WATER BUDGET

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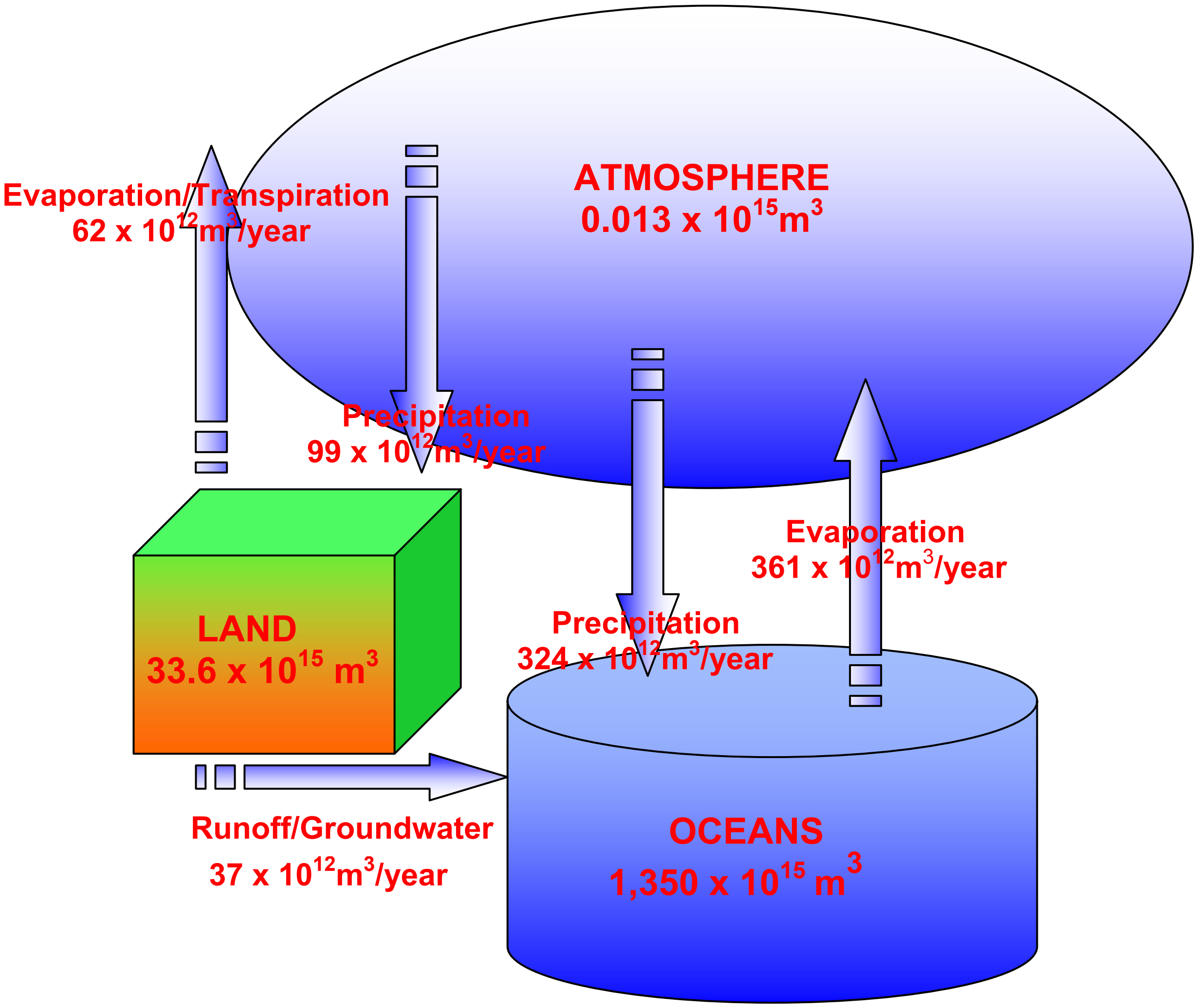
1. Introduction

Interactions of energy and water are the main driving factors which determine the Earth's climate. Climate variability is determined by the interactions of components of the climate system and therefore climate is defined as the state of earth, atmosphere and ocean system, considered over time scales longer than a season. In addition to its role in climate variations, water is a basic component of the whole Earth ecosystem. It provides the basis for life and its relative abundance as freshwater is crucial existence.

Water is the source of all life on earth but its distribution, however, is quite varied; many locations have plenty of it while others have very little. Water exists on earth as a solid (ice), liquid or gas (water vapor). Oceans concentrate 97.3 %, glaciers 2.1 %, ground water (aquifers) 0.6 %, lakes 0.008 %, soil moisture 0.002 %, rivers 0.008 %, atmosphere 0.001%, biosphere 0.00007 %. The water is in a continuous state of change (surface water evaporates, cloud water precipitates, rainfall infiltrates the ground, etc.). However, the total amount of the earth's water does not change. The circulation and conservation of earth's water is called the "hydrologic cycle" ("hydro" means water).



Annual water exchange rates between the land, ocean and atmosphere.

2. Hydrological cycle

Understanding the water circulation in the nature imposes quantification of the different components, basically between the inputs and the outputs of water in a region. This is what we call a water budget. As water moves around the world, it takes different physical forms from liquid to vapors or solid form such as ice. There are five processes at work in the hydrologic cycle: condensation, precipitation, infiltration, runoff, and evapotranspiration. These occur simultaneously and, except for precipitation, continuously.

Condensation is the process whereby the water vapour in the atmosphere is returned to its original liquid state. Condensation generally occurs in the atmosphere when warm air raises, cools and looses its capacity to hold water vapor. As a result, excess water vapor condenses to form cloud droplets, fog, mist, dew or frost. Condensation is not a matter of one particular temperature but of a difference between two. Condensation of water vapour occurs when the temperature of air is lowered to its dew point. The dew point of humid air will be higher than the dew point of dry air. Both air temperature and absolute humidity will determine what type of condensation will occur when the air is cooled.

Precipitation is moisture that falls from the atmosphere as rain, snow, sleet, or hail. Precipitation varies in amount, intensity, and form by season and geographic location.

Infiltration occurs when precipitation seeps into the ground. This depends a lot on the permeability of the ground.

Runoff is the movement of water, usually from precipitation, across the earth's surface towards stream channels, lakes, oceans, or depressions or in the earth's surface. The characteristics that affect the rate of runoff include rainfall duration and intensity as well as the ground's slope, soil type and ground cover.

Evapotranspiration, is the process of returning moisture to the atmosphere. Water on any surface, especially the surfaces of mud holes, ponds, streams, rivers, lakes, and oceans, is warmed by the sun's heat until it reaches the point at which water turns into the vapor, or gaseous, form. The water vapor then rises into the atmosphere.

Transpiration is the process by which plants return moisture to the air. Plants take up water through their roots and then lose some of the water through pores in their leaves. As hot air passes over the surface of the leaves, the moisture absorbs the heat and evaporates into the air.

3. Hydrological balance of the Black Sea

Black Sea, it is an inland sea, with a surface of 413,360 sq km, between SE Europe and Asia, connected with the Mediterranean Sea by the Bosporus, the Sea of Marmara, and the Dardanelles. It is 1,210 km from east to west, up to 560 km wide, and has a maximum depth of 2,245 m. Its largest arm is the Sea of Azov, which joins it through the Kerch Strait. The Black Sea is enclosed by Bulgaria and Romania on the west, Ukraine on the north, Russia on the northeast, Georgia on the east, Turkey on the south..

The Black Sea and the hydrological cycle components

In the north-western side Dnieper, Southern Buh, Dniester, and Danube rivers are the main tributaries ; the Don and Kuban rivers flow into the Sea of Azov. The rivers flowing into the northern part of the Black Sea carry much silt and form deltas, sandbars, and lagoons along the generally low and sandy northern coast. The southern coast is steep and rocky. The Black Sea has two layers of water of different densities. The heavily saline bottom layer which originates in inflowing Mediterranean waters,has very slow motion and contains hydrogen sulfide; it has no marine life. The top layer, much less saline flows in a counterclockwise direction around the sea. There is little tidal action.

Oceanographers have been interested in the Black Sea hydrological balance since the end of the XIX-th century (J.B. Spindler, 1896, 1899) and were taken up by 33 authors in 27 papers published in XX-th century.

Due to the sparse data regarding the quantitative components of water inputs and outputs, mainly precipitations and evaporation, determined different evaluations of the hydrological balance.

The general hydrological balance equation, considering water inputs and outputs is the following:

$$R+P+B+K=E+B_1+K_1$$

where R is river runoff, P represents precipitations, B = water entering through Bosporus Strait and K stands for the water entering through Kerchi Strait; E= evaporation, $B_{1=}$ outflows through Bosporus Strait to the Mediterranean Sea and K_1 water flowing through Kerchi Strait to the Azov Sea.

River inflow, R, represents an accurate component if compared to the other variables due to the presence of the hydrological stations operating on most of the rivers.

Inputs from the precipitations, P, are much more difficult to calculate due to their heterogeneous distribution over the sea and the absence of direct measurements. Long term average of the water input from precipitations ranges from a minimum 119 km^3/year (E.V. Soliankin, 1963; C. Bondar, 1986) to a maximum 300 km^3/year (E. Ozturgut, 1971; U. Unluata et. al., 1990).

The inflow/outflow through Bosporus Strait is differently estimated by the authors.

Inflows through Bosporus were evaluated by H. U. Sverdrup (1942), G.J. W. Neuman and E. Roseman (1954), A. K. Leonov (1960) and D. Ia. Berembeim (1960) to 192 – 193 km^3/year; I. Soliatkin (1963) 176 km^3/year: G. Serpoianu (1973) 123 km^3/year; C. Bondar (1986) 203 km^3/year; U. Unluata et. al. (1990) 312 km^3/year; E. Ozsoy and U. Unluata (1997) 605 km^3/year.

Outflows from the Black Sea to the Mediterranean Sea **through Bosporus** Strait were evaluated by I.B. Spindler (1896) 416 km^3/year, H. U. Sverdrup (1942) 397 km^3/year, G.J.W. Neuman and E. Roseman (1954) 462 km^3/year, I. Soliatkin (1963) 340 km^3/year, G. Serpoianu (1973) 260 km^3/year, C. Bondar (1986) 371 km^3/year, U. Unluata et. al. (1990) 612 km^3/year; E. Ozsoy and U. Unluata (1997) 305 km^3/year.

Inflows from the Azov Sea were evaluated between a minimum 22 km^3/year (I.A. Resetnickov, 1992) and maximum 95 km^3/year (A. K. Leonov, 1960) and the outflows from the Black Sea to Azov Sea between a minimum 29 km^3/year (Rojdestvenski, 1971) and maximum 70 km^3/year (A. K. Leonov, 1960).

The significant differences are the same for the evaluation of the water lost by evaporation.

Each of the hydrological balance components present a remarkable monthly, seasonal and yearly variability, chiefly due to the climatic conditions.