LOCAL CLIMATES

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Contents

Summary

There are different concepts of macroclimate, local climate (or mesoclimate) and microclimate in climatology. According to a majority of climatologists macroclimate is the climate of area or zone characterized by long-term observations at many meteorological stations in the given area or zone, local climate is the climate of area, characterized by observation at one or several stations in the given area, microclimate is the climate environment inside the given area, determined by special microclimatic observations.

The local climate on a horizontal scale from 1 to 100 km and on a vertical scale from 50 to 1000 m is described in this chapter.

The features of local climate are formed by the macroscale and mesoscale heterogeneity, which includes hilly relief, rivers, lakes, diversity of a soil-vegetative cover, large cities. The changes of climatic characteristics because of this heterogeneity can be larger than by transition from one climatic zone to another.

1. Introduction

Distinctions of local climate in different territories are shown first of all in the features of heat and water balances of underlying surface. They produce the differences of other climatic characteristics. The relationship between the components of heat and water balances is very important for the formation of features of local climate. The roughness of underlying surface influences the local climate just as large-scale relief influences the global climate conditions. The height above a sea level has no essential importance while the expositions of slopes and the forms of relief play a leading role in the formation of local climate.

The local circulation (mountain-valley winds, foehns, breezes etc) appears owing to the differences between the components of radiation balance of different forms of relief and water surface.

The prominent kinds of local climate are urban, island, and forest climate.

The local climate of large city is formed under the influence of buildings, streets cover, industrial enterprises, transport and etc. The climatic features of city include the increased surface air temperature in the central part of city (urban heat island), reduced evaporation, disturbance of atmospheric circulation (urban breeze), intensive air pollution, reduction of direct radiation income, intensification of convection, insignificant increase of cloudiness, frequency and sums of precipitation during the warm period, the reduction of fog frequency. Urban climate as a type of local climate can be divided into many microclimate types depended on topography, width of streets, green plantings etc.

Two active surfaces play a significant role for the forming of forest climate (in particular broad leaved forest): the upper surface of leaves and the ground surface which receives the radiation not absorbed by leaves. The radiation flows formed in a forest are results of interaction of the radiation regimes of different vegetation. The solar radiation penetrating through the crowns of trees is weakened little by little. Besides, the relationship between direct and diffuse radiation is changed, since the significant part of direct solar radiation is transformed to diffuse one. As a result the temperature of forest soil surface in summer is lower than in the open country. The differences can reach several degrees. In winter the soil surface temperature in forest is higher than in the open area because of thick snow cover and proper trees radiation. Atmospheric precipitation rises due to the turbulence and intensification of condensation. The great part of precipitation is accumulated by trees crowns. The thickness of snow cover and water stocks are larger than in the open area. Besides, snow is disposed more evenly. The thawing of snow is slowed down because of the reduction of vertical air exchange and shading. It is especially noticeable in coniferous forest. The forest soil freezes through smaller depth. The forest reduces the high water and raises the level of mean water.

The features of the local climate of islands are formed under influence of the significant differences between heat balances of land and water. In coastal zone the local circulation (breezes) appears because of the different temperatures of water and land surfaces. It refers first of all to tropical latitudes where breezes are observed constantly and there is a distinct diurnal course of wind speed and direction. The orography of islands influences the penetration of breeze inland. The heat properties of land and water are very important for the temperature and humidity regimes. The distribution of precipitation is determined by the relief of islands. Besides the precipitation amount is influenced considerably by the presence of cold or warm currents washing an island. The cold currents cause the steady air stratification and reduction of precipitation. The warm currents, on the contrary, strengthen air convection and increase precipitation.

2. Spatial Scales of Local Climate

The processes characterized by wide range of spatial and temporal scales are typical for the atmosphere. The spatial scales are determined by the sizes or length of the air perturbation wave and temporal ones - by the time of their existence or the period of fluctuations. The main reasons producing the differences of atmospheric processes are the features of active surface. An active surface is the surface receiving and giving back energy. This surface is a source of the temperature fluctuations of adjacent layers of air and ground. The processes of absorption and emission of radiation, evaporation and heat exchange occur not only on the surface, but also in layers of various values of thickness. So the active layer is the surface layer assimilated absorbed radiation.

The processes of different scale don't exist separately. Therefore an attempt to divide the atmospheric phenomena into various discrete classes is not always successful. As a result we have large variety of climate classifications by scales.

We can determine the concept "climate" as statistical regime of different-scale atmospheric processes. There are distinguished macroclimate, mesoclimate, local climate, and microclimate. Some authors support also the concept of tono- and nanoclimate. Tonoclimate by its scales occupies an intermediate place between meso- and microclimate. Nanoclimate follows the microclimate.

It is most convenient to use two systems of the criteria of climate scales: qualitative system by S. P. Khromov and quantitative system by. E. N. Romanova.

According to S. P. Khromov it is possible to determine the climate of area or zone, characterized by long-term observations of many meteorological stations in the given area or zone as macroclimate. The climate determined by observations of several stations or station in tract (taxonometric division of landscape) is local climate. The climate of other taxonometric unit – facies - inside the given tract which is determined by special microclimatic observations is microclimate.

The classification characteristics (criteria) of climates according to E. N. Romanova are submitted in the Table 1.

Mesoclimatic features are formed under the action of both macroscale and mesoscale heterogeneity of large area. The elements of macroscale heterogeneity are mountain relief, oceans, and seas. Mesoscale heterogeneity characterizes a hilly relief, rivers, lakes, diversity of soil-vegetative cover, large cities. Microscale ones (hillocks, hummocks, furrows) influences the meteorological regime of the lowest surface air layer and upper layers of ground. Climatic variations of such types of surface relief were offered to term as nanoclimatic ones. These variations can be essential enough and they should be considered when studying the growth and development of agricultural plants.

The differences of climatic characteristics at presence of meso- and microclimatic heterogeneity can be greater at close distances, than by transition from one climatic zone to another one.

Heterogeneity of a underlying surface		Scale of disturbance	
Type	Characteristic	Horizontal	Vertical
Mountain relief Hilly relief Rivers Lakes, seas, oceans Soil-vegetative cover Large city	Mesoclimate System of mountains Massifs having more than 100 km^2 Width more than 1 km The area of mirror from 50 to 100 km^2 Massifs having more than 100 km^2 Areas of city	less than100 km	1000 m
Mountain relief Hilly relief Rivers Lakes, ponds Soil-vegetative cover City, settlement	Microclimate Separate sites Separate hills or groups of hills Width less than 1 km The area of mirror less than 50 km^2 Massifs having less than 100 km^2 Elements of building, separate buildings, streets	less than 10 km	from 100 to 200 m
Microhills and microfalls (hillocks, hummocks, furrows, sinks)	Nanoclimate Separate roughness with difference of heights measured by units and tens of centimeters	from 1 to 3 m	less than 0.5 m

Table 1. The classification characteristics of meso-, micro- and nanoclimate

Table 2 presents the comparisons of latitudinal, high-altitudinal and microclimatic gradients of meteorological elements.

Meteorological element	Gradients		Microclimatic gradient (at distance 100 m)
	latitudinal (at distance 100 km)	high-altitude (at distance 100 m)	
I, $MJ \cdot m^{-2}$ in month	>From 8.4 to12.6	-	From 46.1 to 155.0
R, $MJ \cdot m^{-2}$ in month	From 4.2 to 8.4	-	From 41.1 to 134.1
T,°C	From 0.6 to 0.8	>From 0.5 to 0.7	From 5 to 7
T_{max},°C	From 0.6 to 0.8	>From 0.7 to 0.8	From 9 to 10.5
T_{min},°C	From 0.7 to 0.9	From 0.6 to 0.9	From 6 to 9
τ_f ,daily	From 3 to 5	From 5 to 6	>From 20 to 30
T_{20},°C	From 0.6 to 0.8	-	From 2 to 4

Note: I - direct radiation, R - radiation balance, T - monthly mean air temperature, τ_f - duration of frostless period, T_{20} - soil temperature at depth 20 sm.

Table 2. Latitudinal, high-altitudinal and microclimatic gradients of meteorological elements.

Latitudinal gradients of the radiation characteristics (direct radiation, radiation balance) are approximately 10 times less, than microclimatic gradients between the northern and southern slopes of hills with an angle of 10^0. Approximately same ratio is kept for the characteristics of thermal regime. The microclimatic gradients between the opposite slopes of hills correspond to the change of meteorological elements at 10^0 of latitude and at 1000 m of height. The soil temperature gradient is smaller. It exceeds the latitudinal one at depth 20 cm by the factors from 3 to 5.

The physical modeling seems rather perspective in microclimatic researches. It is expedient to use methods of physical modeling in chambers of artificial climate Standard microclimatic observations of temperature, humidity and wind ought to be made at some levels above the earth's surface. The height of researched air layer depends on the state of active surface (herbage, forest, water surface etc.). If it is impossible to organize measurements at several heights, it is necessary to provide measurements of temperature and humidity at standard heights 0.5 and 2.0 or 0.2 and 1.5 m, soil temperature and wind at height of 1 and 2 m.

3. Heat Balance of Active Surface

The energy and humidity regime of underlying surface is of great importance for microclimate formation. Microclimatic researches use the equations of heat balance and moisture balance of the active surface when considering the basic processes of energy exchange. The heat received by surface as radiation balance substantially depends on the properties and structure of underlying surface and upper soil layers as well as, on the value of albedo. In various landscape zones the albedo can change in a wide range. So, for example, albedo of fresh snow is up to 90%. The albedo of forest depends on the species and season. Dark coniferous forest has albedo about 18%. Albedo of leaf-bearing forest is from 16 to 27%. The reflective properties of ground covered by vegetation include the albedo of vegetation and soil.

The albedo of water is insignificant and makes from 5 to 7% on the average. However in the morning and evening hours (when the height of the sun is small) the albedo of water reaches 80%. As a result of solar radiation absorption the active surface is heated up. Thus the part of heat is spent on long-wave radiation of active surface, heating of air and evaporation. The other part is transferred to deeper soil layers through heat conductivity.

The correlation of the heat balance components determines the formation of meso- and microclimatic features of concrete area. If we consider dry underlying surfaces, almost all received heat is spent for turbulent heat exchange in ground – air system. In the humidified area the process of evaporation is the basic one. Owing to this process soil temperature is reduced. As a result turbulent heat exchange considerably decreases.

The components of heat balance differ substantially in various landscape zones. So, on the Russian territory in the warm season in a forest zone the turbulent flow of heat (P) makes 20%, heat losses for evaporation (LE) -80% of radiation heat. In steppe zone P is from 30 to 50% and LE is from 50 to 70%. In desert P is from 70 to 90% and LE is from 30 to 10%.

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Biographical Sketch

Kobysheva Nina Vladimirovna, Dr. of geogr. Sci., Professor, Honored Scientist, Head of the technical climatology laboratory of MGO, Professor of St-Petersburg University. Fields of scientific interests are statistical methods in climatology, applied climatology. Author of 7 monographs, 3 text-books, Building Standards and Rules "Building Climatology", more then 200 papers. Supervisor and editor of Scientific-Applied reference book. About 25 Candidate's dissertation were defended under her guidance. A member of working group of WMO, working group № 13 CIB, working group № 75 of International Electrotechnical Commission. Was conferred a medal of National Exhibition of economy achievements, medal "Honoured expert of gidro-meteo service", Voeikov's prize, International WMO and CCL certificate.

Was born in 1925 in Omsk city. Was graduated from the Odessa Hydrometeorological Institute in 1948. In 1955 has defended the candidate dissertation after finishing the post-graduate course of Main Geophysical Observatory.