WORLD WATER BALANCE

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Contents

Summary

Water balance is the most important integral physiographic characteristic of any territory—it determines its specific climate features, typical landscapes and opportunities for human land use. Assessment of mean long-term water balances of large regions at a sufficient accuracy depends on reliable estimation of the major water balance components—precipitation, evaporation and runoff (surface and subsurface).

In this chapter quantitative characteristics of water balances of different regions, continents, oceans and the Earth as a whole are mainly based on the use of data from the world hydrometeorological network, on scientific generalizations of observation data, and water balance computations made by Russian scientists, including recent data.

The water balance of each continent (except Antarctica) is given separately for the areas of external runoff and internal runoff (endorheic areas) where precipitation is completely lost to evaporation. All balance components are estimated by independent methods which provide a computation of a balance discrepancy and thus assessment of reliability of the obtained results.

Areas of external runoff occupy about 80% of the Earth's land area. These areas receive 93% of precipitation onto the land; 88% of evaporation occurs there and 100% of the freshwater inflow to the World Ocean.

The whole land area (with islands) receives about 119 000 km^3 of precipitation during a year, or 800 mm. The maximum precipitation layer is observed in South America (1600

mm), the minimum precipitation layer (177 mm) occurs in Antarctica. On the other continents mean precipitation varies within 740 to 790 mm.

The total freshwater inflow to the World Ocean from the continents (without Antarctica) equals 39 500 km^3/year. The oceans also receive about 2400 km^3/year as subsurface runoff not drained by rivers, and 2300 km^3 of freshwater mainly as icebergs and melt runoff from the glaciers of Antarctica. Thus, the total freshwater inflow to the World Ocean from land is about 44 200 km^3/year; this is equivalent to about 370 mm over the areas of external runoff or 300 mm, if related to the whole land area.

Evapotranspiration over continents varies from 420 mm to 850 mm (without Antarctica, where it is about zero). Evapotranspiration from the areas of external runoff is about 1.5 to 2 times greater than that from endorheic areas.

Evapotranspiration values given in the balance include runoff in endorheic areas where it is completely lost for evaporation. It also includes the amount of water used for human activities.

Analysis of water balance discrepancies shows good reliability of present assessment of long-term water balance for continents and large physiographic regions of the world.

Freshwater inflow to the World Ocean equals 502 000 km^3/year, of which 91% is contributed by precipitation (458 000 km^3, or 1390 mm). More than a half of this amount is contributed to the Pacific Ocean.

The Arctic and Pacific Oceans have freshwater excess while the Atlantic and Indian Oceans have freshwater shortage. Freshwater excess is most significant in the southern areas of the Pacific, Atlantic and Indian Oceans because of the surplus of precipitation over evaporation there.

Evaporation from the surface of the World Ocean is about 1390 mm, varying from 220 mm from the Arctic Ocean to 1500 mm from the Pacific Ocean.

The highest freshwater inflow (49% of the total volume) from the continents occurs to the Atlantic Ocean. The effect of freshwater inflow is most important in the Arctic Ocean because its volume equals only 1.2% of the World Ocean volume.

Annual precipitation over the globe (numerically equal to evaporation) equals 577 000 km^3, or 1130 mm. The depth of the evaporation layer from the ocean surface is three times greater than that from land. The volume of water annually evaporating from the ocean surface equals 87% and that from land is 13% of the total evapotranspiration from the Earth's surface.

The data presented in this chapter on global water balance are average figures for a long-term period—the data are characteristic of a stationary climate situation. Scientists are now facing a fundamentally new research problem, i.e. study of world water balance taking account of both natural and anthropogenic factors. Anthropogenic factors are of a particular importance under conditions of ever-increasing human impact on the global climate. This is likely to lead to evident change in the global water balance during the coming decades.

1. Introduction

Water balance is the ratio between water inflow and outflow estimated for different space and time scales, i.e. for the Earth as a whole, for oceans, continents, countries, natural-economic regions, and river basins, for a long-term period or for particular years and seasons. Water balance is the most important integral physiographic characteristic of any territory, determining its specific climate features, typical landscapes, possible water management and land use.

Analysis of water balance components for individual territories and time intervals is of great importance for studies of the hydrological cycle or water circulation in the atmosphere-hydrosphere-lithosphere system, as well as the underlying processes influenced by natural factors and human activities.

Precipitation, evaporation, river runoff and ground water outflow not drained by river systems are basic components determining water balance. Besides these components, there are minor components, too, e.g. moisture due to atmospheric water vapor condensation, deep artesian water outflow, or, conversely, recharge of deep aquifers, water losses for animal survival, etc. According to investigations, however, these components are very small if related to large river basins, regions and the globe—they are of no importance for water balance computation, so they can be ignored.

It should be noted that much fresh water is used in many regions for different human needs. Some of this is returned to water bodies as surface and subsurface runoff, but some water is lost, particularly to evaporation (from irrigated lands, reservoirs, etc.), thus increasing evapotranspiration in the region. This must be taken into account in the appropriate water balance components.

Thus, the assessments of water balances of large regions with sufficient accuracy is reduced to reliable determination of the main water balance components, i.e. precipitation, evaporation and runoff (surface and subsurface). Quantitative characteristics of these components for different regions of the Earth presented in this chapter are mainly based on the results of the global hydrological cycle studies carried out in Russia at the State Hydrological Institute (St Petersburg) and at the Institute of Water Problems (Moscow).

More detailed information about individual water balance components of the Earth is given in *Atmospheric Precipitation of the Earth, Evaporation from the Surface of the Globe, River Runoff to Oceans and Lakes* and *Groundwater Discharge to the Oceans*

2. Water Balance Equations

Water balance equation for any land area and any time interval (without taking account of the above minor components) is as follows:

$$P + R'_s + R'_{un} = E + R_s + R_{un} \pm \Delta S \qquad (1)$$

where: P is precipitation; E is evapotranspiration; R_s and R_{un}, R'_s and R'_{un} indicate surface and subsurface runoff from some land area and surface and subsurface water inflow to the land area, respectively; ΔS is water storage change in the area.

All terms in equation (1) are in mm of water layer, which is a water volume for time unit divided by the area of the land.

If the water balance equation is considered for a long-term period it is simplified, because $\Delta S = 0$.

If the water balance is considered at the global scale, it should be noted that there are regions on each continent which differ greatly in their water balance structure. Most territories on the continents are the zones of so-called external runoff—river runoff from these zones discharges to the World Ocean directly. There are also rather large areas on the continents (probably except Antarctica) which have internal runoff. These endorheic areas are not connected to the World Ocean. River runoff formed in such regions is completely lost to evaporation.

For oceanic slopes and large river basins related to areas of external runoff from the continents (when it is possible to neglect surface and subsurface inflow from adjacent areas) the water balance equation for a long-term period is as follows:

$$P_{ext} = E_{ext} + R_{ext} + R_{un} \qquad (2)$$

In equation (2) P_{ext} is a precipitation; R_{ext} is river runoff (from an oceanic slope) to the ocean (sea, lake); R_{un} is subsurface runoff not drained by river systems and directly discharging to the ocean (sea, lake); E_{ext} is evapotranspiration including additional evaporation due to human activities.

In the areas of internal runoff (endorheic regions) the whole quantity of precipitation is ultimately lost to evaporation, so the water balance equation for a long-term period for such regions is as follows:

$$P_{int} = E_{int} \qquad (3)$$

In equation (3) P_{int} is precipitation; E_{int} is evapotranspiration from endorheic areas, including runoff formed within these areas and water losses for different human needs.

For a continent with available zones of external runoff and endorheic areas, the water balance equation would probably consist of equation (2) and equation (3) joint together:

$$P_{ext} + P_{int} = E_{ext} + E_{int} + R_{ext} + R_{un} \qquad (4)$$

For the World Ocean, as well as for individual oceans (and seas) the freshwater balance equation for the long-term period (without taking account of water exchange between the oceans) will be as follows:

$$E_{oc} = P_{oc} + R_{ext} + R_{un} \qquad (5)$$

where: E_{oc} and P_{oc} are evaporation from the ocean and precipitation onto the ocean surface, respectively; R_{ext} and R_{un} are river water inflow and subsurface water inflow to the ocean.

For the whole Earth for a long-term period and a steady climate situation it is evident that the total precipitation should be equal to evaporation from the water surface plus evapotranspiration from land, i.e. for the world water balance the water balance equation similar to that for endorheic areas is valid:

$$P_{gl} = P_{oc} + P_{ext} + P_{int} = E_{oc} + E_{ext} + E_{int} = E_{gl} \qquad (6)$$

where: P_{gl} and E_{gl} are global values of precipitation and evaporation from the Earth as a whole.

It should be noted that equation (6), just like equations (1) to (5), is valid if we assume that water coming from outer space is balanced by the amount of water vapour lost to space and deep water inflow (or juvenile water) is equivalent to water used for hydration of minerals in the lithosphere.

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Biographical Sketch

Igor Alekseevich SHIKLOMANOV was born on 28 February 1939. In 1961 he graduated from the Leningrad Hydrometeorological Institute (Hydrological Faculty). Since 1961 to the present time has been working at the State Hydrological Institute in St. Petersburg (Russia) in different appointments. Since 1981 he has been the director of the State Hydrological Institute.

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

His scientific interests 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. During 1992-1994 he was Chairman of the Inter-Governmental Council for the IHP (UNESCO); since 1992 to the present he has been a member of the Advisory Working Group, Commission of Hydrology WMO. Since 2000 he has been the Chairman of the Working Group on Water Resources of the Commission of Hydrology (WMO).