CLIMATIC CLASSIFICATION AND CLIMATIC CHANGE

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Klimaklassifikation und Klimaänderung

Zusammenfassung: Das Ziel dieses Aufsatzes ist es, einerseits die Verlagerung einer Reihe klimatischer Grenzen über den größeren Teil Europas während der siebzig Jahre von 1871—1940 aufzuzeigen, und andererseits ihre Abweichungen von der gewöhnlich zugrunde gelegten Standardperiode von 1901—1930 herauszuarbeiten. Es wurde *Köppens* Klassifikation zugrunde gelegt und die Aufzeichnungen der in Abb. 1 genannten Wetterstationen benutzt. Da sich die gegenwärtige Klimaverbesserung in den gemäßigten Breiten hauptsächlich in der Form häufigerer Wärmeperioden und weniger in einer allgemeinen Erwärmung bemerkbar macht, wurde es als vorteilhafter angesehen, für die Lösung dieses Problems an Stelle der im allgemeinen üblicheren arithmetischen Mittelwerte den Begriff der „Klimajahre" nach *Russel* zu verwenden. Freilich führt die Klassifikation der Klimazustände auf einer Jahres-, statt einer Mittelwertbasis, zu einigen Schwierigkeiten — insbesondere in bezug auf die jahreszeitliche Niederschlagsverteilung — so daß schließlich eine Modifikation der *Köppen*schen (Tabelle I) Kriterien durchgeführt werden mußte.

Für die Standardperiode 1901—1930 wurden die Klimagebiete einerseits auf der Grundlage der Mittelwerte (Abb. 2) und andererseits auf der Basis einer Analyse der Klimajahre kartographisch dargestellt und deren hauptsächliche Unterschiede besprochen, insbesondere die in Abb. 3 durchgeführte Unterscheidung zwischen Kerngebieten und Übergangsgürteln. Die tatsächliche Breite dieser Grenzgürtel findet eine eingehendere Berücksichtigung in den Abb. 4 bis 6, die auf der Grundlage einer Kartierung der Klimagrenzen für jedes der dreißig Jahre erarbeitet wurden. In allen diesen Karten spiegelt sich deutlich die wichtige Rolle, der größeren Gebirge bei der Stabilisierung der Grenzen und Einschränkung der Breite der Übergangsgürtel.

Die Veränderungen in der Lage der Grenzen während der Periode von 1871—1940 wurden sowohl durch einen Vergleich des Zustandes von 1901—1930 mit dem von 1871 bis 1900 (Abb. 7 und 8), als auch durch das Studium der Lage der Grenzen von fünf sich überschneidenden Dreißig-Jahr-Perioden (Abb. 9) näher beleuchtet. Die hervorstechendste dieser Veränderungen ist das Vorrücken der C/D-Grenze entlang der norwegischen Küste fast 800 km weiter nach Norden und über Deutschland hinweg ungefähr 500 km nach Osten.

During the last two decades there have been published many varied and detailed studies of the climatic fluctuation which has affected temperate latitudes during the past 50—70 years — studies not only in meteorology and climatology, but also in such allied fields as glaciology and plant ecology. Despite this, little consideration has been given to the possible influence of this fluctuation upon that aspect of climate the study of which has been peculiarly the sphere of the geographer, namely upon the boundaries of climatic regions. The quantitative values on the basis of which these boundaries have been drawn were chosen for their vegetational and ecological significance. A climatic boundary change of any considerable magnitude, if sustained over a sufficient period of time, should therefore in turn be reflected in changes in the distribution both of wild flora and fauna, and of cultivated crops, domesticated animals and types of agriculture.

Aims and methods

This present paper attempts to show the migrations of several climatic boundaries over the larger part of Europe during the 70 years 1871—1940 by considering the position of five overlapping 30-year periods; and also to show the relationship between the internationally accepted standard period 1901—1930 and this changing pattern. Only those stations have been used for which reliable records are available for all or most of these 70 years, so as to ensure as strict comparability as possible between the several 30-year periods studied (Fig. 1). This necessarily means that the resultant patterns are more generalised than those normally representing European climatic regions, but any locational changes of boundaries observable for this simpler pattern will equally apply to the more detailed picture which can be drawn for recent periods on the basis of a closer network of stations [1]). Simplicity of distribution is further increased by the deliberate omission of stations at high altitudes. In these areas, climatic boundary changes would operate vertically with little horizontal movement, and would thus not be possible of representation in simple map form. As a reminder of the modifying influence of mountains, however, and to provide a means of locational comparison between one map and another, all land above 3,000 feet has been shaded.

As has frequently been stressed, the recent climatic amelioration in temperate latitudes has in the main taken the form of more frequent warm conditions rather than warmer over-all conditions. For this reason it was thought more fitting to apply *Russell's* concept of 'climatic-years' to this problem, rather than to employ the more usual arithmetic average [2]). A further factor in favour of the climatic-year approach is that although there have been several applications of the method to North America [3]), conditions in

[1]) *R. Geiger* and *W. Pohl*, „Eine neue Wandkarte der Klimagebiete der Erde nach W. Köppens Klassifikation", Erdkunde, VIII (1954), p. 58.

[2]) *R. J. Russell*, "Climatic Years", Geographical Review, XXIV (1934), p. 92.

[3]) *H. M. Kendall*, "Notes on climatic boundaries in the Eastern United States", Geographical Review XXV (1935), p. 117. *J. R. Villmow*, "The position of the Köppen Da/Db

Europe have not so far been considered on this basis.

The classification used is one of the many modern adaptations of *Köppen's* system, the criteria adopted being as far as possible those defined by *Trewartha*[4]). These formulae were designed for use with the arithmetic average and their application to individual years could lead to various problems. These do not arise so far as temperature criteria are concerned however, whilst the definition of aridity has been largely avoided by 1 restricting the area to non-Russian Europe and 2 ignoring the occurrence of steppe conditions in a few areas of Iberia, partly for this reason and partly because of the lack of sufficient stations to ensure their delimitation throughout the whole of the 70 years. The assessment of rainfall regime on the basis of one year's rainfall presents a real problem, however. *Trewartha's* version of *Köppen's* classification defines the opposing regimes of winter drought summer drought as follows:

w (winter dry) — at least three times as much rain in the wettest month of summer as in the driest month of winter.

s (summer dry) — at least three times as much rain in the wettest month of winter as in the driest month of summer, and the driest month of summer receives less than 3 cm (1·2 in.) of rain.

It frequently happens, even in such areas as southern Italy, that both these conditions are fulfilled at the one station in the same year, and it is virtually impossible to define areas of 'Mediterranean' rainfall regime by these criteria. The modifications finally adopted are given in Table I, but it should be noted that these are more stringent criteria for the definition of a 'Mediterranean' regime than were those of *Trewartha* or of *Köppen* himself.

TABLE I. *Classification criteria for the definition of climatic years.*

Classification Letter	Criteria
C	Warmest month over 10 ° C (50 ° F); coldest month between — 3 ° C (26·6 ° F) and 18 ° C (64·4 ° F).
D	Warmest month over 10 ° C (50 ° F); coldest month below — 3 ° C (26·6 ° F).
ET	Warmest month below 10 ° C (50 ° F), but over 0 ° C (32 ° F).
a	Warmest month over 22 ° C (71·6 ° F).
b	Warmest month below 22 ° C (71·6 ° F).
c	Less than four months over 10 ° C (50 ° F).
f	No distinct dry season; winter three months (Dec.—Feb.) less than three times as much rain as summer three months (June—Aug.); summer three months less than ten times as much rain as winter three months.
s	Dry summer; winter three months (Dec.—Feb.) at least three times as much rain as summer three months (June—Aug.), and driest summer month receives less than 3 cm. (1·2 in.) of rain.

Criteria based on *G. Trewartha,* An Introduction to Weather Climate.

boundary in the Eastern United States", Annals of the Association of American Geographers, XLII (1952), p. 94.

[4]) *G. Trewartha,* An Introduction to Weather and Climate, New York, 1943, Appendix II.

On the basis of these criteria, each of the 70 years was separately classified for each station. Then, the relative frequency of each set of conditions at each station was calculated for the five 30-year periods beginning 1871, 1881, 1891, 1901, 1911, and maps of climatic regions constructed. The basic division between, for example, C and D climates occurs where 15 of the years fall into each category. *Russell* further suggests that the essential core areas of climatic regions are those in which all years fall into the same category, the rest of the area being considered as transitional. If this were applied to Europe, core areas would be few in number and negligible in size. To provide a picture of geater reality and value under European conditions the core areas designated in this present paper are therefore those in which at least 25 out of the 30 years fall into the one category. The transitional areas between these cores are shaded, whilst the basic division of 15 years in each category is shown by a full line.

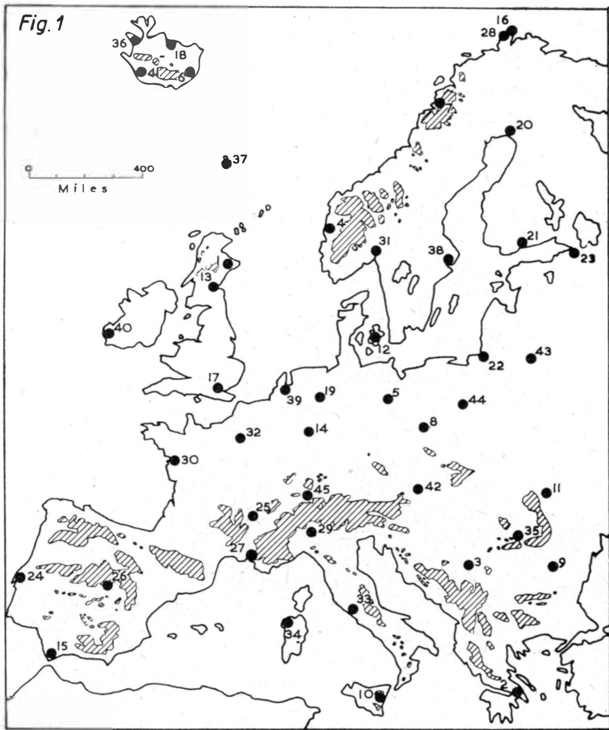
The standard period, 1901—1930

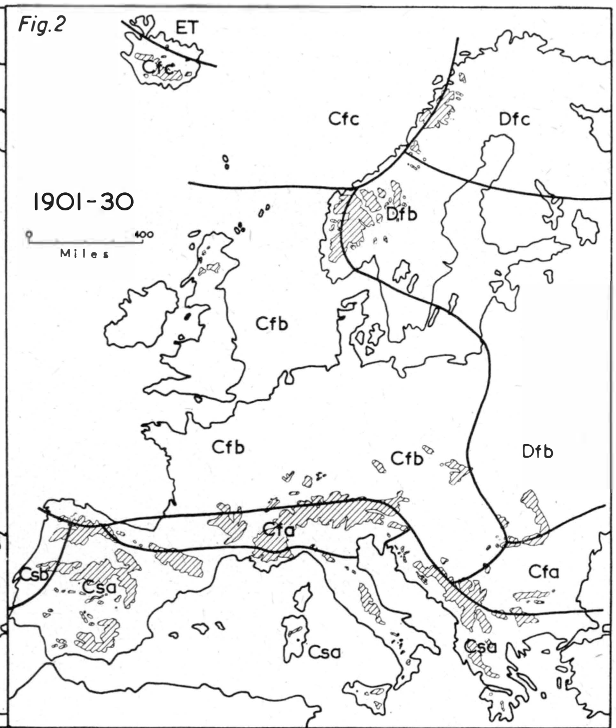
The differences both in distribution pattern and value between climatic region maps based on average values (Fig. 2) and those based on climatic year analysis (Fig. 3) can be studied for the period 1901—1930. Two major differences are apparent:

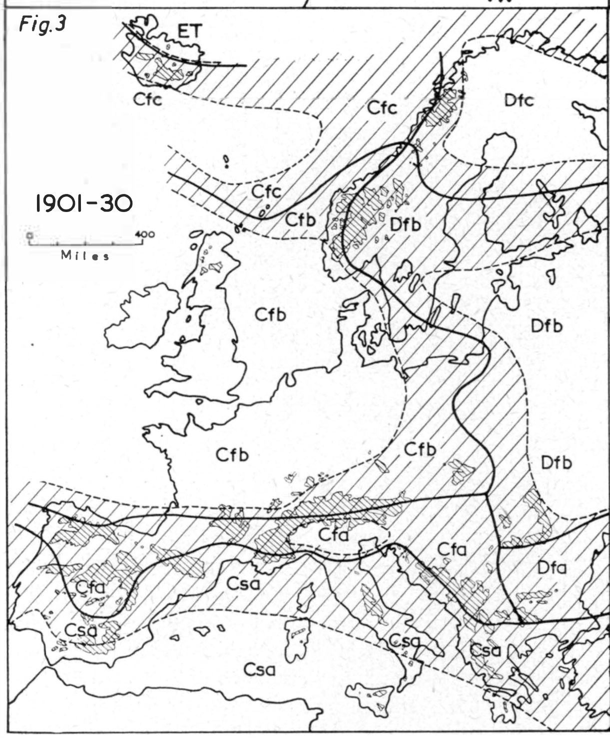
1. the consideration of individual years prevents undue weight being given to years of exceptional conditions, and this may lead to quite considerable differences in boundary location (See Cfa in Iberia and S. E. Europe in Figs. 2 and 3);

2. a distinction between core and transitional areas is made in Fig 3. but is absent from Fig. 2. This distinction is extremely valuable, corresponding more closely to climatic reality than does the instantaneous change from one region to another in Fig. 2.

The width of the transitional belts in Fig. 3 is a true indication of the rapidity of the horizontal







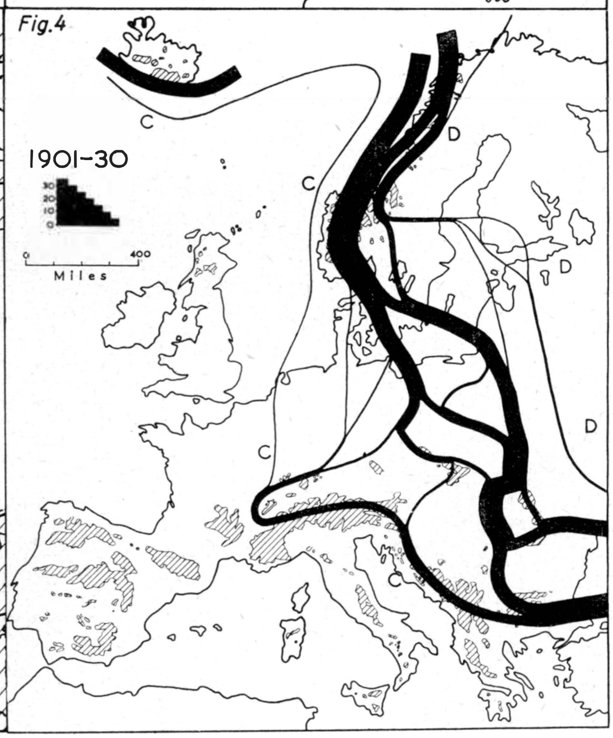
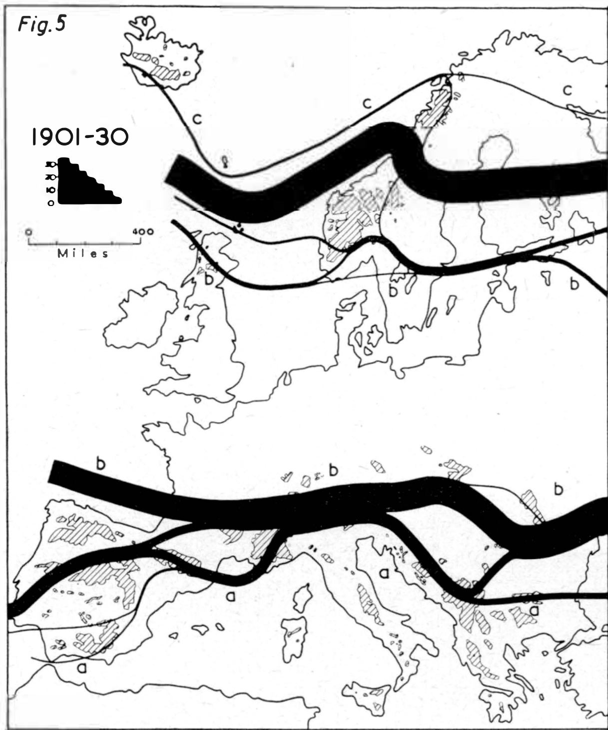


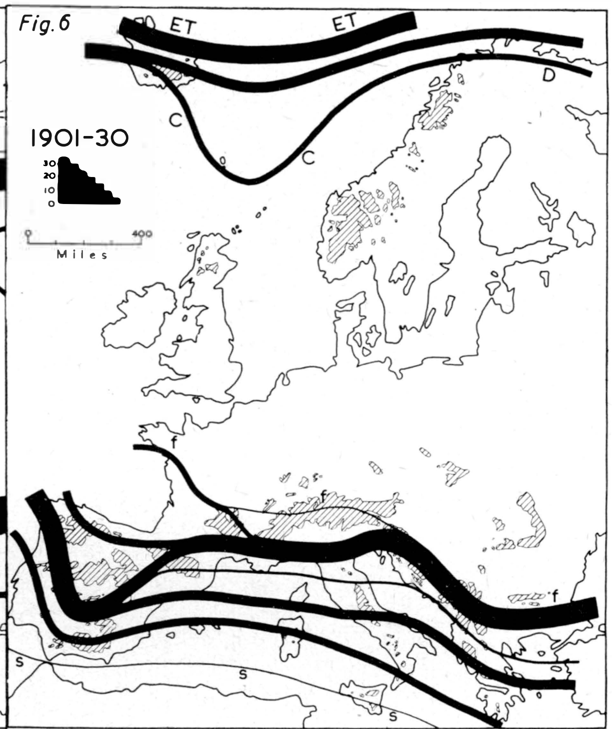
FIG. 1. *Location of stations with long continuous records.* Land above 3000 feet shaded; no stations above this height are used in this paper. Key: 1 Aberdeen — 2 Athens — 3 Belgrade — 4 Bergen — 5 Berlin — 6 Berufjord — 7 Bodö — 8 Breslau — 9 Bucharest — 10 Catania — 11 Cernauti — 12 Copenhagen — 13 Edinburgh — 14 Frankfurt — 15 Gibraltar — 16 Gjesvar — 17 Greenwich — 18 Grimsey — 19 Gütersloh — 20 Haparanda — 21 Helsinki — 22 Königsberg — 23 Leningrad — 24 Lisbon — 25 Lyon — 26 Madrid — 27 Marseilles — 28 Mehavn — 29 Milan — 30 Nantes — 31 Oslo — 32 Paris — 33 Rome — 34 Sassari — 35 Sibiu — 36 Stykkisholm — 37 Thorshavn — 38 Uppsala — 39 Utrecht — 40 Valentia — 41 Vestmanno — 42 Vienna — 43 Vilna — 44 Warsaw — 45 Zürich.

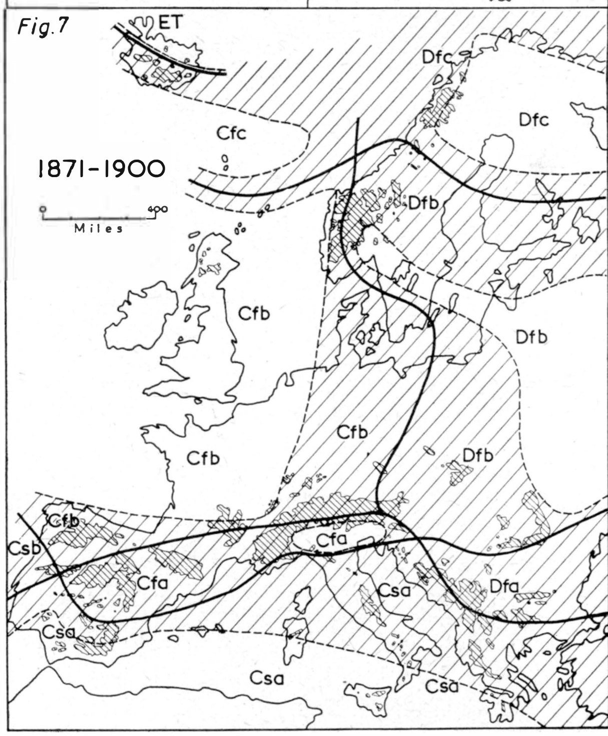
FIG. 2. *Generalised climatic regions of Europe, 1901—1930 (after Köppen and Trewartha), based on average values.* Data from Smithsonian Miscellaneous Collection, Vols. 79, 90. Land above 3000 feet shaded. (Also in Fig. 3 to 9.)

FIG. 3. *Generalised climatic regions of Europe, 1901—1930 (after Köppen and Trewartha), based on climatic year analysis.* Basic regional boundaries in full lines; boundaries of core regions in broken lines; transitional zones shaded.

FIG. 4. *Yearly location of Köppen's C—D boundary in Europe, 1901—1930.* Number of years in which boundary lay in one locality indicated by breadth of line.







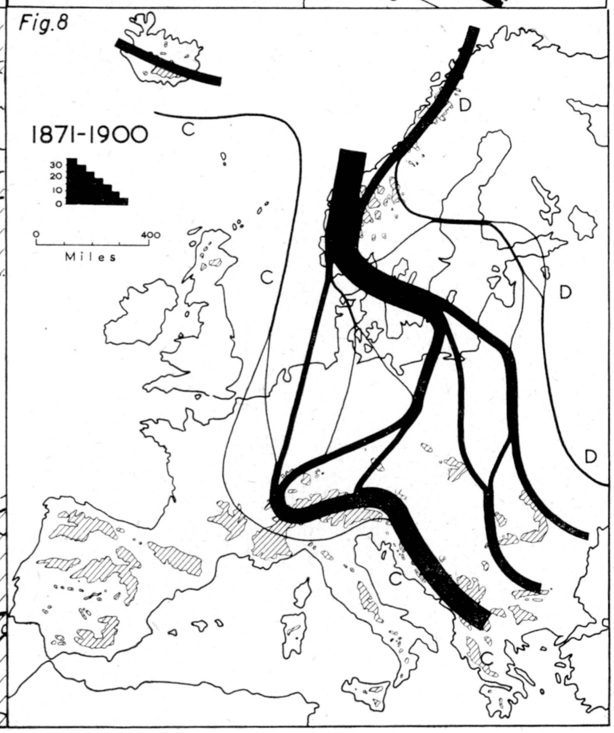


FIG. 5. *Yearly location of Köppen's a—b and b—c boundaries in Europe, 1901—1930.* Number of years in which boundary lay in one locality indicated by breadth of line.

FIG. 6. *Yearly location of Köppen's ET and f—s boundaries in Europe, 1901—1930.* Number of years in which boundary lay in one locality indicated by breadth of line.

FIG. 7. *Generalised climatic regions of Europe, 1871—1900 (after Köppen and Trewartha), based on climatic year analysis.* Basic regional boundaries in full lines; boundaries of core regions in broken lines; transitional zones shaded.

FIG. 8. *Yearly location of Köppen's C—D boundary in Europe, 1871—1900.* Number of years in which boundary lay in one locality indicated by breadth of line.

change in climatic conditions in only a few regions of Europe for in the majority of areas transitional belts include changes in more than one element of the classification. Thus, the transition across Poland is simply between C and D climates (i. e. a change in winter temperatures); that over south-western Europe is between both a—b and f—s categories (i. e. changes in summer temperatures and in the seasonal incidence of rainfall); whilst in south-eastern Europe occur overlapping transitions in both winter and summer temperatures (C—D and a—b categories), and in the seasonal incidence of rainfall too.

The actual widths of the transitional belts between any two classification categories are shown in Figs. 4—6. For each of these, the boundary between, for example, C and D climates (Fig. 4) was drawn for each of the 30 years. When two or more of these lay between the same two stations they have been grouped together on the map, and the number of years in which the boundary lay in any particular locality is indicated graphically by the width of the line at that point.

Several features of interest and significance arise from a consideration of Figs. 4—6. Within the period 1901–1930 the C–D boundary across the North European Plain at one time fell as far west as the eastern borders of Belgium and France, and at another time as far east as to be well within the borders of the U. S. S. R., but the most frequent localities were between eastern Germany and eastern Poland. Again, all points along the western coast of Norway experienced both C and D climates within the period, whilst the east-west section of the boundary varied between central Sweden and Thrace. The thermal boundaries reflecting summer conditions (Fig. 5) are less complex in nature. Nevertheless, the b—c boundary fluctuated considerably between the Arctic Circle and the Lake Väner area of southern Sweden. The a—b boundary, although moving little in its central Alpine section, varied between the northern and southern extremities of Iberia in the west and between the Carpathians and the Stara Planina in the east.

In Fig. 6 two boundaries are shown. In the north lies the southern boundary of the ET (tundra) climate, but scarcity of stations and the large area of ocean necessarily make the lines extremely tentative. In the south, the change in rainfall regime between f and s varied between the mountains backing the northern coastline of the Mediterranean and the shores of North Africa, but in the majority of years the change occurred north of central Iberia, Italy and Greece. The significance of such mountainous areas as western Scandinavia, the Alps, Carpathians, Dinarics and Balkan Mountains, is readily seen in Figs. 4—6. By their effects upon the temperatures, moisture content, and especially upon the trajectories of air masses these mountains hinder the spread of both warming and cooling influences and of precipitation phenomena, thus leading to the stabilisation of boundaries and the restriction of the width of transitional zones.

The recent climatic fluctuation

The magnitude of the change in the present century is probably best seen by comparing the 1901—1930 position (Fig. 3) with that for 1871—1900 (Fig. 7). This latter was the period during which, over most of western Europe and the north-eastern Atlantic, glaciers were at or near their maximum development since the end of the Ice Age, the recent amelioration representing the recovery from this position.

The major differences between Figs. 3 and 7 are brought about by changes in winter temperatures as represented by the C—D boundary, which in all cases lay considerably farther west in 1871—1900 than in 1901—1930. Thus in Scandinavia the occurrence of at least 15 years of C climates was restricted to the coast south of Kristiansund in 1871—1900 whilst by 1901—1930 it extended almost to Narvik, a northward advance of about 500 miles. Again, in south-eastern Europe the large areas experiencing mainly Cfa climate in Yugoslavia and Hungary in 1901—1930 were characterised in the earlier period by Dfa and Dfb climates. It is across the North European Plain that the most striking change occured. In 1901—1930, a general line from Stettin to Dresden represented the eastern boundary of the Cfb core area, where only five years with D climates occurred. During the earlier period, this same general line represented the basic divide between C and D climates, each of these two occurring in 15 years. Furthermore, the eastern boundary of the Cfb core area in 1871—1900 lay 300 miles west of its 1901—1930 position, running from Emden to the Vosges.

The nature of this change in climatic conditions in Germany and Denmark is further stressed by comparing Figs. 4 and 8, which show the position of the 30 yearly C—D boundaries for these two periods. The considerably greater frequency of cold winters in these countries in 1871—1900, as also in parts of south-eastern Europe and along the northern half of the Norwegian coast, is here graphically illustrated. It is striking, however, that the extreme western and eastern limits of the occurrence of C—D boundaries differ little between 1871—1900 and 1901—1930.

The boundaries of the other climatic criteria included in the classification differed to only a very limited and localised extent between the two periods. In fact, what changes there were would seem to be merely the expected fluctuations between two arbitrary samples. Nevertheless, the more frequent cooler summers (b) over north-western Iberia in 1871—1900 (Fig. 7) led to the definition of a Csb climate in central Portugal,

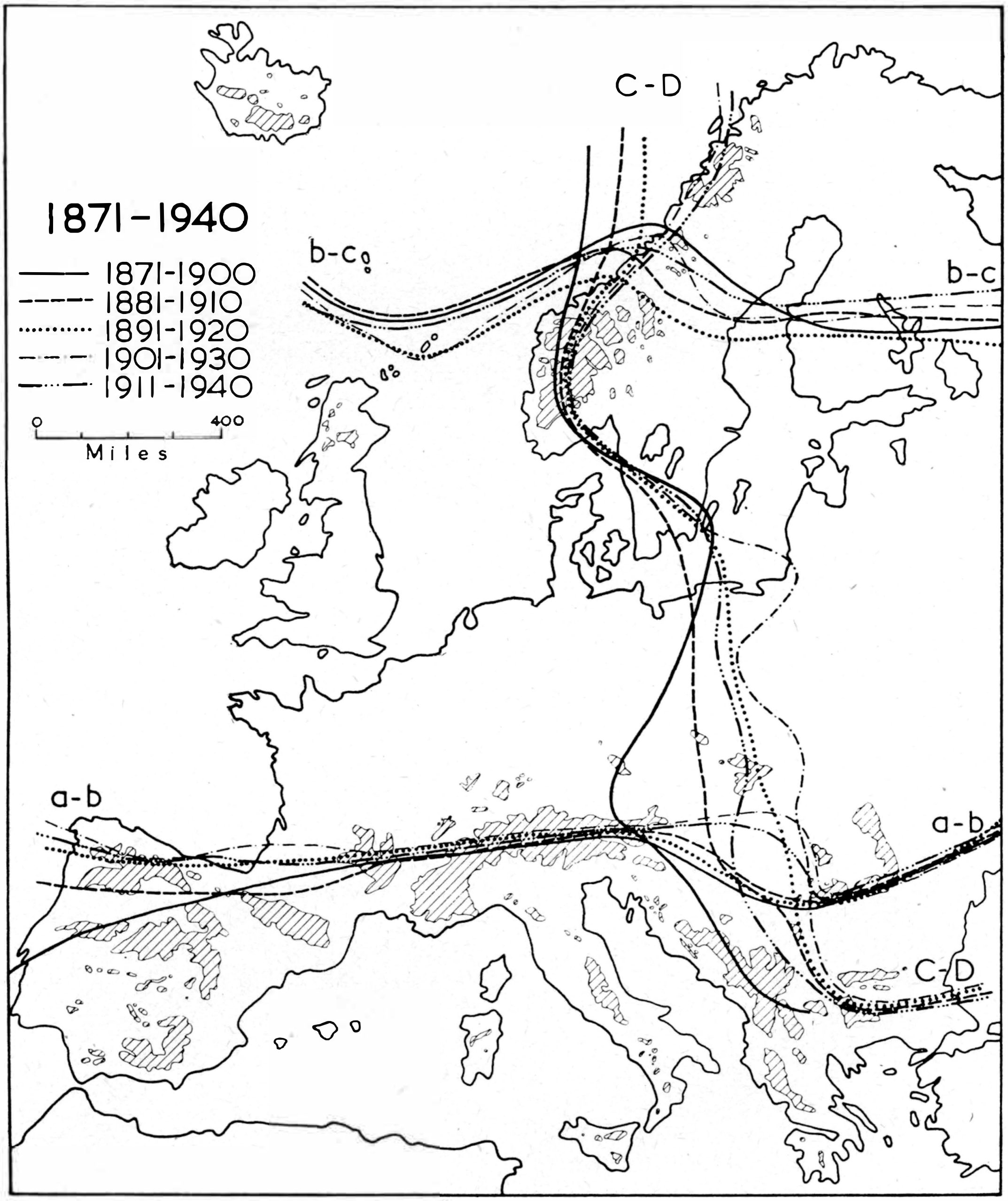


FIG. 9. *Location of Köppen's C—D, a—b and b—c boundaries in Europe for five overlapping 30 year periods, 1871—1940.*

a category which did not exist in 1901—1930 (Fig. 3). Again, a marked change in the location of the f—s rainfall boundary is noticeable in the area of the Gulf of Lions.

Finally, a consideration of the stages by which this change in thermal boundaries took place will help to provide a more complete picture and also help to determine whether the differences described are due to legitimate changes in climate or merely to random fluctuations. In Fig. 9 the basic boundaries (15 years in each category) between C—D, a—b, and b—c conditions are plotted for five overlapping 30 year periods from 1871 to 1940.

As regards the C—D boundary the map would seem to bear out the suggestion made earlier of a legitimate change. Along the Norwegian coast there is a steady and continual northward movement of the boundary, whilst over the North European Plain and the Carpathians-Danube area an equally steady eastward movement occurred up to 1901—1930, but followed by a retreat westwards in 1911—1940. The boundaries based on summer temperatures are less conclusive. In Portugal the change in the a—b boundary shows a northward movement from 1871—1900 to 1891—1920 followed by little change in the other periods, whilst in the central Danube area the contrast is between the three earlier periods and the two later ones. Across Scandinavia, however, the fluctuations in the b—c boundary would seem to be completely random, with no suggestion of a continuous and progressive change in any particular direction.

Conclusions

From the method of approach adopted in this paper, several features of some significance would seem to need stressing:

1. Maps of climatic regions drawn on the basis of climatic-year analysis provide the valuable distinction between core and transitional areas. It is indeed surprising that so little attention has been paid to this method during the past 20 years.

2. The transference of standard classification criteria from an average to an annual basis causes no difficulty as regards temperature, but it does complicate the classification of rainfall, especially its seasonal incidence.

3. The actual period of years chosen for classification affects the location of boundaries in many areas. The changes which occur are partly the result of random fluctuations, and are partly caused by definite changes in climatic conditions.

4. These changes in climate are most marked in Europe in winter i. e. in the relative frequency of years with C and D climates. Whilst this merely supports the work of earlier writers, the magnitude of the horizontal changes in boundary location, especially along the Norwegian coast and across the North European Plain, represents a significant and hitherto unmapped change in the distribution of climatic regions over western and central Europe.

DIE NATIONALITÄTENFRAGE IN SÜDTIROL

Erwiderung auf italienische Antworten
zum Artikel von *Fr. Dörrenhaus*
„Deutsche und Italiener in Südtirol“

Vorwort des Herausgebers:

Die in „Erdkunde“ Bd. 7, 1953, S. 185—216 erschienene Darstellung der Volksgruppen in Südtirol von *Fr. Dörrenhaus* hat ihren ersten Widerhall in der Zeitschrift des Istituto Geografico Militare in Firenze „L'Universo“, 53. Jg., Nov./Dic. 1953 gefunden, unter dem Titel „Italiani e Tedeschi nell'Alto Adige“ aus der Feder des italienischen Romanisten *Carlo Battisti*, Universität Firenze. Vom gleichen Verfasser erschien derselbe Aufsatz umgearbeitet, mit Anmerkungen, einem Vorwort und einem Anhang versehen, unter dem Titel „Il confine italo-austriaco al Brennero“ als Sonderheft des Archivio per l'Alto Adige, Bd. XLVIII, Firenze 1954 (45 Seiten). Nochmals wiederholt findet er sich unter dem Titel „Opzioni, riopzioni e separatismo nell'Alto Adige“ als Nr. 1 von „Quaderni di attualità atesine“ (Firenze, April 1954). In der Rivista Geografica Italiana, Jg. 60, H. 4, 1953, S. 482 ff. erschien eine ungezeichnete kürzere Besprechung, welche nach *Battisti* von *A. Sestini* stammt.

Die Diskussion wurde damit von prominenter italienischer Seite einer Persönlichkeit übertragen, die in der Literatur über die Südtiroler Volkstumsfrage schon bisher, vor allem auch in der Zeit des Faschismus, eine sehr einseitige und extrem nationalistische Haltung eingenommen hat, die