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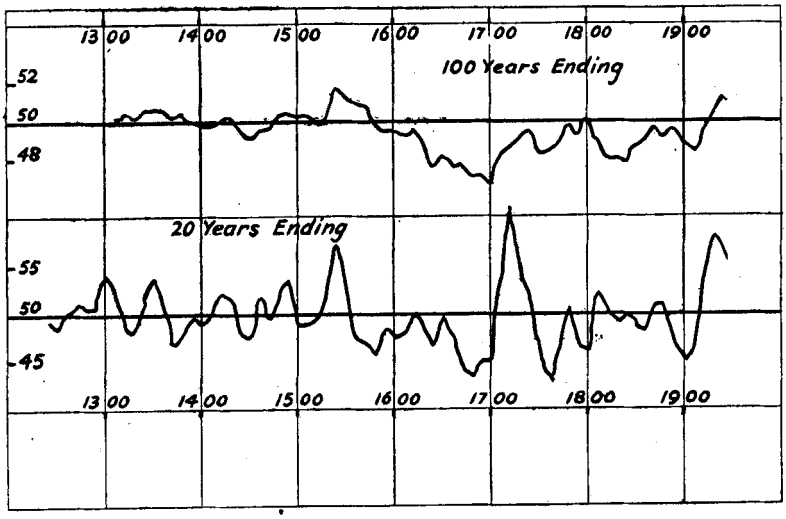
VARIATIONS OF WINTER TEMPERATURE DURING EIGHT CENTURIES

By G. S. CALLENDAR.

On account of the interest shown in this subject during the discussion of Drummond's (1943) paper on the variations of winter temperature at Kew, I thought it would be worth while to re-examine the changes shown by Easton's (1928) coefficients of winter temperature in France over a period of eight centuries.

Easton's values are, of course, well known, so that only a very brief reference to the method he used is required here. In order to obtain comparative figures for winter temperature he assigned the value of 50 to a normal winter, giving lower or higher values in accordance with the available information about the character of each season; thus, for a very cold winter, such as 1891, he gives a coefficient of 8, whereas, in the case of 1869, an exceptionally mild winter, he gives a coefficient of 79.



Easton's coefficients of winter temperature.

Easton has not, so far as I am aware, published any values of later date than the winter of 1915-16, but a comparison between the period means of his coefficients and the winter temperature at Oxford (Lewis, 1937) since 1815, shows that quite good agreement is obtained by simply adding 50 to the Oxford deviations when the latter are expressed in tenths of a degree centigrade. In this way Easton's coefficient can be continued to the latest date with a reasonable degree of homogeneity.

The accompanying figure shows the 100 year and 20 year moving averages of these coefficients over a period of eight cen-

turies. Owing to the smallness of the time scale values have been plotted at intervals of ten years instead of each year, but this makes no appreciable difference to the general run of the curves.

It is evident that a detailed discussion of these curves, especially that for the 20 year averages, would occupy a number of pages, and as such would require a critical analysis of the methods and sources used by Easton to obtain his coefficients. Those interested are referred to Easton's original publications, and also to an article in *La Météorologie* for 1928. There are, however, some further points concerning these variations of winter temperature which I have not seen referred to in connexion with them. These points are briefly discussed in the following notes.

1. The fluctuations shown by the 20-year curve of winter temperature might be assumed to represent either; (*a*) The frequency with which the continental high-pressure system extends westwards of its average position, thus giving cold winters in west Europe, or, (*b*) the intensity and position of the North Atlantic low-pressure system, which, extending further to the north-east than usual, gives mild westerly winds in Europe. Winds from the Greenland area also may be important if their frequency varies in different periods, but they do not, as a rule, dominate the character of the winter season to anything like the same extent, as the two influences mentioned in (*a*) and (*b*).

2. By far the most striking features of the 20 year curve are the three peaks around 1535, 1715 and 1925, denoting periods of some 20 to 30 years of persistently mild winters. It may be assumed that the factors which have brought about these remarkable mild periods are of the exceedingly complex nature which is associated with many meteorological problems. For example, on first thoughts one might expect such periods to be due to an unusual accumulation of warm water in the Norwegian sea, for this should draw the Atlantic low pressure system further north-east than usual. When, however, we turn to the actual observations covering the recent period of mild winters, it is at once seen that this simple explanation is hopelessly inadequate, for right in the middle of the period, from about 1915 to 1919, both the air and water temperatures in the Norwegian sea were decidedly below average, and it was only after the period had passed its climax, in the 1930's, that abnormally warm water was found in the northern seas. Thus we find that the supposed cause becomes instead a result of the process, making still another of those remarkable paradoxes for which meteorology is famous.

That these events are in reality associated with changes in the general circulation of the atmosphere is shown by the occurrence of persistently mild winters over a great part of the North American continent at about the same period as in Europe. For example, the winter temperature curve for Bismarck, in the heart of North America, has almost the same form as that for Oxford, although the variations at the former station have been about twice as great as in England. Until we know much more about the radiative exchanges of the atmosphere, it might be unprofitable to carry the discussion beyond this point.

3. The 100 year curve shows that the average winter temperature probably was higher up to about the middle of the 16th century than it has been over most of the subsequent period. During the following 150 years it was particularly low, and again low after the mild winters of the early 18th century. The coldest 30 year period was from 1657 to 1686, coefficient 42.4, and this was soon followed by the mildest 30 years, from 1699 to 1728, coefficient 58.0. For the recent mild period 1910 to 1939, the coefficient was 56.7, but the basis is slightly different. The coldest individual winters are given as 1408, 1565, 1608, 1709 and 1830, all with coefficient of 4.

4. Matthes (1942) has called the period of three centuries from about the middle of the 16th century to the middle of the 19th century " the little ice age " owing to the advanced position of the glaciers during much of this time. It would appear from the 100 year curve of winter temperature that, over long periods, the winters tend to be colder when the glaciers are in an advanced stage; this perhaps might be expected, although the winter temperature probably is the least important of the seasonal values so far as the glacial régime is concerned.

When mild winters with heavy precipitation accompany cool summers, as occurred during most of the second and third decades of the present century, the conditions may be favourable to the advance of the glaciers, for example, in Scandinavia in the early 1920's, and in the Alps during the second decade (Callendar, 1942). Again referring back to the mild winters of the early 18th century, we learn from Eythorsson (1935) that the glaciers of north-west Iceland were very advanced about 1710, and for the Alps Matthes (1942) says that the Grindelwald glaciers advanced rapidly in 1719. Thus it will be seen that the 20-year curve of winter temperature is a very poor guide to the more fundamental climatic changes represented by widespread variation of glaciers. It should be noted, however, that towards the end of the recent series of mild winters (assuming for the moment that the cold winters of 1940-42 brought this phase to a close), there has occurred a period of warm summers both in America and Europe accompanied by a remarkably widespread and rapid retreat of glaciers.

There is little evidence that the 18th century mild winters were followed by glacial recession comparable with that of the 1930's, although it must be admitted that historical evidence of glacial retreat is extremely scanty; it nearly always happens that only the destructive or unusual advances are recorded.

5. Owing to the great similarity both in intensity and duration of the 18th and 20th century periods of mild winters it would be of considerable interest at the present time if we could draw an analogy between the changes following the former period and those we may expect during the next few decades.

It is known that the Norwegian glaciers reached their maximum development in historical times during the 1740's, that is about 10 years after the close of the mild series of winters, when they were

up to 3 km. in advance of their present positions. Also it is known that the Icelandic glaciers were at least equal to their maximum size about 1750. If these events are to repeat themselves in the 20th century we might expect a catastrophic advance of glaciers during the next 15 years or so, but, as remarked in the previous section, there is virtually no evidence that glacial conditions in the 1720's were comparable with the recessive stage of the 1930's.

As regards cold winters both the 15th and 18th century mild periods were followed by an unusual number of them during the succeeding 30 or 40 years and perhaps we may expect a number of very severe winters in the next three or four decades.

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Ordinary Meeting, May 17, 1944

The election of the following candidates was confirmed :—

FELLOWS

DAVID ERIC ADAMS, 24, Whiteheath Road, Blackheath, Birmingham.

SYDNEY WALTER BANNISTER, 18, Luxfield Road, Warminster, Wilts.

FRANK WILLIAM BAYLEY, 39, Broughton Road, West Ealing, London, W.13.

BRIAN FRANCIS BULMER, M.A., B.Sc., 40, Mount Park Road, Eastcote, Pinner, Middlesex.

JACK ALFRED BUSH, c/o 2, Kashmir Road, London, S.E.7.

NORMAN EDRIC CHITTENDEN, 92, Kingsmead Avenue, Worcester Park, Surrey.

C. COLLINS, No. 3 M.E. Meteorological Unit, R.A.F., Middle East.

ANDREW CRANSTON, c/o R.A.A.F., Base Post Office, London.

FREDERICK WILMOT MIDDLEMIST DOWNER, S.A.A.F., c/o South Africa House, Trafalgar Square, London, W.C.2.

ROBERT SIDNEY JAMES EDWARDS, " Casa Rustica," Commercial Road, Woking, Surrey.

G. E. EMERSON, Mount Hope, Hamilton, Ontario, Canada.

ALLAN EVANS, 43, Grangepark Road, Blackley, Manchester, 9.

NORMAN BRUNEL EVERSHED, 61, Bushmore Road, Birmingham, 28.

HAROLD THOMAS STONE GALPIN, 74, George Frederick Road, Sutton Coldfield, Warwickshire.

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N. H. GODWOOD, R.N. Air Station, Arbroath, Angus, Scotland.

GEORGE GRAY, B.Sc., " Dreva," 7, Belstane Road, Carluke, Lanarkshire.

ALAN CLEMENT GREENWOOD, c/o R.A.A.F., Base Post Office, London.