

REGIONAL DISTRIBUTION OF RIVERS AND STREAMS IN NORTH AND CENTRAL AMERICA

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Summary

North and Central America is a continent of striking contrasts in physiographic and socio-economic features as well as in the rates of human impact on river runoff. As a whole, the continent is rich in river water resources, with an estimated 7900 cu. km year⁻¹ of renewable fresh water resources. This quantity makes 18% of the total world river runoff; the potential water availability for the population is 17 400 cu. m year⁻¹ per capita, which is 2.3 times higher than the world average.

There are many full-flowing rivers on the continent; moreover, the Mississippi and Missouri River system is one of the largest systems in terms of volume of runoff, drainage area and length. There are many lakes on the continent among which there are the Great Lakes—the largest in the world in water surface (the total water area is 251 000 sq. km).

A specific feature of the continent is the extremely uneven water resources distribution, which is not coincidental with the distribution of population and economy, i.e. with fresh water demands. According to physiographic (natural) and economic conditions, the continent can be subdivided into three regions; Northern region, including Canada and Alaska; Central region (USA without Alaska) and Southern region, including Central America and the islands of the Caribbean.

About 63% of the river water resources of the continent and 8% of the total water use fall within the Northern region. In the Southern region these values equal about 14% and 19%, respectively, and in the Central region – 23% and 73%.

If we consider the water availability for the population needs in the three regions, we see that at present it is 27 times higher in the Northern region than in the Southern and Central regions. This difference will increase, in the Southern region in particular, where population growth is very high.

The objectives of further studies in the field of water resources are a more detailed study of river runoff formation and its use in the extreme north and south of the continent, more reliable assessment and prediction of water use in the future, investigation of the effect of global warming on water resources and water availability, and development of various measures for adaptation to possible unfavorable results.

1. Introduction: General Information about the Continent

North and Central America is the third largest continent (after Eurasia and Africa). It occupies 24.2 million sq. km together with the adjacent islands. The largest islands adjacent to it are: Greenland (2.2 million sq. km), Canadian Arctic Islands (1.3 million sq. km), the Great Antilles (210 000 sq. km), and Aleutian Islands, Newfoundland (110 000 sq. km). The Lesser Antilles, the Bahamas and the Bermudas, and a number of other small islands are also referred to North America. The total area of all the islands is about 4.1 million sq. km.

The continent of North and Central America stretches for 7500 km from the Arctic to the tropics and for 6400 km from west to east like a giant triangle. Its northern extremity, i.e. the north extremity of Greenland is at 83°NL being the most northern point of land in the world; the most southern point (at 7°12'NL) is on the Isthmus of Panama connecting North and South America.

There are more than 20 countries on the territory of North and Central America; they greatly differ in climate, socio-economic and political situation, area and population size. Ten countries occupy the mainland continent, and the other countries occupy islands, mainly in the Caribbean. Canada (9976 sq. km), the USA (9363 sq. km) and Mexico (1973 sq. km) are the largest countries.

There are four more countries with an area of more than 100 sq. km: Nicaragua (130), Honduras (112), Cuba (111) and Guatemala (109). The other countries occupy much smaller areas. A specific place is occupied by the large territory of Greenland, under the protection of Denmark.

In 1995 the population of the continent was 453 million. More than a half of the population, about 262 million, inhabited USA; 28 million lived in Canada, 95 million in Mexico, and the remaining 68 million lived in the other countries of Central America.

The physiographic features of North and Central America are variable, which is explained by its geographic situation, configuration and the complex composition of its surface. The shoreline of the continent is indented by numerous bays, gulfs and peninsulas. The largest peninsulas, Labrador, Alaska, Baja California, Yucatan, Florida, etc. project far into the ocean. The coasts of the continent are separated by Hudson Bay in the north and by the Gulf of Mexico in the south; these extend deep into the continent and greatly affect its physiography. Hudson Bay is closely connected with the Arctic Ocean; the water temperature there does not exceed 10 °C; ice events are observed in Hudson Bay most of the year and it serves as a kind of refrigerator for the inland regions of the continent. Conversely the warm Gulf of Mexico is a source of a heat and moisture. This explains great differences in the climate conditions of the continent; the climate varies from sub-Arctic in the north to subtropical in the south. Canada and Alaska (USA) are in the zone of temperate and sub-Arctic climates; USA – in temperate and subtropical climates; Mexico and the countries of Central America are in the zone of subtropical and tropical climates.

The North American continent is very rich in natural resources. There are vast fertile areas with climate favorable for agriculture, abundant water resources with large river and lake systems, large mineral deposits, and vast woodlands with precious timber.

2. Factors Affecting Network Development and Runoff Regime

2.4. Topography, Landscape

The river network in North and Central America, just as on other continents, is closely connected with climate, soils and plants, as well as with human activities to a great extent.

North and Central America is characterized by variable topography, though in general (e.g. if compared with Eurasia) the relief is less elevated: plain areas occupy double the area of mountainous terrain. Mountains extend along the entire west coast whereas the central and eastern parts of the continent are plains and lowlands, except for the (not very high) Appalachians.

Physiographic zones of the continent and types of landscapes representing geographic complexes of similar origin and relief, and formed under conditions of similar climates, soil types and plants are given in Figure 1.

The northeastern part of the continent is occupied by the Laurentian Shield, its contemporary relief was formed by the glaciation during the Quaternary period; hills alternate with numerous lakes connected with the ocean by a dense but poorly developed river network. In some places of the Laurentian Shield lakes occupy 50 to 60% of the area. The permafrost zone occupies almost all the north part of the shield. Along with tundra, taiga landscapes are widespread (see Figure1).

Southward and westward of the Laurentian Shield there is a very large plain; its surface tends to a gradual rise in the direction of the Cordilleras and Appalachians and to a gradual fall to the Gulf of Mexico. The vast area between the Cordilleras and Appalachians is usually subdivided into three physiographic regions, i.e. Central Valley, Great Plains and Coastal Plains, the latter consisting of Gulf Plain and Atlantic Coastal Plain. The largest river systems of the continent—Mississippi and Missouri, St. Lawrence and Mackenzie rivers—have been developed on large plains.

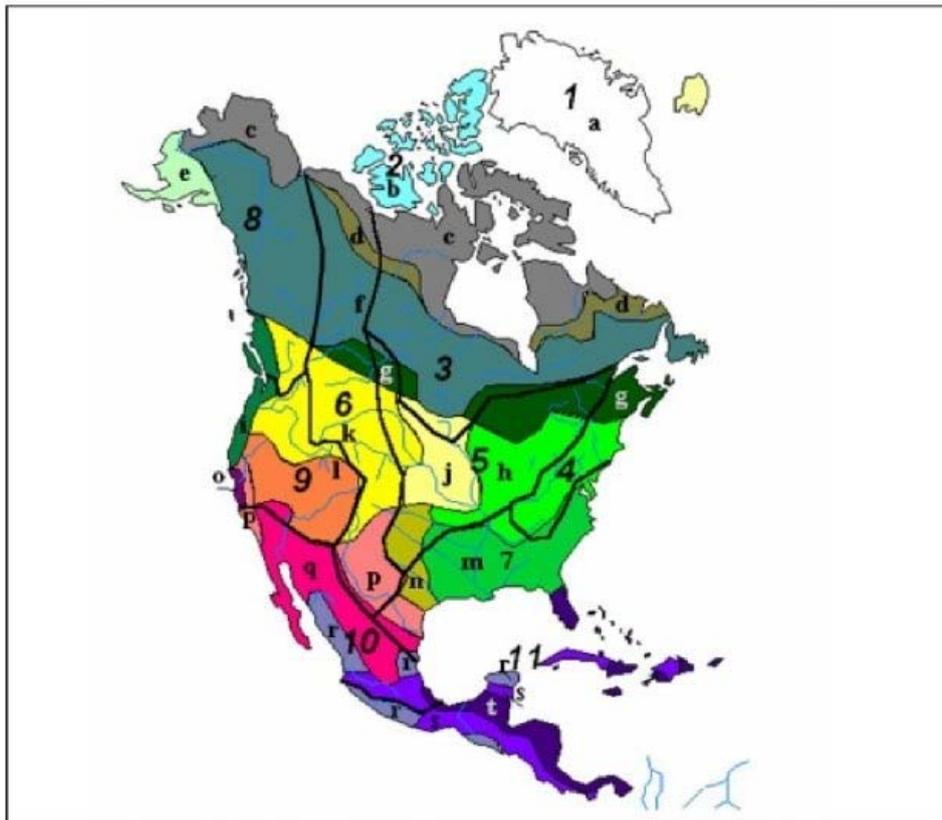


Figure 1. Types of landscapes and physiographic zones of North and Central America.

The Central Valley extends southward from the Laurentian Shield. In its north, the Central Valley has evident marks of glaciation with typical shapes of glacial and lake-glacial relief; the Great Lakes (the world largest lake system) are found here. Predominant elevations of 150-500 m high, the types of natural landscapes alternate from taiga and subtaiga in the north to broad-leaved forests and forest-steppes in the center and subtropics in the south. Intensive cultivation of the territory stimulated development of urban landscapes, especially in the coastal areas of the Great Lakes.

To the west of the Central Valley there are the Great Plains, located on the next elevated step; the Great Plains extend along the entire east slope of the Cordilleras as a wide stripe. In fact, it is a system of plateaus divided by ledges gradually rising towards the Cordilleras, with the ledges distributed at elevations up to 1500 m. Here, the surface of the Great Plains is cut by numerous streams rising in the mountains. In general,

however, the surface of the Great Plains is flat—steppes prevail. In the north forest-steppe and taiga landscapes are predominant.

The coastal plains, i.e. Gulf Plain and Atlantic Coastal Plain are flat; the coastal areas being severely marsh-ridden. A number of flat horizontal terraces gradually drop to the ocean water level. These terraces are intersected by numerous rivers flowing down the Central Valley, Great Plains, Cordilleras and Appalachians. South forest types of landscapes depend on the humid subtropical climate here. Westward, the forests are replaced by forest-steppes and steppes; forest tropical landscapes are observed in the extreme south of Florida (see Figure 1).

The geology and topography of the eastern part of the continent are closely associated with the Appalachians formation. The Appalachians are characterized by forest landscapes of boreal, subboreal and subtropical types presented by the appropriate altitudinal belts.

The Cordilleras (the major mountain system of North America) occupy the western part of the continent. It is one of the world's largest mountain systems because it extends into South America. Its length is about 7000 km, the width varying from 800 km (in Canada) to 1600 km (in USA).

The Cordilleras mountain system is usually subdivided into several reaches corresponding to appropriate physiographic zones: North Cordilleras, Central Cordilleras, Mexican Plateau and Central America. The Cordilleras consist of three longitudinal orographic belts almost all over their length, i.e. East belt, or Rocky Mountains, West belt or Pacific range and Inner belt. Each belt consists of a number of mountain ridges and plateaus.

The West or Pacific range contains the highest ridges; Mount McKinley (6193 m) is the highest point of the Alaska Range.

The Inner Belt forms several plateaus, i.e. Yukon Plateau and Fraser Plateau in the North Cordilleras, and the Columbia and Colorado Plateaus and Great Basin in the Central Cordilleras.

The upper reaches of many river systems of the continent rise in the North and Central Cordilleras (the Yukon River, Peace River- Mackenzie, Fraser, Missouri, Columbia and Colorado rivers). The Columbia River, one of the largest rivers in North America, flows along the Columbia Plateau and forms, together with its tributaries, a system of canyons to 1 km deep. But one of the world's deepest gorges is formed by the Colorado River. This is the Grand Canyon, 320 km long and 1800 m deep, cut by the vertical river erosion through the multicolored strata of mountain rocks in the middle reaches of the Colorado River.

The Mexican Plateau is a continuation of the Central Cordilleras where the Coast Range forms the California Peninsula. In the north of the Mexican Plateau streams are temporary and shallow; in the south the rivers are full-flowing, with many lakes. The climate of the inner part of the Plateau is extremely dry, tropical deserts prevail.

The Antilles and the Isthmus (a continuation of the Cordilleras) connecting North and South America, are included into Central America. The relief of Central America is very complex. Dozens of volcanic cones extend almost as a continuous chain from the frontier of Mexico and Guatemala to Panama. Landscapes are quite variable, i.e. savannas occupy plains, there are savannas in mountains depending on the slope exposure, intermittent wet and permanent wet tropical and subtropical forests occur. The rivers here are small, but numerous and full-flowing.

2.5. Climate

Climate characteristics, precipitation and air temperature in particular, are basic factors determining river network density, distribution of rivers over the area, runoff regime by month and season, and extreme values. North and Central America, extending from 80°N to 7°S covers almost all climate belts from the Arctic to subequatorial areas. The amount of heat coming from solar radiation tends to be higher from north to south. Air temperatures tend to be higher in the south, and the nature of the atmospheric circulation, annual total precipitation and precipitation regime are subject to change.

Mean annual precipitation on the continent is about 800 mm; areal precipitation changes are extremely great, i.e. from 30 to 50 mm in Death Valley (Great Basin) and in Baja California, to 6000 to 7000 mm in the mountains of the Central American Isthmus. The east coast and most of the west coast are characterized by precipitation above 1500 mm; almost everywhere in Central America precipitation exceeds 2500 mm.

Air masses from the Pacific, the Caribbean Sea and the Gulf of Mexico are the main sources of moisture for the continent. A stable western mass transport is typical of most of the continent, except extreme northern and southern areas, where a meridional air mass transfer prevails.

The complex relief of North America explains the range of effect of air masses of different origin. High ridges of the Cordilleras restrict the transport of wet air masses from the Pacific to the central part of the continent; most of the precipitation falls onto the windward slopes (3500 to 4000 mm). Eastward, without any large orographic obstacles, warm humid air masses from the Caribbean Sea and from the Gulf of Mexico penetrate far into the continent. Cold and dry air masses from the Arctic do not meet any such obstacles either and extend far southward to the inner plains, thus contributing to precipitation falls and lower air temperatures for most of the year.

Specific features of the atmospheric circulation are observed during the year, with slight changes during the seasons. In winter, two areas may be selected as anomalous in terms of thermal regime, i.e. a warm northwestern area and a cold northeastern area. Continuous west winds during this time provide warm and rainy weather on the Pacific coast. Even in January the air temperature on most of the western Canadian coast is about 0°C. Eastward, the sea air is transformed into continental, and winter in the inner plateaus of the Cordilleras is frosty and dry.

The northeastern area is characterized by cold winter temperatures from -9 °C (mean air temperature of January) in the Great Lakes area to -24 °C to -32 °C in the north of the Labrador Peninsula, due to severe and cold winds from the Arctic region.

Air masses from the Atlantic, transporting not only heat but moisture too, produce a warming effect on the Atlantic coast of USA.

On the northeast part of the Appalachians the snow cover depths late in winter may be 1.5 to 2.0 m. A deep snow cover occurs in Canada, north of the Great Lakes, but it tends to be thinner with increasing distance from the Atlantic coast.

In the Central Valley, which is accessible for Arctic and tropical air masses, the winter weather is quite variable. Severe frosts alternate with frequent thaws; moreover, soils are often subject to a deep freeze-up because of the thin snow cover.

To the south of 30°N, trade winds and dry monsoons from the continent prevail in winter; winter is sunny, dry and warm here.

The air temperature in January varies from +8 °C (north Mexico) to +24 °C in the countries of Central America.

In summer the weather is hot on most of the continent; in the east it is hot and rainy. The arctic region is an exception; cold air masses from the Arctic prevail here, low air temperatures are also typical of the northwest areas of the continent.

Low precipitation in summer is a characteristic feature for most of the western part of the continent. The major air mass transport in summer occurs from northwest. This air is cool with some moisture.

Only in southern Alaska and in British Columbia (Canada) where the air masses move perpendicular to the mountain ridge, are abundant rainfalls and snowfalls observed.

In California the hot summer with some rains is affected by dry trade winds. As the distance from the Pacific coast increases, the climate becomes more continental and dry.

In the hollows of the Great Basin and in southwestern USA air temperatures in summer rise to almost the highest ever observed on the Earth. But in mountains the air temperatures tend to fall rapidly. Vast areas of the Rocky Mountains, Sierra Nevada, Colorado Plateau and eastern ridges of the Great Basin in fact have optimal heat conditions in summer.

Southward of 30°N the summer is hot and humid. Here Pacific trade winds meet humid air masses from the Atlantic and a tropical front is formed, accompanied by much precipitation.

In the southeast of the continent and on the adjacent islands the summer weather is warm with abundant rainfalls caused by wet monsoons. In summer and in autumn tropical cyclones are observed resulting in high precipitation and damage.

In the Central Valley and Great Plains precipitation in summer displays a sudden decrease from east to west. In general, precipitation on the plains of the continent is quite sufficient to form a relatively dense river network.

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Biographical Sketch

Igor Alexeevich SHIKLOMANOV was born in February 1939. In 1961 he graduated from the Leningrad Hydrometeorological Institute (Hydrological Faculty). Since 1961 to the present time he has been working at the State Hydrological Institute in St. Petersburg (Russia) in different appointments. Since 1981 has been is the director of the State Hydrological Institute.

In 1967 I.A.Shiklomanov defended his theses for a candidate's degree and in 1975 – a theses for a doctor's degree on "Hydrology and Water Resources". Since 1985 he has been a professor specializing in "Water Resources"; since 1991 – a Corresponding Member and since 2000 – Academician of the Russian Academy of Natural Sciences with the speciality "Hydrology".

The scientific interests of I.A. Shiklomanov include water resources, water balance, water use, the global hydrological cycle, effects of human activity and anthropogenic climate change on water resources and hydrological regime. He has published about 200 scientific papers, including 9 monographs.

I.A. Shiklomanov has made a notable contribution to international cooperation within the framework of UNESCO, WMO, IAHS, and IPCC: from 1992 to 1994 he was the Chairman of the Inter-Governmental Council for the IHP (UNESCO). From 1992 to the present time he is a member of the Advisory Working Group, Commission of Hydrology WMO, and since 2000 he has been Chairman of the Working Group on Water Resources of the Commission of Hydrology (WMO).