. The cyclonic gales so common on our coasts, especially in winter, blow hardest between S.W. and N.W., and on these occasions the summit is usually enveloped in fog. On the other hand, in anti-cyclonic weather the air has hardly any sensible horizontal motion, and is generally clear and warm.

In the following short table are given the general results of the classification of the winds according to percentage, and distributed over eight points of the compass:—

| Weather. | N. | N.E. | E. | S.E. | S. | S.W. | W. | N.W. | Calm. | |
|-----------|-------|------|-------|-------|-------|-------|-------|-------|-------|-----|
| Clear . . | 17.45 | 6.01 | 11.63 | 18.85 | 16.74 | 8.91 | 6.17 | 3.54 | 10.67 | 100 |
| Foggy . . | 16.88 | 5.28 | 3.63 | 5.64 | 6.95 | 17.82 | 23.72 | 16.65 | 3.43 | 100 |

If the winds were equally distributed round the compass we should have 12.5 per cent. from each point. In clear weather the amounts are above the average for N., S.E. and S.; in foggy weather, they are above the average for S.W., W., N.W. and N.; the maximum falling on W., with 23.72 per cent., and the minimum on E., with 3.63 per cent.

Rainfall.—In continuous foggy weather there is always some precipitation measured, and it is usually very abundant. There is only one spell of foggy weather in which no precipitation was registered, and that was January 1897. In continuous clear (not necessarily cloudless) weather it may be said that it never rains at all. The only exception which could be taken to this might be the cases of June and August. In June, in the 2895 selected hours, the total amount of rain measured was 1.243 ins., giving an average of one hundredth of an inch in twenty-four hours. In August, in the 971 selected hours, 0.72 in. fell, giving an average of 0.018 in. per twenty-four hours. There are only five occasions in the course of the thirteen years when more than one-tenth of an inch of rain fell during the clear weather of any one month, and the chief of these are 0.685 in. in August 1890, and 0.298 and 0.774 in. in June of 1887 and 1893 respectively. Two-thirds of the whole rain fell in these five months, the remaining third is distributed over forty months, and 111 months out of the total of 156 have none at all.

If we now turn to foggy weather, we see a very different state of things. As already pointed out, there is only one spell of foggy weather where no rain or precipitation has been measured. The smallest mean daily rainfall in foggy weather is

0·590 in. in April. The highest daily mean is 1·286 in. in September, and next to it comes February with 1·270 in., and October with 1·163 in. April, May, June, July, and August are all under the mean for the year, which is 0·998 in., or almost exactly one inch. When it is remembered that in foggy weather the air is always saturated, and besides that it has disseminated through it particles of water, which form the fog, on which the vapour can immediately and without resistance condense, and that in summer there is a much larger percentage of water vapour present in the atmosphere than is found in winter, it appears somewhat remarkable that the summer rainfall per foggy day should be so much lower than that of winter. When we turn to the maximum rainfall of any foggy day in each month during the thirteen years, we find these same months below the average again. The absolute maximum for the thirteen years falls on the 3rd October 1890, when 7·287 ins. fell in the twenty-four hours; the next highest value, 6·668 ins., falls on 6th February 1894, and the maximum rainfall on a foggy day is above five inches in December, January, and March. The greatest fall in one hour occurred between fifteen and sixteen hours on 14th January 1890, when 0·850 in. fell.

The following short table puts together concisely the results of the rainfall measurements in the two kinds of weather, and shows clearly the great contrast between them in this respect:—

| Month. | CLEAR WEATHER. | | | FOGGY WEATHER. | | | | | |
|------------------|------------------|--------------------------|-----------------------------|-----------------|--------------------------|------------------------|------------------------------|------------------|-------|
| | Number of Hours. | Total Rainfall in Month. | Mean Rainfall per 24 Hours. | Number of Days. | Total Rainfall in Month. | Mean Rainfall per Day. | Maximum Rainfall in one Day. | Date of Maximum. | |
| | | Inches. | Inch. | | Inches. | Inches. | Inches. | Day. | Year. |
| January, . . . | 606 | 0·004 | 0·00015 | 86 | 93·029 | 1·082 | 5·476 | 29 | '92 |
| February, . . . | 1,158 | ·033 | ·00069 | 54 | 68·587 | 1·270 | 6·668 | 6 | '94 |
| March, . . . | 1,335 | ·003 | ·00005 | 78 | 82·602 | 1·059 | 5·210 | 11 | '90 |
| April, . . . | 1,728 | ·110 | ·00153 | 59 | 34·782 | 0·590 | 2·530 | 22 | '90 |
| May, . . . | 2,228 | ·392 | ·00422 | 27 | 20·555 | 0·761 | 2·880 | 15 | '92 |
| June, . . . | 2,895 | 1·243 | ·01030 | 42 | 32·579 | 0·776 | 2·108 | 16 | '97 |
| July, . . . | 1,502 | 0·169 | ·00270 | 46 | 41·452 | 0·901 | 2·337 | 13 | '90 |
| August, . . . | 971 | ·720 | ·01777 | 58 | 55·852 | 0·963 | 3·483 | 29 | '92 |
| September, . . . | 1,296 | ·046 | ·00085 | 79 | 101·646 | 1·287 | 4·930 | 31 | '91 |
| October, . . . | 951 | ·064 | ·00161 | 64 | 74·438 | 1·163 | 7·287 | 3 | '90 |
| November, . . . | 983 | ·076 | ·00185 | 88 | 91·660 | 1·042 | 4·294 | 28 | '93 |
| December, . . . | 697 | ·000 | ·00000 | 66 | 71·049 | 1·076 | 5·340 | 12 | '85 |
| Sums, . . . | 16,350 | 2·860 | | 747 | 768·231 | | | | |
| Mean, . . . | | | 0·00389 | | | 0·998 | 4·379 | | |

Barometric Pressure.—Next to the rainfall, the most striking difference between clear and foggy weather on Ben Nevis is shown by the large and continuous excess of pressure in clear weather over that in foggy weather. At every hour of the year, without a single exception, the mean monthly pressure is several tenths of

an inch higher in clear than in foggy weather. The maximum excess recorded in the table is 0·602 in. at twenty-one hours in January, and the minimum is 0·296 in. at fourteen hours in February. In the following small table the mean monthly and the mean annual excesses of pressure in clear weather over that in foggy weather are given in the first line, and the difference of the mean monthly excesses from the annual excess are given in the second line.

| Jan. | Feb. | Mar. | April. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Mean. |
|-------|-------|-------|--------|-------|-------|-------|-------|-------|-------|-------|-------|------------|
| 0·570 | 0·320 | 0·501 | 0·353 | 0·372 | 0·390 | 0·414 | 0·433 | 0·519 | 0·550 | 0·537 | 0·513 | 0·456 inch |
| +·114 | -·126 | +·045 | -·103 | -·084 | -·066 | -·042 | -·023 | +·063 | +·094 | +·081 | +·057 | 0·000 |

Roughly speaking, in spring and summer the excess is below the mean, excepting the month of March, and in autumn and winter it is above the mean. The drop from the maximum to the minimum value in one month, from January to February, is very remarkable, but the recovery in March to a much higher value, and indeed to a second maximum, suggests that there are special reasons for this irregularity which may be accidental to the particular years under consideration. It is certainly difficult to imagine, though it is well worth while to try to find out, what conditions vary so much and so rapidly between January and April that the excess of pressure in question should show the variations which we observe in the table.

A general summary of the movements of the barometer during the year is presented in the tables on the following page, in terms of the inch and the millimetre respectively.

Tension of Aqueous Vapour.—In foggy weather the vapour tension is that of saturation at the temperature of the air. As the water particles which form the fog permeate the whole of the air, any addition of heat has the effect of changing into vapour a portion of the fog, and any loss of heat has the opposite effect, of condensing some of the vapour of the air on the water (or ice) of the fog, both being accompanied by a certain exchange of heat. In the clear weather the atmosphere is generally in a state far removed from saturation, and the effect of addition or removal of heat is simply a rise or fall of temperature. In itself the air in clear weather has no means of increasing its supply of water vapour.

The barometric pressure is the measure of the sum of the tensions of the various gaseous constituents of the atmosphere. If this pressure is diminished all the constituents expand proportionately, and their tensions diminish also proportionately. If the pressure is increased they contract in the same proportion, and their tensions increase proportionately.

Therefore the determination of the tension of the aqueous vapour in the atmosphere, combined with that of its barometric pressure, furnishes *an exact analytical method* for the determination of the composition by volume of the air, in respect of water vapour and permanent gas.

METEOROLOGY OF BEN NEVIS IN CLEAR AND FOGGY WEATHER.

Summary.—Barometric Pressure—Inches.

| | n. | Jan. | Feb. | March. | April. | May. | June. | July. | August. | Sept. | Oct. | Nov. | Dec. | Mean. |
|----------------|-------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| Clear Weather. | Absolute maximum, | Inches. 26.005 | Inches. 26.063 | Inches. 25.946 | Inches. 26.003 | Inches. 26.014 | Inches. 25.992 | Inches. 25.929 | Inches. 25.925 | Inches. 25.981 | Inches. 26.047 | Inches. 26.068 | Inches. 25.914 | Inches. 25.991 |
| | Absolute minimum, | 24.791 | 24.686 | 24.324 | 25.072 | 25.115 | 25.179 | 23.217 | 25.231 | 24.979 | 24.937 | 25.003 | 24.798 | 24.946 |
| | Range, | 1.214 | 1.377 | 1.622 | 0.931 | 0.899 | 0.813 | 0.712 | 0.694 | 1.002 | 1.090 | 1.065 | 1.116 | 1.045 |
| | Mean, | 25.618 | 25.532 | 25.472 | 25.536 | 25.659 | 25.657 | 25.628 | 25.660 | 25.712 | 25.670 | 25.663 | 25.536 | 25.612 |
| Foggy Weather. | Absolute maximum, | 25.838 | 25.807 | 25.663 | 25.824 | 25.744 | 25.755 | 25.612 | 25.691 | 25.761 | 25.749 | 25.947 | 25.800 | 25.766 |
| | Absolute minimum, | 24.011 | 23.869 | 23.943 | 24.188 | 24.830 | 24.757 | 24.686 | 24.360 | 24.260 | 24.371 | 24.085 | 23.742 | 24.259 |
| | Range, | 1.827 | 1.938 | 1.720 | 1.636 | 0.914 | 0.998 | 0.926 | 1.331 | 1.501 | 1.378 | 1.862 | 2.058 | 1.507 |
| | Mean, | 25.048 | 25.212 | 24.971 | 25.183 | 25.287 | 25.267 | 25.214 | 25.227 | 25.193 | 25.120 | 25.126 | 25.023 | 25.156 |
| Difference, | 0.570 | 0.320 | 0.501 | 0.353 | 0.372 | 0.390 | 0.414 | 0.483 | 0.519 | 0.550 | 0.537 | 0.513 | 0.456 | |

Summary.—Barometric Pressure—Millimetres.

| | n. | Jan. | Feb. | March. | April. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Mean. |
|----------------|-------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| Clear Weather. | Absolute maximum, | mm. 660.66 | mm. 661.93 | mm. 659.13 | mm. 660.40 | mm. 660.66 | mm. 660.15 | mm. 658.62 | mm. 658.62 | mm. 659.89 | mm. 661.67 | mm. 662.13 | mm. 658.12 | mm. 660.17 |
| | Absolute minimum, | 629.67 | 627.13 | 617.73 | 636.78 | 637.80 | 639.57 | 640.59 | 640.84 | 634.49 | 633.99 | 635.00 | 629.92 | 633.63 |
| | Range, | 30.99 | 34.80 | 41.40 | 23.62 | 22.86 | 20.58 | 18.03 | 17.78 | 25.40 | 27.68 | 27.18 | 28.20 | 26.54 |
| | Mean, | 650.75 | 648.46 | 646.94 | 648.72 | 651.77 | 651.77 | 651.00 | 651.77 | 653.04 | 652.02 | 651.77 | 648.72 | 650.50 |
| Foggy Weather. | Absolute maximum, | 656.34 | 655.58 | 651.77 | 655.83 | 653.80 | 654.31 | 650.50 | 652.53 | 654.31 | 654.05 | 659.13 | 655.32 | 654.46 |
| | Absolute minimum, | 609.86 | 606.30 | 608.08 | 611.89 | 630.68 | 628.91 | 627.13 | 618.75 | 616.21 | 619.00 | 611.89 | 603.00 | 615.98 |
| | Range, | 46.48 | 49.23 | 43.69 | 43.94 | 23.12 | 25.40 | 23.37 | 33.78 | 38.10 | 35.05 | 47.24 | 52.32 | 38.48 |
| | Mean, | 636.27 | 640.34 | 634.24 | 639.57 | 642.37 | 641.86 | 640.34 | 640.84 | 638.83 | 638.05 | 638.30 | 635.51 | 639.07 |
| Difference, | 14.48 | 8.12 | 12.70 | 9.15 | 9.40 | 9.91 | 10.66 | 10.93 | 13.21 | 13.97 | 13.47 | 13.21 | 11.43 | |

Summary.—Tension of Aqueous Vapour in Inches, and Percentage of the same in the Air.

| n. | Jan. | Feb. | March. | April. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Mean. |
|---------------|--|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Clear Weather | Absolute maximum, | 0.217 | 0.197 | 0.207 | 0.272 | 0.456 | 0.374 | 0.424 | 0.367 | 0.289 | 0.264 | 0.257 | 0.305 |
| | Absolute minimum, | 0.020 | 0.012 | 0.007 | 0.021 | 0.048 | 0.087 | 0.093 | 0.072 | 0.038 | 0.016 | 0.010 | 0.037 |
| | Range, (1-2) | 0.197 | 0.185 | 0.200 | 0.251 | 0.408 | 0.287 | 0.331 | 0.295 | 0.251 | 0.248 | 0.247 | 0.268 |
| | Mean, | 0.0892 | 0.0790 | 0.0933 | 0.1230 | 0.1731 | 0.2218 | 0.2365 | 0.2390 | 0.1944 | 0.1395 | 0.1110 | 0.0848 |
| Foggy Weather | Absolute maximum, | 0.221 | 0.223 | 0.274 | 0.214 | 0.265 | 0.335 | 0.348 | 0.374 | 0.348 | 0.265 | 0.238 | 0.286 |
| | Absolute minimum, | 0.077 | 0.030 | 0.078 | 0.091 | 0.113 | 0.160 | 0.171 | 0.136 | 0.113 | 0.091 | 0.071 | 0.106 |
| | Range, (5-6) | 0.144 | 0.193 | 0.196 | 0.123 | 0.152 | 0.180 | 0.177 | 0.238 | 0.235 | 0.174 | 0.167 | 0.180 |
| | Mean, | 0.1364 | 0.1519 | 0.1471 | 0.1555 | 0.1794 | 0.2074 | 0.2239 | 0.2447 | 0.2190 | 0.1975 | 0.1700 | 0.1478 |
| Clear Weather | Difference, (4-8) | —0.0572 | —0.0729 | —0.0538 | —0.0325 | —0.0063 | +0.0126 | —0.0157 | —0.0246 | —0.0580 | —0.0590 | —0.0630 | —0.0346 |
| | Mean Barometric Pressure, | 25.613 | 25.532 | 25.472 | 25.536 | 25.659 | 25.657 | 25.660 | 25.712 | 25.670 | 25.663 | 25.536 | 25.612 |
| Foggy Weather | Mean % of H ₂ O (100 × 4/10), | 0.314 | 0.309 | 0.365 | 0.482 | 0.674 | 0.921 | 0.892 | 0.756 | 0.553 | 0.433 | 0.332 | 0.476 |
| | Mean Barometric Pressure, | 25.048 | 25.212 | 24.971 | 25.183 | 25.287 | 25.267 | 25.227 | 25.193 | 25.120 | 25.126 | 25.023 | 25.156 |
| Clear Weather | Mean % of H ₂ O (100 × 8/12), | 0.583 | 0.600 | 0.589 | 0.675 | 0.710 | 0.888 | 0.970 | 0.868 | 0.785 | 0.675 | 0.590 | 0.725 |
| | Difference, (11-13) | —0.239 | —0.291 | —0.223 | —0.133 | —0.036 | +0.045 | —0.078 | —0.112 | —0.232 | —0.242 | —0.258 | —0.149 |

Summary.—Tension of Aqueous Vapour in Millimetres, and Percentage of the same in the Air.

| n. | Jan. | Feb. | March. | April. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Mean. |
|---------------|--|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Clear Weather | Absolute maximum, | 5.51 | 5.00 | 5.26 | 6.61 | 11.58 | 9.50 | 10.77 | 9.32 | 7.34 | 6.71 | 6.53 | 7.74 |
| | Absolute minimum, | 0.51 | 0.31 | 0.18 | 0.33 | 1.22 | 2.21 | 2.36 | 2.97 | 2.41 | 2.30 | 2.25 | 0.95 |
| | Range, (1-2) | 5.00 | 4.69 | 5.08 | 6.28 | 10.36 | 7.29 | 8.41 | 7.49 | 6.37 | 6.30 | 6.25 | 6.79 |
| | Mean, | 2.26 | 2.01 | 2.36 | 3.12 | 4.39 | 5.64 | 5.99 | 5.82 | 4.93 | 2.82 | 2.16 | 3.76 |
| Foggy Weather | Absolute maximum, | 5.61 | 5.66 | 6.96 | 5.44 | 6.73 | 8.53 | 8.84 | 9.50 | 8.84 | 6.73 | 6.05 | 7.26 |
| | Absolute minimum, | 1.96 | 0.76 | 1.98 | 2.31 | 2.87 | 4.06 | 4.34 | 3.45 | 2.31 | 2.31 | 1.80 | 2.70 |
| | Range, (5-6) | 3.65 | 4.90 | 4.98 | 3.13 | 3.86 | 4.47 | 4.50 | 6.05 | 5.97 | 4.42 | 4.25 | 4.56 |
| | Mean, | 3.71 | 3.86 | 3.73 | 3.94 | 4.55 | 5.26 | 5.69 | 5.56 | 5.03 | 4.32 | 3.76 | 4.65 |
| Clear Weather | Difference, (4-8) | —1.45 | —1.85 | —1.37 | —0.82 | —0.16 | +0.30 | —0.40 | —0.63 | —1.50 | —1.50 | —1.00 | —0.89 |
| | Mean Barometric Pressure, | 650.75 | 648.46 | 646.94 | 648.72 | 651.77 | 651.77 | 651.77 | 653.04 | 652.02 | 651.77 | 648.72 | 650.50 |
| Foggy Weather | Mean % of H ₂ O (100 × 4/10), | 0.344 | 0.309 | 0.366 | 0.482 | 0.674 | 0.921 | 0.892 | 0.756 | 0.553 | 0.433 | 0.332 | 0.576 |
| | Mean Barometric Pressure, | 636.47 | 640.34 | 634.24 | 639.57 | 642.37 | 641.86 | 640.34 | 639.83 | 638.05 | 638.30 | 635.51 | 639.07 |
| Clear Weather | Mean % of H ₂ O (100 × 8/12), | 0.583 | 0.600 | 0.589 | 0.615 | 0.710 | 0.819 | 0.970 | 0.868 | 0.785 | 0.675 | 0.590 | 0.725 |
| | Difference, (11-13) | —0.239 | —0.291 | —0.223 | —0.133 | —0.036 | +0.045 | —0.078 | —0.112 | —0.232 | —0.242 | —0.258 | —0.149 |

Temperature.—The mean temperature of the year is $3\cdot57^{\circ}$ F. higher in clear weather than in foggy weather. Amongst the monthly values this excess is greatest in June, when it reaches $10\cdot11^{\circ}$ F. In the first three months of the year the difference is in the opposite sense. The temperature is then higher in foggy than in clear weather, the excess being $2\cdot92^{\circ}$ F. in February. The mean temperature of the months October to March is almost the same for both kinds of weather, being $28\cdot70^{\circ}$ F. for clear and $28\cdot51^{\circ}$ F. for foggy weather. Amongst the hourly values the greatest excess of temperature in clear over that in foggy weather is $13\cdot4^{\circ}$ F. at fifteen hours in June, and the greatest difference in the opposite sense is $4\cdot3^{\circ}$ F. at one hour in March. The range of mean hourly temperature is much greater in clear than in foggy weather in every month.

In this respect again the difference between clear weather and foggy weather on Ben Nevis is the same in kind as that between the dry season and the rainy season in the Tropics.

In foggy weather the mean daily range of temperature is very small in winter, and by no means large in summer. The maximum mean daily range is $2\cdot5^{\circ}$ F. in May, when the mean monthly temperature is $31\cdot42^{\circ}$ F. The maximum mean monthly temperature, $39\cdot58^{\circ}$ F., falls in August, and then the daily range is only $1\cdot7^{\circ}$ F. In clear weather the maximum mean monthly temperature, $46\cdot46^{\circ}$ F., falls in July, and the maximum mean daily range, $8\cdot2^{\circ}$ F., falls in the same month. In clear weather the effect of adding heat is to raise the temperature of the air and to increase its volume. In foggy weather a large portion of it is rendered latent by the evaporation of a portion of the water in a very fine state of subdivision disseminated through it. It may be doubted whether the direct heat of the sun has any part in producing the diurnal range of temperature during continuous foggy weather. At the upper surface of the fog-cloud we would expect the sun's rays to be largely reflected from the dazzlingly white surface which such a cloud always presents when viewed from above in bright sunshine, and that the remainder would be absorbed in evaporating the upper layer of fog, leaving nothing to be transmitted downwards. There is, as a rule, a resultant current of air upwards during the day; and when the cloud, as is often the case, does not spread to a great distance from the mountain side, the lower ground is enjoying sunshine, and the upward circulation is very active. The fact that the month of May has the greatest amount of clear weather and also the greatest daily range of temperature in foggy weather seems to support this view. In winter the daily range of temperature is under 1° F.

Mean Hourly March of Temperature in each Month.—This is conveniently treated with respect to the hourly change of temperature during the day and without respect to the actual temperatures at these hours.

If we review the curves which have been drawn for each month, and are to be found in the original paper, we see that they fall into two distinct types. The one

type is predominant in the winter months and the other in the summer months. For this purpose the winter months are October to March, and the summer months April to September. The principal feature which distinguishes the winter months from the summer months in clear weather is the occurrence in the former of a *pronounced nocturnal heating effect*. This shows itself particularly in the curves for November, December, January, and February; in October and March the passage between the summer and winter types is apparent.

Confining our attention more especially to the four months about midwinter, we find the abnormal feature referred to very strongly marked in November.

It persists in the month of December, and, apparently, more intensely relatively to the normal solar heating than in November. At the first glance at the curve it would not be thought so, for there is no prominent rise and fall of the curve during the night, as in November. The fall is then just before sunrise, but the minimum and with it the fall and rise between the diurnal and the nocturnal heating is almost obliterated, so that the curve, after rising in the forenoon to the normal maximum in the early afternoon, hardly falls at all, and merges into the nocturnal heating, forming a very flat curve, nearly parallel to the base line.

Nocturnal heating is observed in foggy weather in most of the months, and it takes the form of a sharp rise of temperature between midnight and 1 A.M., which then falls gradually to a minimum at or near the hour of sunrise; but there are exceptions to this, as in November, and particularly in January, when the temperature rises very uniformly from a minimum at midnight to a maximum at noon, and then falls again as uniformly to the midnight minimum again.

It must not be forgotten, in dealing with the winter months at Ben Nevis, that the solar influence is very small. Lying in lat. $56^{\circ}48'$ N. the sun's meridian altitude at the winter solstice is only $9^{\circ}35'$, and the length of the day is under $6\frac{1}{2}$ hours. It is, therefore, chiefly at this season that we might expect terrestrial or geographical influences to produce their most apparent effect. With the march of the season the influence of the sun increases very rapidly, and it has a tendency to obliterate the effects of other agents, especially in the hours of the day when its heating power is increasing or diminishing most rapidly. In the summer months, when the diurnal range of temperature is considerable, it is only in the neighbourhood of the epochs of maximum and of minimum temperature that other influences can make themselves felt. At these times, and especially at the time of maximum temperature, the heating and cooling influences are for a time in a condition approaching equilibrium, during which the temperature remains nearly constant, and its curve runs sensibly parallel to the line of time-abscissæ. Here we might expect other influences to show themselves; and, in fact, if we inspect the curves, especially those relating to clear weather, we see that most of them show great irregularities in the neighbourhood of the extremes. Nearly all the clear weather curves have strongly-marked irregularities near the date of minimum temperature, and most of them, as February, March, August, and October, show similar irregularities near

the date of maximum. In foggy weather the hour to hour irregularities of mean temperature are, as might be expected, much less striking, with, however, the exception of the month October, when we have a very remarkable oscillation of temperature from hour to hour during the whole morning. If we were to calculate the mean temperature of the morning from the odd hours, 1, 3, 5 11, we should find it quite half a degree lower than if we used the even hours, 2, 4 12. One reason for the greater uniformity of the temperature curves in foggy weather than in clear weather is that there are no effects of alternating cloud and sunshine. In clear weather we have these effects, and to some extent they must be held responsible for the irregularities apparent. This, however, applies only to the daylight hours, and we see that the irregularities in clear weather are by no means confined to these hours.

In dealing with the barometric pressure we have found something very similar to what we have just noticed in regard to temperature, namely, that the curves for foggy weather are much smoother and more uniform than those for clear weather, and the clear weather barometric curves present nearly as irregular and serrated an outline as those of temperature.

The Table on page 14 gives a summary for the year of the movements of temperature. The mean dew-point for each month is given for clear weather, and the excess over it of the mean monthly temperature in foggy weather is given. It is only in June and July that the mean temperature of the air in foggy weather is under the mean dew-point in clear weather. As the air is always completely saturated in foggy weather on Ben Nevis, the temperature of the air is also its dew-point.

In this paper, no distinction is made between one kind of fog and another, and they are not distinguished in the monthly sheets of the Observatory. There are, however, several different kinds of fog, and these are clearly distinguished by the observers living on the mountain. There is the very wet fog, which is called *mist* in the log, and there is the comparatively dry fog, which is logged *fog*. Then both the fog and mist in winter seem to be much denser than in summer. These belong to the elements of meteorology which cannot be expressed in numbers. They are as important as those which can be so expressed; and they can be brought into the discussion of the meteorology of the mountain with their due weight and importance only by men who have spent a considerable time there as observers. Whether wet or dry, the fog which characterises the climate of the mountain is nothing but *cloud* under another name. The lower surface of the clouds which form on the hills rising out of the Western Ocean is found generally at a height of about three thousand feet above the sea. On the west coast of Scotland the air is very damp, and the clouds abundant, consequently the observatory on the summit of Ben Nevis is usually situated in the heart of the common clouds of the country. It may, therefore, be claimed that it is in reality an observatory established in the clouds, and that the observations made in it furnish a record of the meteorology of the clouds. In this respect the Observatory of Ben Nevis is unique.