SOME VARIATIONS IN EUROPEAN CLIMATIC TEMPERATURE

By Richard Fay

United States Weather Bureau

(Manuscript received 25 January 1958)

ABSTRACT

An attempt is made to depict mean circulation patterns associated with observed-temperature climate changes in northwest Europe during the period 1780–1930. Use is made of observed pressure gradients associated with warm and cold seasons and of computed annual wind directions at several stations. Results are presented as possible winter and summer mean circulation patterns at 30-yr intervals.

1. Introduction

The climatic warming which has been so pronounced in northern Europe has received considerable study. The question arises as to how long this has been going on and how widespread it is. From indirect data such as tree rings, glaciers, *etc.*, Ahlmann (1949) has concluded that a cooling tendency started in about 1300 AD and that this tendency reversed about 1800-1850. Willett (1950) has shown that during the last century there has been cooling in northern North America and southwestern Asia as opposed to warming elsewhere in northern latitudes. Direct evidence of climatic temperature change extending back for more than a century is, with one or two exceptions, available only from the European area.

Studies of British records by Brooks (1935) indicate an increasingly maritime climate there since 1871. Data from Lancashire, England (Manley, 1946) since 1753 show that temperatures there have been rising since 1771-1780 and that the rise is primarily due to rises during January with no noticeable trends in other months. The recent warming in Iceland (Eythorson, 1949), Sweden (Wallen, 1949), and Norway (Hesselberg and Birkeland, 1940) has been noted in every season, although the June temperatures in Norway do show a cooling tendency.

The purpose of this paper is to discuss the variations of this temperature climate and to attempt to associate these variations with general circulation patterns.

2. Data and methods

The choice of stations used for analysis was based on length of record as published in the World Weather Records (Clayton, 1927, 1934). Edinburgh, Copenhagen, Berlin, Wilno (55N–28E), and Vienna were chosen for study because of their long records. The temperatures were analyzed by taking 30-yr monthly and annual means at 15-yr intervals. The average for each period is expressed as a departure from the 1901–1930 normal, as recommended by the Warsaw

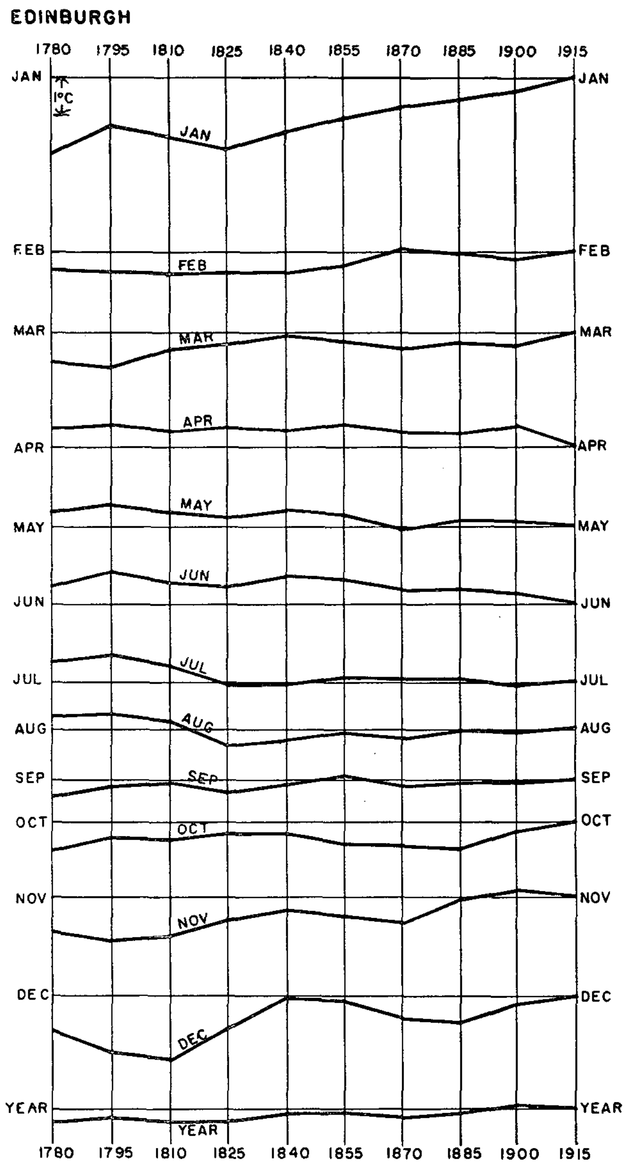

FIG. 1. Edinburgh. Monthly and annual temperature departures from the 1915 normal. The time scale across top and bottom. Horizontal lines labeled on right and left are monthly and annual normals. Vertical temperature scale indicated in upper left. When curve is below reference line, temperature is below normal.

Conference of 1935. The 15-yr interval was chosen to emphasize trends. One-, five-, and ten-year intervals have been used in other studies, but these appear to oscillate about the long-term trend and are unnecessarily detailed for this type of analysis.

In the following discussion the period is referred to as the middle year of the interval; thus 1825 refers to the mean of the years 1811 to 1840. All temperatures are in degrees Celsius. "Continentality" as used in this paper is defined as the average summer (June-July-August) temperature minus the average winter (December-January-February) temperature.

3. Discussion

Edinburgh's annual temperature (fig. 1) indicates a small but persistent increase since about 1825. This has been due primarily to the January increases which have amounted to almost 2C, in close aggrement to the Lancashire records computed by Manley (1946). The winter trend (fig. 7) has been towards warming since about 1810, and here January's strong tendency is augmented by the December rise from 1810 to 1840, and the slight February increase from 1840 to 1870. This winter increase has been offset somewhat in the annual curve by the early summer (April–June) decrease. The resulting decrease in continentality is shown in fig. 2.

Although similarly situated close to the sea, Copenhagen's temperature trend is somewhat different from Edinburgh's (see fig. 3). The winter warming (fig. 7) does not start until 1840 whereas the summer cooling virtually ceased in 1870. Fig. 2 indicates that Copenhagen is more continental than Edinburgh, as might be expected, but this continentality is decreasing.

The warming tendency in Berlin (fig. 4) has been almost continuous since 1810 but has leveled off since 1870. The winter warming was particularly marked from 1840 to 1870 (fig. 7) and although the warming continued until 1915 this was offset by summer cooling from 1870 on. The recent summer cooling is well distributed from June to September. Decreasing continentality (fig. 2) has been almost continuous since 1795.

The most remarkable feature of the Vienna record (fig. 5) is the strong and continuous summer cooling. This alone was enough to decrease the continentality from 1825 and the tendency has been reinforced by marked winter warming since 1885. Note that this is due primarily to the December and January temperatures and only to a small degree in February. The cooling is not confined to the three summer months but is evident from April to October, with the exception of recent (since 1885) May warming.

Data from Wilno were interrupted from 1916 to 1920 and as a result the reference normal is the 30-yr period from 1901 to 1915 plus 1921 to 1935, and this is arbitrarily referred to as 1918. Fig. 6 shows that annual temperatures in Wilno have been cooling slightly since 1885. This is due to summer cooling (fig. 7) and the strong February trend (see fig. 6) beginning in 1870. The variability of the monthly curves indicates that Wilno may be in a maritime regime for some time and

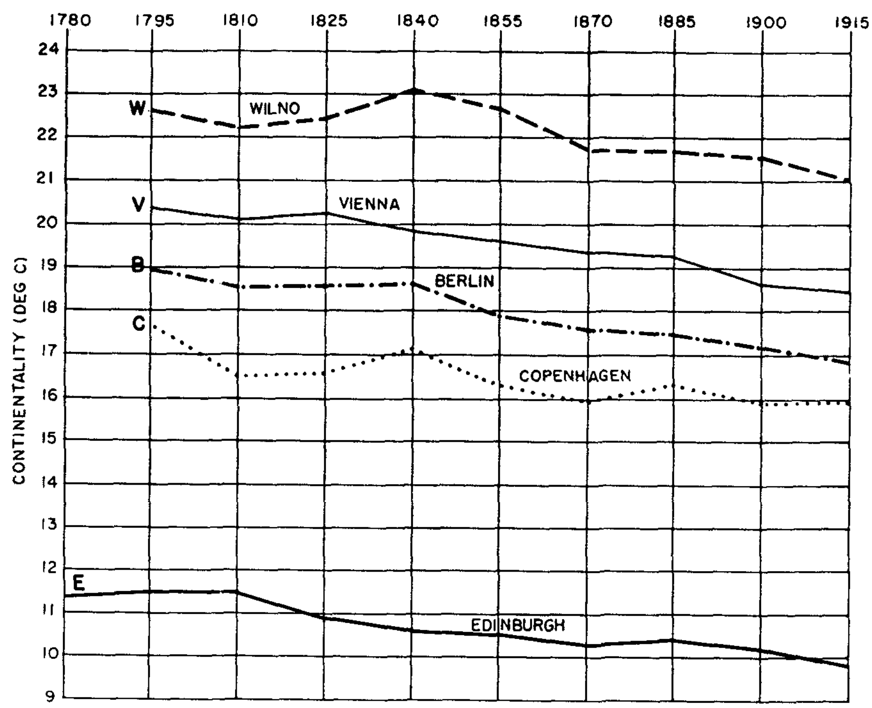

FIG. 2. Continentality, as defined in the text, for the five stations indicated. Time period is indicated on vertical lines.

then become more continental, or vice versa. Possible circulation patterns associated with this will be discussed in the next section.

4. Associated circulation patterns

It is apparent when considering the monthly curves for the five stations that some months contribute more to the seasonal temperature variations than others. This implies that there may be significant differences in circulation pattern between two months in any one season. Rather than try to explain these differences on the basis of mean monthly circulations, it was decided to try to depict the seasonal (summer and winter) fluctuations by possible mean seasonal circulations.

In northwestern Europe one would expect above-normal westerly gradients to be associated with above-normal winter temperature and below-normal summer temperature. Also subnormal gradients would be associated with colder winters and warmer summers. This hypothesis was tested, using what pressure data are available (mostly from about 1870) from Greenwich and Thorshavn to test the gradient over Edinburgh, from Vienna and Copenhagen to test Berlin, and from Berlin and Hvar, Jugoslavia to test Vienna. In each case there is a fairly definite relationship between monthly (January and July) mean gradients and monthly mean temperatures as hypothesized. To a

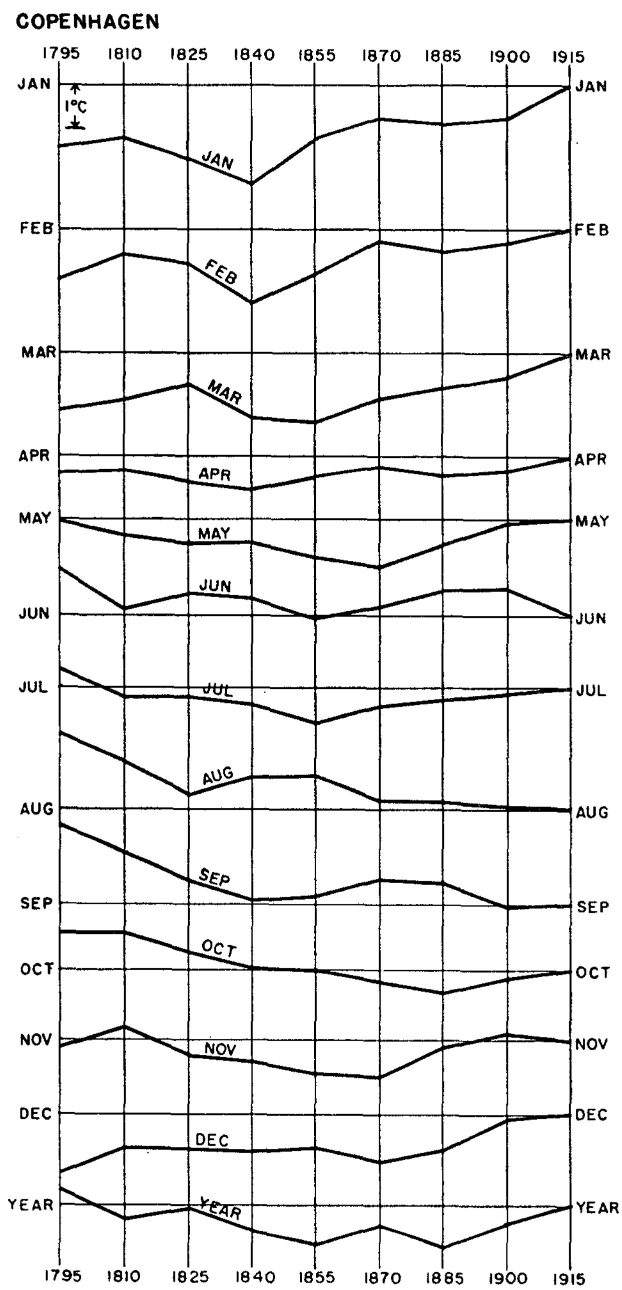

Fig. 3. Copenhagen. Same as fig. 1.

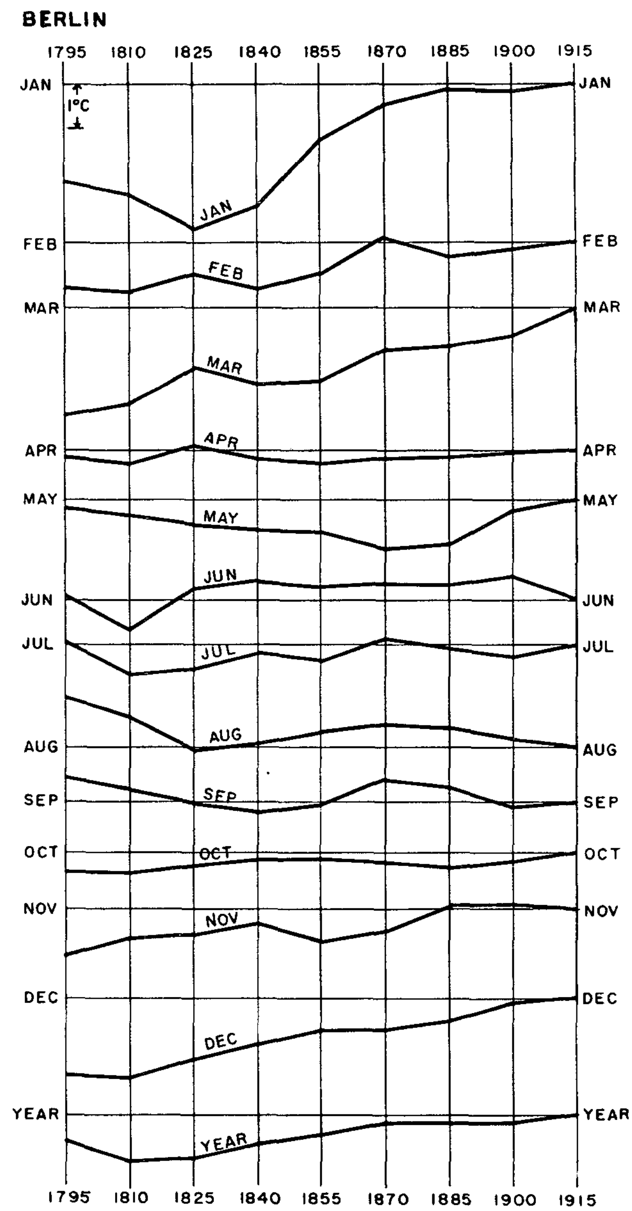

Fig. 4. Berlin. Same as fig. 1.

large degree, the circulation patterns shown in fig. 9 and 11 are based on the above consideration. Certain other facts and deductions were used, and these are listed below with the source indicated in parantheses.

a. Summer temperatures in Stockholm have been below normal since 1795, reaching a minimum about 1860 and a submaximum about 1815 (Hesselberg and Birkeland, 1940).

b. At Tromso, Norway, summer temperatures have been below normal since 1860 with minima about 1870 and 1900 (Hesselberg and Birkeland, 1940).

c. At De Bilt, Netherlands, summer temperatures are warmest with east to southeast winds, coolest with southwest to northwest winds. Warmest winter temperatures occur with west-southwest winds, coolest with east winds (Hartman, 1918).

d. Mean annual winds in the Netherlands have been backing since about 1780 (Labrijn, 1945).

e. An east-west band of pressure maximum moved south from the latitude of Iceland in about 1875 to southern Europe by 1905 (Schove, 1950).

f. Summer 14h temperatures at Vienna from 1921–1940 averaged about 4C warmer with southeasterly winds than with westerly winds. These two quadrants include about 65 per cent of all winds (Schedler, 1944).

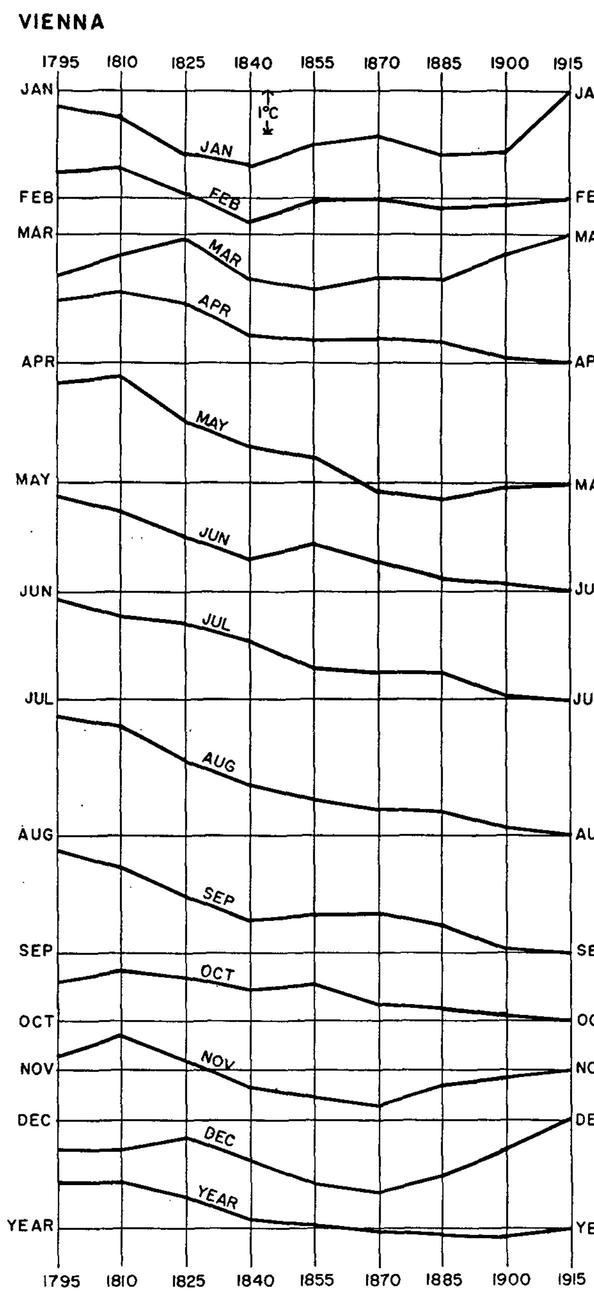

FIG. 5. Vienna. Same as **fig. 1.**

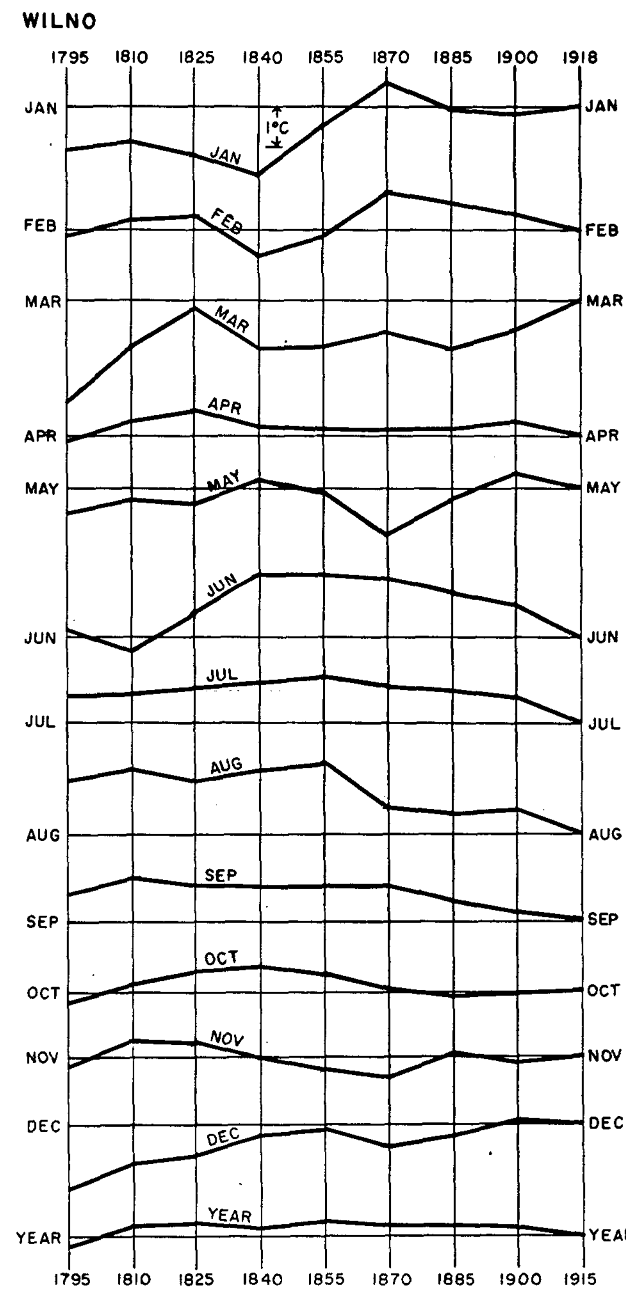

FIG. 6. Wilno. Same as **fig. 1.**

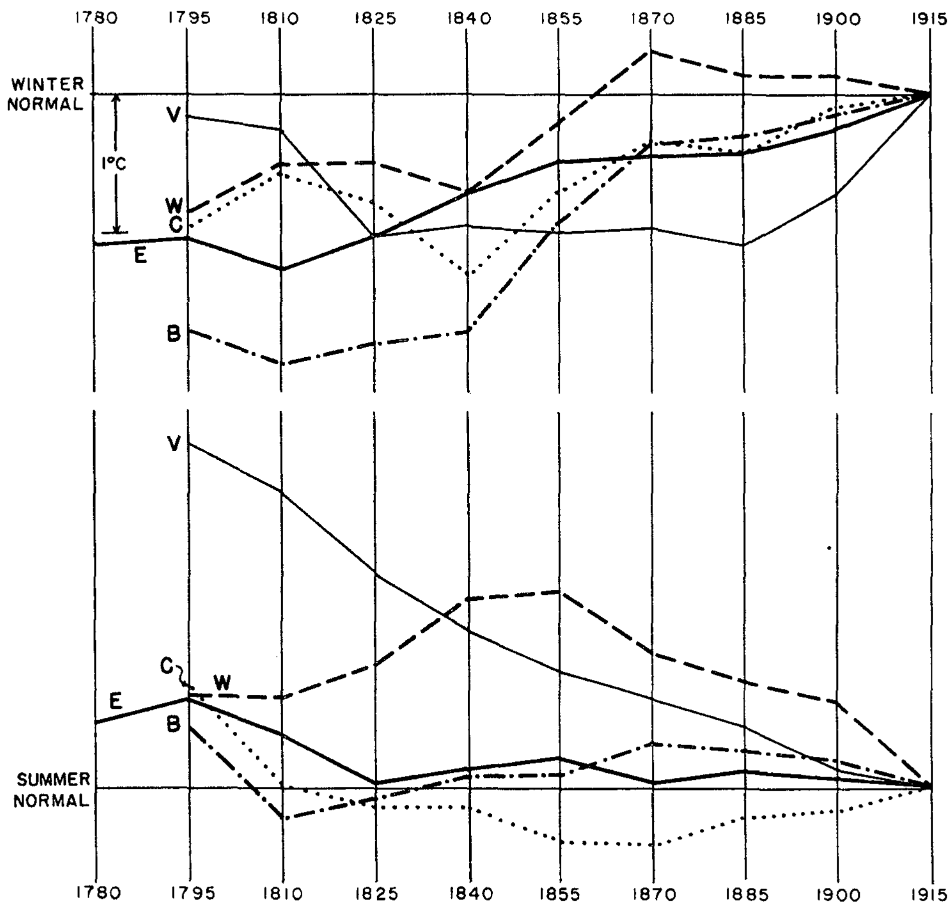

FIG. 7. Winter and summer temperature anomalies expressed as departures from the individual station's 1915 normal. Time period indicated on vertical lines. Vertical temperature scale indicated in upper left. When curve is below normal line, temperatures are below normal.

g. Annual resultant winds at London veered from 190 deg in the 1751–1800 period to 239 deg in the period 1901–1930 (Brooks and Hunt, 1933).

h. The pressure difference between north and south Denmark increased 39 per cent between about 1895 and 1945 (Lysgaard, 1949).

i. The period of minimum temperature is followed by a period of minimum rainfall (Schove, 1950 and Lysgaard, 1949. See also *e.* above).

j. Vienna summers cooled in recent years due to an increase in the northerly wind component (Winter, 1951).

With these items in mind, it is now possible to estimate circulation patterns for winter and summer seasons at 30-yr intervals since 1795. The normal patterns, representing the period 1915, are indicated in figs. 8 and 10 and were derived from the U. S. Weather Bureau Technical paper (1952).

A. *Winter:*

In the 1795 period, winter temperatures were at a minimum in Edinburgh, Berlin, and Wilno while Copenhagen was below normal and Vienna was near normal. The pattern which these facts seem to point to is a northwestward extension of the Siberian High and a general northward shift of the entire European ridge. Winds at Vienna are indicated as somewhat

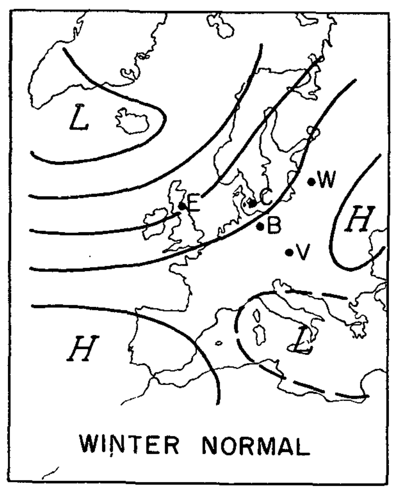

FIG. 8. Winter normal (1915) sea-level pressures. Five-mb isobars. Stations studied are located by large dots with identifying letters. E—Edinburgh, C—Copenhagen, B—Berlin, V—Vienna, W—Wilno.

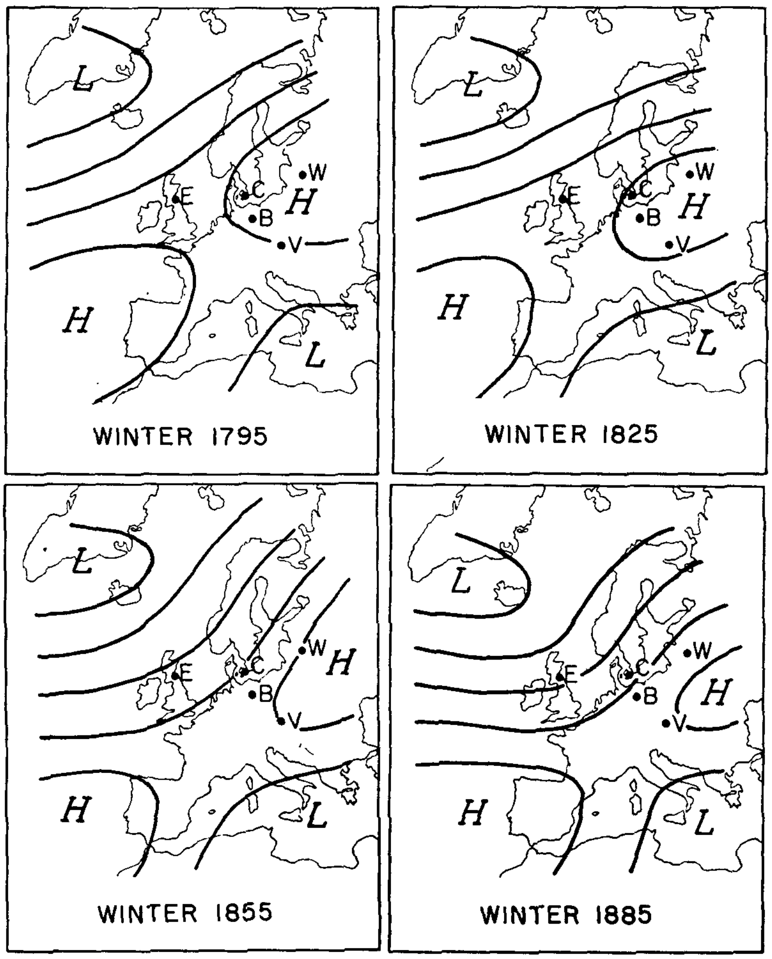

FIG. 9. Proposed winter circulation patterns for the periods indicated. Stations located as in fig. 8.

more easterly than normal, producing somewhat below-normal temperatures. Throughout northwest Europe the westerly winds are indicated as weak or absent (fig. 9a).

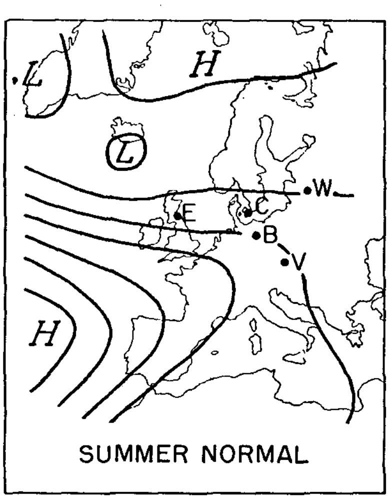

FIG. 10. Summer normal (1915) sea-level pressure. Two-mb isobars. Stations located as in fig. 8.

The period around 1825 is depicted in fig. 9b. The change from the earlier period is most pronounced in the warming at Wilno and the cooling at Vienna. This is indicated by shift of the Siberian ridge southward, with some weakening. Thus Wilno can be influenced more frequently by westerly circulations while Vienna comes under a more east-northeasterly regime with little change indicated at the other three cities.

Warming at Edinburgh, Berlin, and Wilno was most pronounced between 1825 and 1855, while there was little change at Copenhagen and Vienna. This suggests a further southward shift of the European ridge as shown in fig. 9c, with increasing westerlies to the north while maintaining east-northeasterly circulation at Vienna. The cooling at Copenhagen and Wilno between 1825 and 1840 indicates that there may have been a slight temporary northward expansion of the Siberian High during that period, but the longer-term trend seems to be a southward shift of the entire European ridge.

Except for Vienna, warming continued from 1855 to 1885, but it was very slight at Edinburgh. Fig. 9d indicates a possible circulation pattern. The westerlies

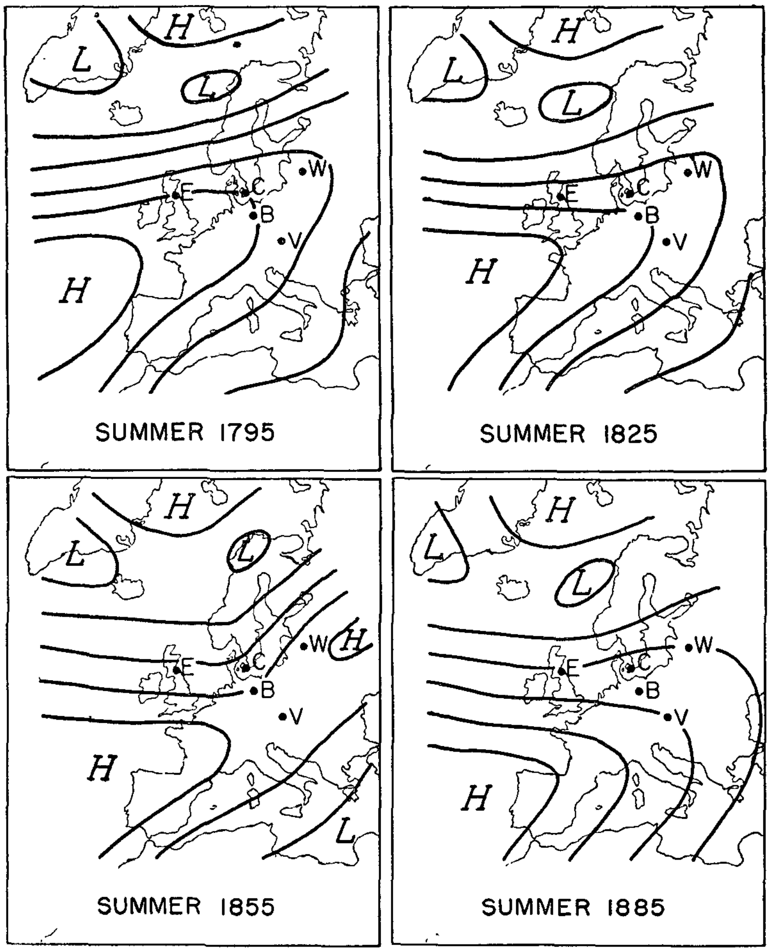

FIG. 11. Proposed summer circulation patterns for the periods indicated. Stations located as in fig. 8.

have again shifted south without much strengthening while the Siberian High has become very narrow. The circulation over Edinburgh has veered somewhat but has also become somewhat stronger due to the shift of the pressure maximum southward into central Europe (par 4*e* and 4*g*). The subsequent cooling at Wilno can be explained by a reorientation of the Siberian High cell giving Wilno a more off-continent circulation than during the 1885 period. The westerlies to the north continue to increase and the circulation over Vienna becomes more variable, indicating less frequent northeasterly components.

B. *Summer:*

The summer circulations are more difficult to depict because of the weaker circulation and the smaller variability of the maritime summer temperatures. It can be shown that there is good correlation between the sea-surface temperatures in the Baltic and summer-air temperatures at Wilno and, to a lesser degree, between sea-surface temperatures northwest of England and the air temperature at Edinburgh. However, it would probably be misleading to say that the sea temperature controls the air temperature; rather, we should say that the atmospheric circulation controls them both to a large degree. Rodhe (1952) reaches a similar conclusion in regard to the Baltic: "the water temperature is mainly a function of the air which has been in contact with the sea surface." The sea certainly reduces the extremes of summer temperature but evidently the atmospheric circulation is still the main controlling factor in the European summer temperature climate.

In the 1795 period, all five cities were above normal during the summer months. Edinburgh was having its warmest summers of the entire 150 yr. The apparent cause for this is a northward displacement of the Azores-European ridge, a rather weak gradient over all of northwest Europe, and a moderate easterly circulation over Vienna. Fig. 10 is the summer normal circulation (1915) computed in the same way as the winter normal for comparison with earlier periods. Fig. 11a illustrates a probable circulation for the 1795 period. Note that this pattern agrees with cool Scandinavian summers at this time (par 4*a* and 4*b*).

By 1825 (fig. 11b) Edinburgh, Copenhagen, and Berlin had all cooled to close to normal, Wilno had warmed slightly and Vienna cooled. These changes suggest a southward shift of the westerlies to near their normal position, a weakening of the westerly circulation at Wilno and of the easterly circulation at Vienna. The westerly circulation is also reduced over southern Sweden to account for the slight warming at Stockholm.

During the next 30 yr, Edinburgh, Berlin, and Wilno warmed while Copenhagen and Vienna cooled (as did Stockholm). This can best be explanied by a slackening of the westerly gradient in the west and an increase in the east (fig. 11c). This configuration requires a trough or convergence zone in the North Sea area and suggests a small isolated High cell in eastern Europe. This helps to account for the maximum at Wilno. It appears that at this period Vienna must be near the center of a col as the European ridge drifts southward.

Towards the end of the century, Copenhagen is still below normal but slightly warmer than in 1855; Edinburgh and Berlin are essentially unchanged, while Wilno and Vienna are cooler. Fig 11d is a possible circulation pattern for this situation. Edinburgh remains in a near normal gradient; Copenhagen, slightly above normal. The cooling at Wilno requires a more on-shore circulation from the Baltic, while the slight warming at Berlin requires some slackening of the gradient there. Vienna is coming more under the influence of a northwesterly current from the Atlantic (par 4*j*). The ridge in fig. 11d is in a more southerly position than normal. There is some evidence in the pressure data from Berlin and Vienna that the ridge was south of its normal position, altough this data is not necessary to explain the observed temperature changes.

5. Conclusion

The observed changes in temperature climate in northwest Europe, together with some facts and deductions about other meteorological parameters, have served as a basis for constructing possible mean circulation patterns at 30-yr intervals. These patterns suggest that there has been an increasing gradient during the period 1780–1930 together with a southerly shift of the mean European ridge and of the westerlies to the north. Willett (1953) has suggested that this mechanism is the onset of a glacial period; however, the time scale covered in this paper is two to three orders of magnitude less than the glacial-interglacial epochs. Should the southward shift of the ridge continue, it is conceivable that the warming trend in northern latitudes would reverse.

Acknowledgment.—The author wishes to thank the Woods Hole Oceanographic Institution for the use of its facilities and for the advice and help of several of its members.

REFERENCES

Ahlmann, H. W., 1949: The present climatic fluctuation. *Geog. Jour.*, **112**, 4–6, 165–195.

Brooks, C. E. P., and T. M. Hunt, 1933: Variations of wind direction in the British Isles since 1341. *Quart. J. r. meteor. Soc.*, **59**, 375–387.

——, 1935: The change of climate in the British Isles. *Meteor. Mag.*, **70**, 153–157.

Clayton, H. H., 1927 and 1934: World weather records. *Smiths. misc. Coll.*, **79** and **90**.

Eythorson, J., 1949: Temperature variations in Iceland. *Geog. Ann.*, **31**, 36–55.

Hartman, M. A., 1918: Le climat des Pays-Bas. B. Temperature de l'air. *Med. Verh. K. Ned. meteor. Inst.*, **24**, 27–104.

Hesselberg, T., and B. J. Birkeland, 1940: Säkulare Schwankungen des Klimas von Norwegen. Die Lufttemperatur. *Geof. Pub.*, **14**, 5–106.

Labrijn, A., 1945: The climate of the Netherlands during the last two and a half centuries. *Med. Verh. K. Ned. meteor. Inst.*, **102**, 1–114.

Lysgaard, L., 1949: Recent climatic fluctuations. *Folia Geog. Danica*, **5**, 86 pp.

Manley, G., 1946: Temperature trends in Lancashire 1753–1945. *Quart. J. r. meteor. Soc.*, **72**, 1–31.

Rodhe, N., 1952: On the relation between air temperature and ice formation in the Baltic. *Geog. Ann.*, **34**, 175–202.

Schedler, A., 1944: Wind und Wetter in Wien. *Z. Meteor.*, **61**, 117–123.

Schove, D. J., 1950: The climatic fluctuation since 1850 in Europe and the Atlantic. *Quart. J. r. meteor. Soc.*, **76**, 147–165.

Wallen, C. C., 1949: The shrinkage of the Karsa Glacier and its probable meteorological causes. *Geog. Ann.*, **31**, 275–291.

Weather Bureau, U. S., 1952: Tech. pap. No. 21.

Willett, H. C., 1950: Temperature trends of the past century. *Cent. Proc. r. meteor. Soc.*, 195–206.

——, 1953: *Climatic change.* Cambridge, Harvard Univ. Press, 51–72.

Winter, H., 1951: Änderungen in Sommerklima seit 150 Jahren. *Archiv. Meteor. Geophys. Bioklim.*, **B3**, 65–71.