OBJECTIVE EMPIRIC CLASSIFICATIONS OF EARTH'S CLIMATE

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Summary

The most widely used objective empiric classifications of climates are discussed. Principles of grouping climates, major climatic categories and types according to Koeppen's system are described. The approach to classifying climates proposed by Thornthwaite, is considered. Thornthwaite's first version of classification using the concepts of thermal and precipitation effectiveness is described, and his final classification system, based on principles of the soil-water budget, is presented.

1. Introduction

Among descriptive grouping systems (see *Methods of Climate Classification)*, which unlike genetic classifications give world maps of climates but don't analyze the reasons for the climatic pattern, we choose classifications constructed on the basis of data from meteorological observations, using objective quantitative criteria.

The first descriptive classifications, that appeared in the second half of the 1800s, did not apply strict criteria to differentiate climatic zones. In those works the climatic boundaries were generally in accordance with natural vegetational boundaries and were constructed without use of definite values of meteorological indices. The development of a world system of meteorological observations, progress in climatologic synthesis of results—in particular mapping of average temperature and precipitation over the globe—provided the possibility to devise objective empiric climate classifications.

It is important to underline that we do not regard as classifications those zoning schemes which operate with a single meteorological variable (for instance, temperature, or precipitation). We believe that multidimensionality is a fundamental feature of the

concept "climate". So, when discussing objective empiric classifications, we shall mean those classification systems developed on the basis of two, or more, meteorological characteristics.

In this chapter we consider Koeppen's and Thornthwaite's classifications. These are the most popular of the descriptive climate classifications.

2. Koeppen's classification

The division of climatic classifications into various groups is not totally objective, so attribution of some classifications to a particular group, is to some extent, conditional. There are, however, some classifications with well-expressed typical features.

Wladimir Koeppen devised a system of classification, which can be related to some of the most developed climatic classifications based on formalized criteria in terms of meteorological elements.

Koeppen was born in Russia in the family of a Russian academician who specialized in the field of ethnography. He began his scientific activity in St. Petersburg at the Main Physical Observatory (now Voeikov Main Geophysical Observatory) as a climatologist. Later, when he was about thirty, he was invited to lead the Department of Synoptic Meteorology at the German Marine Observatory in Hamburg.

Koeppen was engaged in development and modification of his climate system for about 40 years. His first classification scheme was published in 1900, and at that time its botanical principle as a basis was very clear. Starting from the boundaries of vegetation zones and provinces, he aimed to find features of temperature and rainfall regime characteristic of different botanical regions, and in the final variants of his classification he defined climatic types using only objective criteria derived from meteorological indices.

Koeppen's classification is based on simple numerical characteristics of temperature and precipitation regime constructed on monthly means of air temperature and rainfall totals. He did not attach great importance to annual average temperature, and he considered existence or absence of seasonal changes as a determinant factor for development of organic life. When finding climatic types Koeppen used such seasonal and monthly characteristics as winter and summer rainfall totals, the temperature of warmest and coldest months, and so on.

The means of classification chosen by Koeppen are the most readily available for investigation, because since the beginning of regular meteorological observations, monthly values of temperature and precipitation have been regularly published. This factor, and the good agreement between landscape zones and Koeppen's climate types, promoted widespread use of his system in different regions of the world.

Following De Candolle's conceptions of geographical zonality, Koeppen selected in each hemisphere, five major climatic zones, which are denoted by capital letters as follows:

A. Tropical rainy climates.
B. Dry climates.
C. Warm temperate climates (without regular snow cover).
D. Cold temperate climates with strongly pronounced winter and summer.
E. Polar climates.

These climatic belts are distinguished using temperature criteria (A - the warmest, E - the coldest), with the exception of type B. The boundaries of climatic zone B are defined according to the criterion of aridity in the form of different relationships between yearly mean temperatures and precipitation totals, depending on seasonal specialties of rainfall regime.

To designate subtypes of climate in different zones Koeppen uses combinations of two or three letters: the first letter denotes the major category of climate (A, B, C, D, E) which the type belongs to; the second letter characterizes, as a rule, the regime of precipitation fallout, and the third letter indicates particularities of thermal regime. The most important designations as used, and brief descriptions of climatic types, are given in Tables 1 and 2. The boundaries of world distribution of climatic types are represented as a scheme in Figure 1.

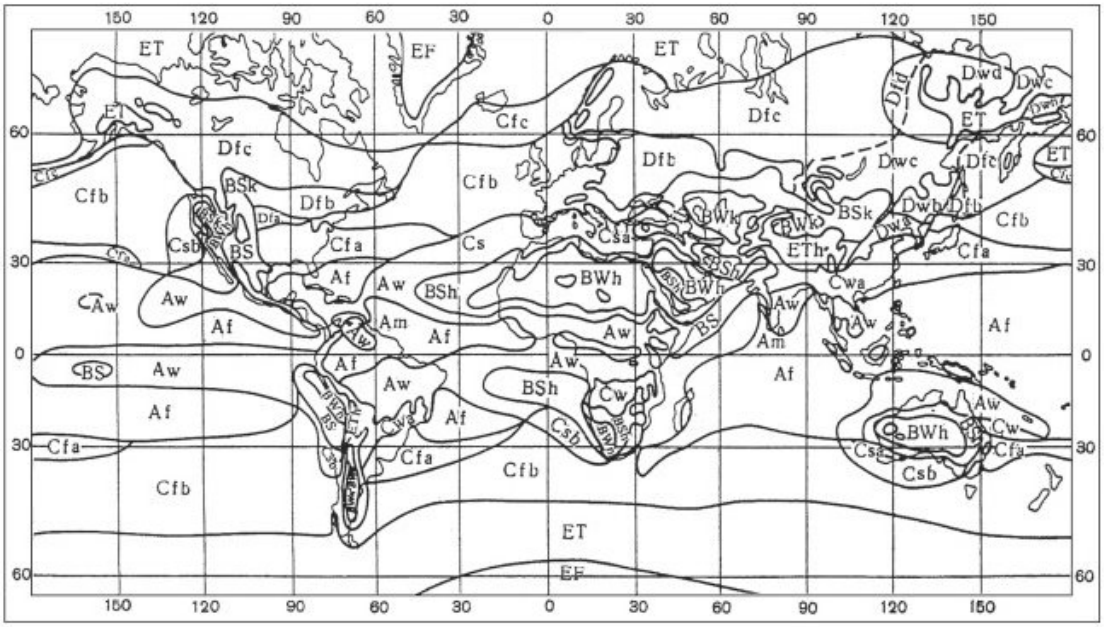

Figure 1. World distribution of climatic types according to Koeppen's scheme

Major category	Additional symbol	Number of symbol in designation of climate	Criteria
A	-	-	Mean temperature of coolest month not less than 18 °C
B	-	-	Average annual precipitation (mm) less than the limit of aridity, which can be calculated as 20*T (where T – average annual temperature in °C) when winter precipitation is dominant, as 20*T+140 when precipitation is evenly spread, and as 20*T+280 under domination of summer precipitation
C	-	-	Mean temperature of coldest month less than 18 °C but greater than -3 °C. Mean temperature of warmest month not less than 10 °C
D	-	-	Mean temperature of coldest month not greater than -3 °C. Mean temperature of warmest month not less than 10°C.
E	-	-	Mean temperature of warmest month less than 10 °C
A	f	2nd	Mean precipitation total in driest month not less than 60 mm
A	m	2nd	Mean precipitation total in driest month less than 60 mm; its addition to 100 mm less than 4% from average annual precipitation
A	w	2nd	Mean precipitation total in driest month less than 60 mm; its addition to 100 mm greater than 4% from average annual precipitation
B	S	2nd	Average annual precipitation is greater than one-half of the limit of aridity for category B
B	W	2nd	Average annual precipitation is less than one-half of the limit of aridity for category B
C, D	s	2nd	Mean precipitation total in driest month for summer season less than one-third of the amount in the wettest month of the winter season
C, D	w	2nd	Mean precipitation total in driest month for winter season less than one-tenth of the amount in the wettest month of the summer season
C, D	f	2nd	Constantly moist (criteria for neither s, nor w not satisfied)
E	T	2nd	Mean temperature of warmest month greater than 0 °C but less than 10 °C
E	F	2nd	Mean temperature of warmest month equal to or less than 0 °C
B	h	3rd	Average annual temperature not less than 18 °C
B	k	3rd	Average annual temperature less than 18 °C
C, D	a	3rd	Mean temperature of warmest month 22 °C or above
C, D	b	3rd	Mean temperature of warmest month less than 22°C. Mean monthly temperature above 10 °C for 4 months or more
C, D	c	3rd	Mean temperature of warmest month less than 22 °C. Mean monthly temperature above 10°C less than for 4 months
D	d	3rd	Mean temperature of coldest month less than -38 °C

Table 1. Symbols and criteria for divisions in Koeppen's classification.

Categories and types	Characteristics
A	Tropical rainy climates; hot all seasons
Af	Hot; rainy in all seasons
Am	Hot; monsoon regime of precipitation with seasonally excessive rainfall
Aw	Hot; winter dry
B	Dry climates
BS	Semi-arid
BSh	Semi-arid; hot
BSk	Semi-arid; cold winter
BW	Desert
BWh	Desert; hot
BWk	Desert; cold winter
C	Warm temperate climates; mild winter
Cs	Mild winter; dry summer
Csa	Mild winter; dry summer; hot summer
Csb	Mild winter; dry summer; warm summer
Cw	Mild winter; dry winter
Cwa	Mild winter; dry winter; hot summer
Cwb	Mild winter; dry winter; warm summer
Cf	Mild winter; moist all seasons
Cfa	Mild winter; moist all seasons; hot summer
Cfb	Mild winter; moist all seasons; warm summer
Cfc	Mild winter; moist all seasons; cool summer
D	Cold temperate climates; severe winter
Dw	Severe winter; dry winter
Dwa	Severe winter; dry winter; hot summer
Dwb	Severe winter; dry winter; cool summer
Dwc	Severe winter; dry winter; short cool summer
Dwd	Severe winter; dry winter; extremely cold winter
Df	Severe winter; moist all seasons
Dfa	Severe winter; moist all seasons; hot summer
Dfb	Severe winter; moist all seasons; warm summer
Dfc	Severe winter; moist all seasons; cool summer
Dfd	Severe winter; moist all seasons; extremely cold winter
E	Polar climates
ET	Very short, cool summer (tundra climate)
EF	Perpetual ice and snow

Table 2. Characteristics of major categories and main climatic types in Koeppen's classification.

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Biographical Sketch

E.I. Khlebnikova was born in 1945 in Leningrad, USSR. In 1963 she entered Leningrad State University, Mathematics and Mechanics Faculty, and in 1968 graduated from the Dept. of Theory of Probabilities and Mathematical Statistics of this University. In 1968 she began to work at the Main Geophysical Observatory in the Dept. of Climatology and in 1975, after postgraduate studies in meteorology and climatology, she received the scientific degree of Candidate in Maths & Physics. Since 1998 she has held a position of leading scientist in the Dept. of Applied Climatology. Dr. Khlebnikova has thirty years of experience in climatology including research on statistical modeling of meteorological processes, methodology of climate monitoring and different aspects of statistical interpretation of meteorological and other observations. She has more than 50 publications in these fields.