CLIMATE ZONES AND TYPES

E.I. Khlebnikova
Main Geophysical Observatory, St. Petersburg, Russia

Keywords: Antarctic zone, Arctic zone, climate zone, equatorial belt, subarctic (subantarctic) belt, subequatorial belt, subtropical belt, temperate belt, tropical belt.

Contents

Summary

Major climate zones and types of the Earth are considered using Alisov's genetic classification as a framework. General circulation features of different climatic belts are

discussed. Energy budget characteristics for the main climatic zones are presented. Brief description of the main climatic types is given.

1. Introduction

The following discussion of world climate zones and types is based on the genetic classification of the Earth's climates, which was devised by B.P. Alisov (see *Genetic classifications of Earth's climate*). According to this classification system, four major climatic belts—equatorial, tropical, mid-latitude and arctic (Antarctic), which are dominated by equatorial, tropical, polar and arctic (Antarctic) air masses respectively—are differentiated in the globe. In addition to these major belts, some intermediate belts—subequatorial, subtropical and subarctic—are also recognized. In each major climatic zone Alisov differentiates, generally, four climate types—continental, oceanic, west coast and east coast climates—and highland climate as a special kind. In some belts the distinctions between definite types are negligible, and so the system includes just twenty-seven types of climate (see *Genetic classifications of Earth's climate,* Table 2), including fourteen types of lowland climates (for the land surface), eight types of oceanic climates and five groups of highland climates.

It is important to note that in most popular classification systems only typification of lowland climates is considered, and the number of major categories usually accounts for 11-16. For instance, in the rather popular classification of the American geographer A. Strahler, thirteen basic climatic types were distinguished. Where the number of major categories is significantly more (for example, in the Thornthwaite system) the classification has not come to be widely used.

The following description of climate zones and types of the Earth should be read in conjunction with Figure 1 in *Genetic classifications of Earth's climate,* which presents the geographical disposition of major zones and the types examined.

2. General circulation features of major climate belts

2.1. Equatorial belt

Equatorial air is formed from the tropical air, brought to the equator by the trade winds of northern and southern hemispheres. The formation takes place in the area of the equatorial depression which has weak winds. The main thermodynamic process, accompanying air transformation, is a moistening of the air.

Equatorial air is distinguished by its great stock (reserve) of unstable energy. It is saturated with moisture, and the conditions of vertical air stratification are favorable for release of the energy. In this connection, convective clouds are of exceptionally great importance in regions with equatorial air.

Radiation processes play a dominant role in the genesis of equatorial climate (see below). Under the influence of the total combination of circulation and radiation factors, there is a moderately hot and very humid climate with high precipitation in the

equatorial belt of America and Africa.

2.2. Subequatorial belt (the belt of equatorial monsoons)

The regions of equatorial monsoons occupy the area between the summer and winter locations of the tropical front in both hemispheres. In summer, equatorial air spreads towards the tropics, and the winter monsoon is a movement of tropical air towards the equator.

The direction of the summer monsoon is mainly determined by the influence of baric depressions, arising over the continents in this season. On the western coasts and on the continents, the monsoon has a western component; on eastern coasts it has an eastern component. The flow of tropical air with eastern component is a head current, which equatorial air, being a relatively cold air mass, interacts with in lower layers. At the western coasts of the continents, and in the central regions of the continents, relatively cold and humid equatorial air meets hot and dry continental tropical air. This results in the dryness of tropical fronts and in low precipitation amounts. Precipitation falls mainly behind the front, in equatorial air masses, and has a character of local convective shower-rains. Owing to this, precipitation decreases on the continents, moving further from the equator, because of the decrease in vertical thickness of the humid equatorial current.

To a large extent, the winter monsoon is a trade wind, and it has an eastern component everywhere. In the winter half of the year, while tropical air prevails in the monsoon regions, western and central regions are more arid, because of the incoming dry continental air. In winter, precipitation amount sharply decreases at the eastern coasts as well, but air humidity remains high and moderates the dryness of the winter period.

A typical feature of the equatorial monsoon climate is the clearly marked period of summer rains, accompanied by increase in cloudiness, high air humidity and a certain fall of temperature. This summer minimum is related to the incoming cold equatorial air, and in the latitudes closer to the equator, to the summer decrease in the height of the sun.

2.3. Tropical belt

In summer, the formation of the tropical air over the continents takes places in low-gradient thermal depressions, and in winter – in the areas of high pressure.

The tropical air is dry and of a stable stratification in its nature, since adiabatic heating of the descending anticyclone air causes a decrease in the vertical gradient of temperature and lower relative humidity. Over the ocean, the tropical air gets moistened in the lower layers, and comes with trade winds to the eastern coasts of the continents with great amounts of moisture-unstable energy, differing insignificantly in temperature and humidity from the equatorial air. Over the continents, it retains its dryness, acquires still higher temperature, and is distinguished by high dust content.

Continental tropical climate is characterized by extreme dryness. The typical landscape,

associated with this climate, is desert and arid steppes. In inner continental regions, at latitudes close to the tropics, there is almost complete lack of precipitation, because of dry air and a high level of condensation. This level is almost never reached during the process of thermal convection, despite intensive development of thermal convection in lower layers, over the heated soil. As a result of a powerful convection, strong whirlwinds, raising enormous columns of dust, sand and even shingle, often arise over the continents. Cyclones of the polar front only occasionally penetrate into the tropical zone, causing showery rains of short duration.

Dryness and sharp variations of soil temperature contribute to a rapid destruction and disintegration of rocks. As a result, the lower layer of the air, even with weak winds, saturates with dust, which causes an increase in temperature. Under such conditions, air temperature may reach world maximal values (up to 60 °C). Daily temperature ranges sometimes exceed 35 °C. As compared with the equatorial belt, annual temperature ranges are also high, resulting from the annual march of the tropical air temperature associated with the considerable changes in the height of the sun. Advective factors, i.e. the incoming of the temperate or equatorial air, may be of great importance only in the boundary regions of the tropical belt.

Climate of the western coasts of the continents (of the eastern periphery of oceanic anticyclones). In the eastern part of the subtropical anticyclones over the oceans, the lower layer of the trade wind is relatively cold, due to the air coming from the temperate latitudes. Above this relatively cold air, warmer air of the upper layers of the trade wind flows in the same direction, being heated due to the air descending in the anticyclones. Temperature inversion, resulting from this, prevents the development of ascending currents and the formation of clouds and precipitation. Cold sea currents, washing the western coasts of the continents in the tropical latitudes, facilitate the strengthening of trade wind inversion. Due to the insufficient vertical exchange, the air, lying below the layer of inversion, is very humid, so fogs often occur there.

This climatic type is observed on the western coasts of the continents in the tropical zone, and features almost complete lack of rains, while relative humidity is high, especially in summer, during the activation of oceanic anticyclones. Temperatures are comparatively low all the year round. Fogs are observed rather frequently. Owing to the big difference between sea and land temperature, breeze circulation is exceptionally developed here. During the day, when the breeze is blowing, air humidity sharply increases on the coast. Conversely, at night it falls because of the wind from the continent. Daily breezes typically have high force and often penetrate deep into the continent (up to 100 km), like stormy winds.

Climate of the eastern coasts of the continents (on the western periphery of oceanic anticyclones). At the western periphery of anticyclones, trade wind inversion is considerably weaker; it is located higher than the condensation level of the lower humid layer of the trade wind and does not prevent the resolution of moisture-instability and the falling of precipitation. The climatic conditions are rather similar to equatorial ones. Only in winter, falls in temperature may be observed, caused by the incoming temperate air mass.

Relief plays a substantial role here. Owing to the considerable trade wind speeds and peculiarities of moistening, extreme contrasts in the distribution of precipitation occur in the highlands, resulting in great variety of landscapes (tropical forests, savanna and steppes).

2.4. Subtropical belt

As with the regulation of precipitation regime by the seasonal displacement of the tropical front in the climate of equatorial monsoons, winter and summer changes in the location of polar fronts cause dry and rainy spells in the subtropics. The climate in the subtropics is formed under the influence of seasonal changes from tropical to temperate air, and of the cyclonic activity on the front that bounds these air masses.

Continental subtropical climate is influenced by many factors, which are active at different seasons. In summer, in vast baric depressions of thermal origin, very dry continental tropical air, analogous in its features to the air of continental trade winds, is formed over the strongly heated soil of deserts and steppes. Summer transformation of the temperate air into the tropical one starts over the continents in the temperate latitudes, and this causes thermal homogeneity of the air over vast territories, the blurring of the fronts and the setting of dry clear weather. In winter, the difference in the features of the temperate and tropical air is important, causing the formation of a front between these air masses and the development of cyclone activity at this front. The winter-spring rainy spell is related to this cyclonic activity.

The distinctive feature of the weather regime in the continental subtropics is the monotonously dry and hot summer, with mean temperatures of about 30 °C, and very unstable winter with precipitation and sharp changes in temperature. Even in the southern regions of the continental subtropics (in northern hemisphere) frosts may reach -15 °C. The annual precipitation amount does not usually exceed 500 mm, and may be much less. High temperature and the dryness of summer with the normal lack of precipitation, stresses the vegetation, and so the prevailing landscapes in this zone are arid steppes and semi-deserts.

Coastal subtropical climates. In the subtropical belt the climates of the western and eastern coasts of the continents are as different as in the trade wind areas. In summer, when subtropical anticyclones spread into the higher latitudes, these differences are due to the same factors as in the tropical belt; in winter, they are conditioned by particular factors. On the western coasts of the continents, i.e. on the eastern periphery of the subtropical anticyclones, clear and dry weather prevails in summer, while on the eastern coasts, on the western periphery of the anticyclones, heavy precipitation falls in summer.

Climatic conditions of the winter season depend on the location of the polar front. On the western coasts of the continents, the polar front is displaced from the mid-latitudes to the subtropical latitudes; cyclone activity develops here, causing precipitation to fall during the whole winter season. On the eastern coasts, under the influence of powerful current of the temperate continental air, formed in the continental winter anticyclones, the polar front moves to considerably lower latitudes (especially on the eastern coasts of

Asia), and the subtropical regions are filled with dry and relatively cold air. Under prevailing conditions of anticyclonic circulation, precipitation sharply decreases here, compared to summer.

Thus, in the subtropical zone the climate of the western coasts is characterized by clear dry summers and mild rainy winters. The climate of the eastern coasts is characterized by humid hot summers, and dry and relatively cold winters. The climate of the eastern coasts is of a monsoon character: the winter monsoon is a flow of continental temperate air, and summer monsoon, of tropical marine air. These climatic peculiarities are reflected in the types of vegetation. On western coasts, with dry summers, landscapes of Mediterranean type including vegetation of semi-arid zones prevail. Under conditions of rainy hot summers, luxuriant moist forests occupy the eastern coasts.

A typical feature of the subtropical climates, distinguishing them from the tropical climate, is snowfall that is a regular though rather infrequent phenomenon. It does not form a snow cover in the lowlands, but in the highlands, it may stay for several weeks. The rare snowfall may be observed in lower latitudes, up to the tropics, but it is not a feature of this climatic type.

2.5. Temperate belt

The features of the air masses which are formed in middle latitudes, are determined mainly by the peculiarities of the radiation balance of this latitudinal belt. They also depend very much on the character of the surface boundary layer, and the air masses of marine and continental origin are very different. On analyzing the climates of the temperate belt, however, we must keep in mind that the prevalence of the polar air masses over the other types of air masses is not very high: only 60-70% in the central regions of the continents, and about 40% at the edges. One of the main features of the temperate belt is intensive cyclonic activity. The tropical and arctic air masses may penetrate deep into the zone of the mid latitudes, causing sharp changes in temperature and prevailing weather conditions. This differentiates the climates of mid latitudes from those of tropical regions.

In mid latitudes, the frontal processes become a very important climatic factor. The main precipitation amount in these latitudes is of a frontal origin; thermal convection precipitation does not play a significant role. In winter, precipitation falls over the continents during the process of external moisture exchange between the ocean and the continent. In summer, the process of inner moisture exchange over the continent itself is of a certain importance. In spring, the source of the soil moisture is mostly snow cover, formed in winter due to the precipitation of external moisture exchange. In the mid latitudes of the inner continental regions, precipitation is accumulated gradually during a whole winter, and so the precipitation of the cold period is of great significance for general moistening.

Continental climate of the temperate belt. Continental air is formed in the inner continental regions from the marine air of the temperate belt and from the arctic (Antarctic) air. Summer transformation results from the heating of air masses and is rather fast, due to the convection in the relatively cold air being unstable. The most

intensive is transformation in anticyclones, when the weather is calm and clear.

In winter, the marine air is cooled over the continent, but the arctic air is heated, though very slowly. The marine air transformation is also slowed down, if compared to summer, because of the absence of thermal convection, and the impediment in the vertical exchange. Heavy cloudiness, which usually accompanies the incoming marine air in the winter, and strong winds, also help to maintain the features of the marine air, flowing deep into the continent. But relatively warm marine air is often driven out from the Earth's surface to the higher layers by the cold continental air.

The physical features of continental air undergo sharp changes, depending on the season. In summer, the continental air is characterized by comparatively high temperature, low relative humidity, and by unstable stratification in lower layers. In winter, the continental air has low temperature, considerable humidity and stable stratification, causing its further cooling. Winter inversions of temperature—sometimes very substantial ones—cause the setting of calm, cold weather and are typical for the air masses of this type. Snow cover plays an important role, being an essential peculiarity of winter landscape on the continents in the middle and high latitudes.

In the temperate belt not only the features of the continental air, but also the incoming marine air masses, determine the thermal and moistening regime. This incoming effects both extreme deviations and mean data. Fully continental climate can occur only on the large continents. This is because the influence of the surface layer on the air masses permanently moving over it, can be displayed completely only over vast areas, and the conditions of atmospheric circulation, typical for this belt, arise only over the great continents.

In the temperate belt, the level of thermal influence of the surface layer on the character of atmospheric circulation over the continents increases sharply as compared to the tropics. As a result, continental temperate climate is found only in the northern hemisphere. The processes of summer and winter transformation of air masses equally cause the weakening of cyclonic activity over the continents, and decrease in cloudiness. Under such conditions, radiation balance, as a climatic factor, acquires paramount importance. The type of vegetation in continental climate is characterized by a natural change from taiga in northern regions to steppe in southern regions. Broad-leaved forests are mainly typical of climates which are transitive from oceanic to continental.

Climate of the western coasts of the continents. Marine air prevails on the western coasts of the continents. As a result, the western coasts in the temperate belt have a climate with a rather warm (for these latitudes) winter, and relatively cool summer, and with high humidity and considerable precipitation amount all the year round.

Moderate temperature range and high air humidity are the peculiarities of the very marine air, and uniform distribution of precipitation throughout the year is a result of cyclonic activity: in summer, at the polar, and in winter at the polar and arctic fronts.

These features of the climate of the western coasts in mid latitudes distinguish it sharply

from the neighboring subtropical climate—with its hot and dry summer. On the western coasts in the temperate belt, mean temperature decreases with the increase in latitude, but almost everywhere, it still remains positive in winter. Temperature latitudinal changes in temperature occur not so much due to the change in the marine air temperature as due to more frequent incoming of the arctic (in the North) and tropical air (in the South).

Monsoon climate of the eastern coasts of the continents. The climate of the eastern coasts of the continents in the temperate zone of the northern hemisphere, as in lower latitudes, has a monsoon character. The winter monsoon is the northwestern current of the cold continental air, driving the polar front to subtropical zone. In summer, the polar front advances to the higher latitudes, and cyclonic activity, developing at the front, ensures a rainy summer.

Thus, the monsoon climate of the eastern coasts in the temperate belt is characterized by the cold, clear, winter with low amount of snow, and by the rainy moist summer.

2.6. Subarctic belt

The borders of the subarctic (subantarctic) belt are determined by the location of the arctic (Antarctic) front in winter and in summer. In summer, the arctic front arises in the form of separate branches, not very connected with each other, and so it is difficult to determine its general location. Owing to this, the borders of the subarctic zone are less definite, than the borders of the other zones.

The main features of the subarctic climate are determined by the peculiarities of the radiation process (see below). Over the continents, there is a sharply marked anticyclonic weather regime, within extremely low air temperatures and weak winds in winter. The prevalence of the cold arctic air in winter, and the warm continental air in summer causes an exceptionally high annual range of air temperature.

Precipitation is mainly of frontal origin in the subarctic belt. Precipitation is comparatively low, especially on the continents.

-
-
-

Bibliography

Budyko M.I. (1956). The Heat Budget of the Earth's Surface, 256 pp., Gidrometeoizdat, Russia. [in Russian]. [This is a fundamental work on heat-balance climatology where peculiarities of different climate zones are considered in terms of heat balance]

Critchfield H.J. (1983). General Climatology. [This is a general guide on climatology including the description of the main climatic types and applied problems]

Drozdov O.A., V.A. Vasiliev, N.V. Kobysheva, A.N. Raevsky, L.K. Smekalova, E.P.Shkolny (1989). Climatology, 568 pp., Leningrad: Gidrometeoizdat [in Russian]. [This considers the main controlling factors of climate and the principles of climate classification]

Global Climate Normals 1961-90. US National Climate Data Center (http://www.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwAW~MP) [This CD-ROM contains information on the 1961 - 1990 global standard climate norms for over 4000 stations worldwide]

International Station Meteorological Climate Summary. Version 4.0. US National Climate Data Center (http://www.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwAW~MP) [This CD-ROM gives climatologic summaries for more than 2600 locations worldwide]

Landsberg H.E. (1969-87). World Survey of Climatology, Vol.1-15, [This is a comprehensive detailed edition on climates of particular regions of the Earth]

Monthly Climatic Data for the World. US National Climate Date Center (from 1948 up to present) [This publication contains monthly mean temperature, pressure, precipitation, vapor pressure, and sunshine for approximately 2000 surface stations worldwide]

Strahler A.N. and Strahler A.H. (1987). Modern Physical Geography.-[This contains a description of climates of the world according to Strahler's system of classification]

Trewarta G.T. (1981). The Earth's Climate Problems. [This contains the description of the main climatic types, soils and also vegetation]

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 studyies in meteorology and climatology, received a scientific degree of Candidate in Math & Physics. Since 1998 she has been a 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.