

that the rule of pressure varying as the square of the velocity might be trusted to hold for the whole range of possible wind velocities, excepting perhaps for the very lowest. Mr. Ellis had referred to the momentum of pressure plates. He believed that the high pressures recorded were mostly due to the momentum of the moving parts carrying the index beyond its proper position; and Mr. Ellis's remarks about the Greenwich anemometer had confirmed his belief. Mr. Strachan had remarked that the subject of wind pressure generally was one of mechanics, and no doubt it was so. This special branch of mechanics, however, viz. hydro-dynamics, was so difficult, and the mathematical analysis required so complicated and abstruse, that personally he could not attempt to approach the subject from that side, and he believed that it was only in a few limited cases that a rigorous mathematical solution could be obtained.

In conclusion, he should like to say that he thought the tube form of anemometer a very good one indeed, but there were two points about it which must not be overlooked. It was essentially a pressure and not a velocity instrument, and its indications of velocity would certainly depend upon the density of the air. Secondly, if the registering part be placed away from the head, as must generally be the case, the communication must be made by means of two tubes, in such a manner that the actual pressure of air in the room in which the registering part is placed cannot affect the instrument. Otherwise, the opening of a door or window, or even stirring up the fire and increasing the draught up the chimney, would appear on the record as a change of wind velocity.

On the Difference produced in the Mean Temperature derived from Daily Maximum and Minimum Readings, as depending on the time at which the Thermometers are read.

By WILLIAM ELLIS, F.R.A.S., of the Royal Observatory, Greenwich.

[Received May 17th.—Read June 18th, 1890.]

THE maximum and minimum readings of air temperature which appear in the *Greenwich Observations* are those of the maximum and minimum thermometers on the revolving stand, and refer to the civil day from midnight to midnight. When the Greenwich maximum and minimum temperatures were first communicated to the Royal Meteorological Society for insertion in the *Meteorological Record*, in the table giving results for London stations, they were supplied as thus tabulated for the Greenwich volume, and as indeed previously also appearing in the *Weekly Return* of the Registrar General. But on this arrangement, the separate daily readings were not comparable with those of the other London stations, since the latter were tabulated according to the plan adopted by the Society for stations termed "Climatological." In consequence of which the Greenwich values, since the beginning of the year 1886, have, at the request of the Society, been supplied according to the climatological plan, that is to say the reading of the

maximum thermometer for the twenty-four hours ending 9h. a.m. is entered to the preceding civil day, and the reading of the minimum to the same civil day.

Without consideration of the matter it might be supposed that, with values tabulated according to the two methods described, the monthly means of the maximum and minimum readings would, on the average, be similar on both systems. But on making the necessary comparison, a perceptible difference, almost always in the same direction, was found to exist, not only between the means of the maximum readings, but also between the means of the minimum readings. This, it appeared to me, might have sufficient interest for the Fellows of the Royal Meteorological Society to make it desirable to communicate to the Society the results of a comparison made for the four years 1886 to 1889. The differences found to exist between the two sets of means are given in Table I., from which Table II. is formed showing the differences in the mean temperature of the different months thereby produced, as derived from the mean of the maximum and minimum readings.

It will, of course, be understood that the differences given in the Tables are differences of indication of the same maximum and the same minimum thermometer (those of the revolving stand) arising simply from difference in the method of tabulation.

TABLE I.

Month.	Excess of Climatological Maximum above Civil Day Maximum.					Excess of Climatological Minimum above Civil Day Minimum.				
	1886.	1887.	1888.	1889.	Mean.	1886.	1887.	1888.	1889.	Mean.
January ..	+0 ^o 2	+0 ^o 2	+0 ^o 4	0 ^o	+0 ^o 20	+0 ^o 3	-0 ^o 5	-0 ^o 5	-0 ^o 4	-0 ^o 27
February ..	0 ^o	+0 ^o 1	0 ^o	+0 ^o 1	+0 ^o 05	-0 ^o 1	+0 ^o 3	+0 ^o 3	0 ^o	+0 ^o 13
March	0 ^o	+0 ^o 2	+0 ^o 4	0 ^o	+0 ^o 15	+0 ^o 3	+0 ^o 5	+0 ^o 5	+0 ^o 1	+0 ^o 35
April	+0 ^o 3	0 ^o	+0 ^o 2	+0 ^o 1	+0 ^o 15	+0 ^o 8	+0 ^o 4	+0 ^o 3	+0 ^o 3	+0 ^o 45
May	+0 ^o 2	+0 ^o 2	+0 ^o 2	0 ^o	+0 ^o 15	+0 ^o 7	+0 ^o 5	+0 ^o 7	+0 ^o 5	+0 ^o 60
June	+0 ^o 1	+0 ^o 2	0 ^o	+0 ^o 3	+0 ^o 15	+0 ^o 4	+0 ^o 5	+0 ^o 1	+0 ^o 3	+0 ^o 33
July	+0 ^o 3	0 ^o	+0 ^o 7	+0 ^o 1	+0 ^o 27	+0 ^o 6	+0 ^o 5	0 ^o	+0 ^o 3	+0 ^o 35
August	0 ^o	0 ^o	+0 ^o 3	0 ^o	+0 ^o 08	+0 ^o 5	+0 ^o 2	+0 ^o 9	+0 ^o 5	+0 ^o 52
September	+0 ^o 1	0 ^o	-0 ^o 1	0 ^o	0 ^o 00	+1 ^o 6	+0 ^o 7	+1 ^o 0	+0 ^o 9	+1 ^o 05
October	0 ^o	0 ^o	0 ^o	0 ^o	0 ^o 00	+0 ^o 6	+0 ^o 3	+0 ^o 3	+0 ^o 5	+0 ^o 42
November ..	+0 ^o 1	+0 ^o 4	-0 ^o 2	-0 ^o 1	+0 ^o 05	+0 ^o 2	+0 ^o 5	+0 ^o 4	+0 ^o 4	+0 ^o 38
December ..	+0 ^o 1	+0 ^o 3	+0 ^o 4	+0 ^o 8	+0 ^o 40	-0 ^o 1	-0 ^o 3	+0 ^o 3	-0 ^o 1	-0 ^o 05
Means	+0 ^o 12	+0 ^o 13	+0 ^o 19	+0 ^o 11	+0 ^o 14	+0 ^o 48	+0 ^o 30	+0 ^o 36	+0 ^o 28	+0 ^o 36

Examining the various columns of Table I. it is seen how persistent is the tendency to difference in one direction. Especially is this so as regards the means of the minimum readings, which not only differ more than do those of the maximum readings, but differ also by amounts that vary considerably with the time of year, being apparently greatest in spring and autumn, less in summer, and least, being indeed reversed in direction, in winter. The difference between the means of the minimum readings in the month of September is especially remarkable, particularly in the year 1886. In explanation of these differences

TABLE II.

Month.	Excess of Climatological Monthly Mean Temperature above Civil Day Monthly Mean Temperature.				
	1886.	1887.	1888.	1889.	Mean.
January	+0 ^o .25	-0 ^o .15	-0 ^o .05	-0 ^o .20	-0 ^o .04
February	-0 ^o .05	+0 ^o .20	+0 ^o .15	+0 ^o .05	+0 ^o .09
March	+0 ^o .15	+0 ^o .35	+0 ^o .45	+0 ^o .05	+0 ^o .25
April	+0 ^o .55	+0 ^o .20	+0 ^o .25	+0 ^o .20	+0 ^o .30
May	+0 ^o .45	+0 ^o .35	+0 ^o .45	+0 ^o .25	+0 ^o .37
June	+0 ^o .25	+0 ^o .35	+0 ^o .05	+0 ^o .30	+0 ^o .24
July	+0 ^o .45	+0 ^o .25	+0 ^o .35	+0 ^o .20	+0 ^o .31
August	+0 ^o .25	+0 ^o .10	+0 ^o .60	+0 ^o .25	+0 ^o .30
September	+0 ^o .85	+0 ^o .35	+0 ^o .45	+0 ^o .45	+0 ^o .52
October	+0 ^o .30	+0 ^o .15	+0 ^o .15	+0 ^o .25	+0 ^o .21
November	+0 ^o .15	+0 ^o .45	+0 ^o .10	+0 ^o .15	+0 ^o .21
December	0 ^o .00	0 ^o .00	+0 ^o .35	+0 ^o .35	+0 ^o .18
Means	+0 ^o .30	+0 ^o .22	+0 ^o .27	+0 ^o .19	+0 ^o .25

it is to be remembered, first as regards the maximum, that the daily reading for the twenty-four hours ending 9h. a.m. being, according to the climatological plan, placed to the preceding civil day, if the temperature between midnight and 9h. a.m. should in any case be higher than that for the twenty-four hours ending with midnight, the recorded climatological maximum will be higher than that for the civil day ending at midnight, and a few instances of this kind occurring during a month tend to throw up the climatological mean as compared with the civil day mean. On the other hand, as regards the minimum, if the temperature between 9h. a.m. and midnight should fall below that for the twenty-four hours ending with 9h. a.m., the minimum recorded for the civil day will be lower than that recorded on the same day on the climatological plan, and this occurring occasionally during a month tends to make the climatological mean again relatively high. So that the climatological mean maximum and minimum both become increased as compared with those given by tabulation according to the civil day. Or the mean temperature as derived from the mean of the maximum and minimum readings differs, according to the system of tabulation employed, in the way shown in Table II.

There is a converse case, both as regards maximum and minimum, not apparently occurring so frequently as the cases before mentioned, excepting in winter, and consequently generally insufficient to compensate for their influence on the mean values. For instance, the temperature may happen to be higher between midnight and 9h. a.m. than at any time during the twenty-four hours ending with the following 9h. a.m., in which case the civil day maximum would be the higher of the two. Or the temperature may be lower between 9h. a.m. and midnight than during the twenty-four hours ending with the following midnight, in which case the climatological minimum will be the lower of the two.

The anomalies mentioned arise only when the diurnal variation of

temperature is abnormal. When the daily maximum occurs at the ordinary time, in early afternoon, and the minimum shortly before sunrise, the maxima and minima, on both the systems of tabulation mentioned, would, in the absence of great fluctuations of temperature from day to day, be in this country generally similar. The cases of abnormal change first mentioned are those that more frequently occur, excepting in winter, whilst those afterwards spoken of are more especially prevalent in winter.

As respects the great difference between the means of the minimum readings in September 1886, I have gone over the numbers again, and find the difference to be really correct, and due to the instances in which the temperature before midnight fell below that of the preceding night. On one day especially, September 10th, the minimum for the twenty-four hours ending 9h. a.m. was $61^{\circ}1$, the climatological minimum for the day, but before the midnight following the temperature fell to $46^{\circ}0$, which was the minimum for the day according to civil reckoning. Thus $0^{\circ}5$ of the difference ($1^{\circ}6$) between the monthly means was produced by this one case.

It may be further pointed out, as concerns the variation between the means of the minimum readings during the course of the year (last column of Table I.) that the greatest differences occur at those periods of the year which, on the average, are most free from cloud, spring and autumn, whilst the negative differences are found during the most cloudy period, that of winter.

The tabulation of the maximum and minimum readings according to the plan adopted for Second Order stations, by which the maximum and minimum readings for the twenty-four hours ending 9h. p.m. are placed to the day of reading, seems likely to give mean values more in accordance with those found from tabulation according to the civil day, but I am not at present prepared to offer any evidence on this point.

ADDENDUM.

Reference is made in the preceding paper to the system of registering the maximum and minimum temperature adopted for stations of the Second Order (according to which they are tabulated for the twenty-four hours ending 9h. p.m.) as likely to give means more in accordance with those found from values referring to the civil day, but no evidence on the point is given. It however happens that the observations of the thermometers in a Stevenson screen and on the roof of the Magnet House at the Royal Observatory are recorded on the Second Order station plan, and as their daily readings have been compared with the corresponding readings of the ordinary maximum and minimum thermometers on the revolving stand, the monthly means of the observed differences, if applied to the monthly means of the Stevenson screen and roof thermometers, enable us to infer therefrom the monthly means of the ordinary maximum and minimum thermometers on the revolving stand according to the Second Order station system, and so

compare them with means of readings of the same thermometers applying to the civil day, midnight to midnight. In these results Sundays are omitted, the Stevenson screen and the roof thermometers not being read on Sundays, but as the question is one of differences, this does not signify, so long as the same days are used in all cases. Such results are available for the years 1886, 1887, and 1888, but not for 1889, the discussion of the work for that year not being yet complete. By the process described, apparently involved, but under the circumstances really saving labour, it will be seen that in the annexed tables we have, as before, simply differences of indication of the same maximum thermometer and the same minimum thermometer (those of the revolving stand) as depending entirely on the method of tabulation.

TABLE III.

Month.	Excess of Second Order Maximum above Civil Day Maximum.				Excess of Second Order Minimum above Civil Day Minimum.			
	1886.	1887.	1888.	Mean.	1886.	1887.	1888.	Mean.
January	+0.1	+0.2	+0.2	+0.17	+0.2	0.0	-0.2	0.00
February	-0.1	0.0	+0.2	+0.03	+0.1	+0.75	+0.35	+0.40
March	-0.1	-0.05	+0.25	+0.03	0.0	+0.3	+0.1	+0.13
April	-0.1	+0.15	0.0	+0.02	+0.3	+0.3	+0.3	+0.30
May	+0.1	0.0	+0.1	+0.07	+0.5	+0.65	+0.5	+0.55
June	+0.1	+0.05	0.0	+0.05	+0.5	+0.55	+0.1	+0.38
July	0.0	0.0	+0.05	+0.02	+0.4	+0.5	+0.2	+0.37
August	0.0	+0.05	0.0	+0.02	+0.5	0.0	+0.6	+0.37
September	0.0	0.0	0.0	0.00	+0.7	+0.6	+0.4	+0.57
October	+0.1	+0.05	0.0	+0.05	+0.1	+0.3	+0.25	+0.22
November	+0.1	+0.2	+0.2	+0.17	0.0	+0.15	+0.3	+0.15
December	+0.3	+0.45	+0.1	+0.28	-0.6	+0.2	+0.1	-0.10
Means	+0.04	+0.09	+0.09	+0.08	+0.22	+0.36	+0.25	+0.28

ROYAL OBSERVATORY, GREENWICH.

Excess of Values of Climatological Maximum, Minimum and Mean Temperature, above the corresponding Civil Day values, 1886 to 1889.

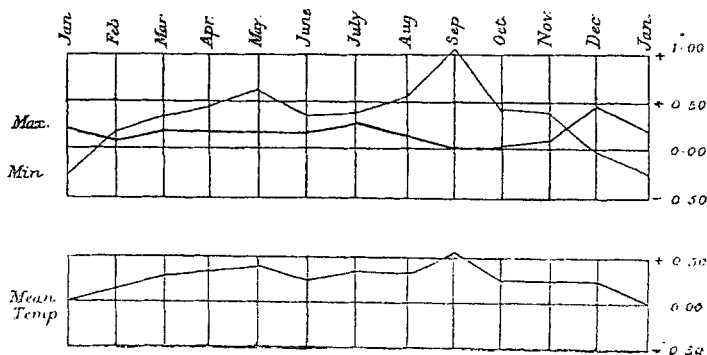


FIG. 1.

TABLE IV.

Month.	Excess of Second Order Monthly Mean Temperature above Civil Day Monthly Mean Temperature.			
	1886.	1887.	1888.	Mean.
January	+0 ^o .15	+0 ^o .10	0 ^o .00	+0 ^o .08
February	0 ^o .00	+0 ^o .38	+0 ^o .28	+0 ^o .22
March	-0 ^o .05	+0 ^o .12	+0 ^o .17	+0 ^o .08
April	+0 ^o .10	+0 ^o .23	+0 ^o .15	+0 ^o .16
May	+0 ^o .30	+0 ^o .32	+0 ^o .30	+0 ^o .31
June	+0 ^o .30	+0 ^o .30	+0 ^o .05	+0 ^o .22
July	+0 ^o .20	+0 ^o .25	+0 ^o .12	+0 ^o .19
August	+0 ^o .25	+0 ^o .02	+0 ^o .30	+0 ^o .19
September	+0 ^o .35	+0 ^o .30	+0 ^o .20	+0 ^o .28
October	+0 ^o .10	+0 ^o .18	+0 ^o .13	+0 ^o .14
November	+0 ^o .05	+0 ^o .17	+0 ^o .25	+0 ^o .16
December	-0 ^o .15	+0 ^o .33	+0 ^o .10	+0 ^o .09
Means	+0 ^o .13	+0 ^o .23	+0 ^o .17	+0 ^o .18

ROYAL OBSERVATORY, GREENWICH.

Excess of Values of Second Order Maximum, Minimum and Mean Temperature, above the corresponding Civil Day values, 1886 to 1888.

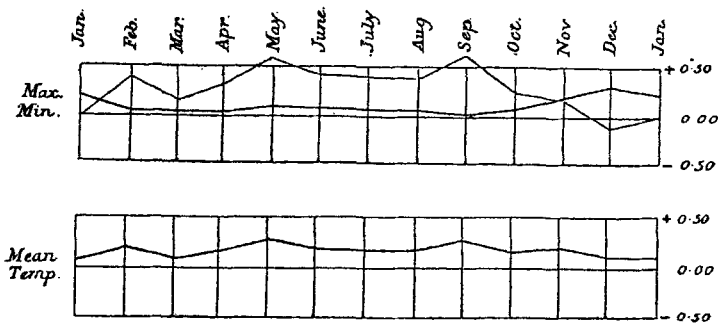


FIG. 2.

It thus appears that the differences between the Second Order system means and the civil day means are of the same general character as in the comparison given in the paper between the Climatological means and the civil day means, but are less in amount. There is not, however, such marked variation between the means of the minimum readings in different parts of the year as is shown in the comparison with the Climatological means.

The mean monthly numbers of Tables I., II., III., and IV., are graphically exhibited in the accompanying diagrams (Figs. 1 and 2).

DISCUSSION.

The PRESIDENT (Mr. Latham) asked if the same instruments were used for all the observations.

Mr. BAYARD said that he was much interested in these comparisons. He had thought, when the question of the difference between the Climatological and Second Order observations had occurred to him, that it would be very slight, and certainly Mr. Ellis's results showed that the variation was not greater than might be due to what was termed 'personal equation.' Very few observers would agree precisely when reading the same thermometer to tenths of a degree.

Mr. O. HARDING inquired whether Mr. Ellis could give any idea of the number of occurrences of abnormal variations between the climatological and civil day maximum and minimum temperatures. He was surprised that the difference between the means was not greater, for he had found when using the Greenwich climatological temperatures, that they frequently differed considerably from the civil day values.

Mr. MARRIOTT said that he was very pleased indeed that Mr. Ellis had taken up this subject, because it bore so closely on the system of observations organised by the Society. The table of differences between the Second Order and Climatological temperatures was very striking, and he was glad to see that there was such close agreement. He then proceeded to explain on the blackboard the principles upon which the Climatological and Second Order Observations were made, and showed how abnormal variations in temperature produced the differences between the maxima and minima observed under the conditions of the two methods.

Mr. SYMONS said that as it was only the civil day readings that differed so largely from the climatological readings, the results of this paper seemed to point to the desirability of the Greenwich Observatory authorities adopting the ordinary meteorological day, either ending at 9 a.m. or 9 p.m.

Dr. TRIPE said that there was every reason to be satisfied with the results of this comparison. The system of Climatological stations organised by the Society was chiefly arranged to suit the convenience of a large number of observers who found it impracticable to take regular evening observations, and the close agreement between the results of observations made by the same instruments on this plan and of those made under Second Order conditions, proved the wisdom of the course taken in establishing these Climatological stations on their present basis. He should have expected more *plus* signs during February than were shown in Mr. Ellis's tables, as a rise in the temperature during the night is a rather common occurrence in this month.

Mr. ELLIS in reply said that the maximum and minimum thermometers on the revolving stand, in the Stevenson screen, and on the roof of the Magnet House, are really different instruments, but it would be seen that it was not the indications of these different instruments that come into comparison in the paper, the results given being simply differences of the means of readings of the maximum and minimum thermometers on the revolving stand, as depending on the method of tabulation: they were therefore strictly comparable. The differences are not in general large, but they are real, and not of the character of personal equation. As regards the number of times that the daily maximum and minimum readings, taken according to the climatological plan, differ from the readings on the civil day system, the numbers for the year 1886 have been counted, with the following result:—

Month.	Maximum differs on	Minimum differs on	Month.	Maximum differs on	Minimum differs on
January ...	8 days.	18 days.	July ...	3 days.	7 days.
February ...	4 "	7 "	August ...	1 "	8 "
March ...	1 "	11 "	September ...	1 "	16 "
April ...	5 "	10 "	October ...	3 "	10 "
May ...	3 "	8 "	November ...	6 "	13 "
June ...	3 "	10 "	December ...	11 "	20 "

Monthly mean temperatures (mean of maximum and minimum) on the climatological plan may be considered to be practically similar to means on the Second Order system. But both differ from the civil day means. Since, how-

ever, it has been authoritatively laid down that, at primary stations, maximum and minimum readings should be tabulated according to the civil day, ending with midnight, we cannot, as suggested, give up the civil day arrangement, although if thought desirable the monthly means of readings might be given in addition, according to the Second Order system and Climatological plan.

On the distribution of Barometric Pressure at the average level of the Hill Stations in India, and its probable effect on the Rainfall of the Cold Weather.

By W. L. DALLAS, of the Meteorological Office, Calcutta.

(Communicated by R. H. SCOTT, F.R.S.)

(Abstract.)

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THE author shows, by a comparison of the cold weather rainfall of India in January 1889 and January 1890, that whereas the former was in excess of the average over the greater part of North-western India and in Ceylon, the latter was very deficient in both quarters. On comparing the mean distribution of pressure in the two months as shown by stations on the plains, he finds that their main features are very similar, except that the general pressure was lower in the latter and drier year. In both years it was such as to produce a preponderance of anticyclonic winds. When, however, he compares the pressures at the hill stations (at elevations varying between 3,500 and 7,500 ft.) he finds that these afford evidence of baric gradients of very different intensities in the two years, and reversed in direction from those on the plains. According to the method of reduction adopted by the author, the gradients in January 1889 appear to be about double those prevailing in January 1890, and to this circumstance he attributes the greater prevalence of Southerly winds and rainfall in January 1889.

He also compares the barometric conditions, winds and rainfall of two storms that passed across Northern India in February 1889 and February 1890, and finds that at low levels their barometric features were remarkably alike, the rainfall being much heavier at the hill stations, while none fell in the Southern Punjab in the storm of the latter year, whereas in that of the former year it was more general on the plains. But in the barometric readings of the hill stations, he finds evidence of a very different distribution of pressure, and he considers that herein lay the explanation of the differences in the rainfall.