HYDROSPHERE STRUCTURE AND ITS RELATIONSHIP TO THE GLOBAL HYDROLOGICAL CYCLE

V. S. Vuglinsky
State Hydrological Institute, Russian Federation,Russia

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Contents

Summary

The hydrosphere is the combination of all the free water on the Earth that is not chemically and/or physically confined within the minerals of the Earth's crust. The hydrosphere occupies the major portion of the Earth's surface, i.e. more than 380 mln sq. km or more than 75% of the total area of planet.

The volume of the hydrosphere is about 1.4 bln cu.km. Oceans and seas form the major portion of the hydrosphere. They contain $1.37 \cdot x\ 10^9$ cu.km of water or about 94% of the total volume of the hydrosphere. Heat storage in oceans and seas is great and controls the energy regime on the Earth's surface, producing conditions required for life. Subsurface water is the second largest component of the hydrosphere, its volume being about $0.6\ x \cdot 10^9$ cu.km, or 4% of the total mass of the hydrosphere. The zone of intensive water exchange extends to a depth of 0.3 to 0.5 km, where subsurface water is present as perched water, soil and subsoil moisture. The zone of slower water exchange extends deeper, to 1.5 to 2 km, from where water exchange between surface and subsurface waters is difficult. Snow and ice storage follow subsurface water by volume. The major portion of ice occurs in glaciers and is $2.4\ x \cdot 10^7$ cu.km, of which more than 90% is concentrated in Antarctic glaciers. The portions of the other components of the hydrosphere, besides the above three, are small and can be regarded as "minor" components of the hydrosphere. These components comprise the water in rivers, lakes

and swamps, soil moisture and water vapor in the atmosphere. River water is most important for human life because this particular component of the hydrosphere provides most of the fresh water for people. The waters of the hydrosphere are inter-related not only by their origin but due to the water cycle, in which all parts of the hydrosphere are joined by the main dynamic forces causing the motion of the water cycle system, i.e. energy and gravity forces.

1. Introduction

The hydrosphere is a combination of all kinds of free water on the Earth—free in the sense that it is not chemically and/or physically confined with minerals, i.e. this water can move under the influence of the gravity forces and heat (energy). Water motion also means a transition of water from a certain aggregate phase to another. The hydrosphere forms an interrupted watery envelope of the Earth, because it involves not only the World Ocean, but discrete water bodies (rivers, lakes, swamps, etc.).

The hydrosphere occupies the major portion of the Earth' s surface, more than 380 mln sq.km or more than 75% of the total area of the planet. If the water of the hydrosphere were evenly distributed all over the Earth's surface, it would cover the planet with a water layer 3000 m deep. Oceans and seas are the prevailing components of the hydrosphere on the Earth; their total area is 361 mln sq.km. Glaciers occupy about 16 mln sq.km (almost 11% of the land area). Much smaller land areas are occupied by lakes, reservoirs and rivers (about 2.3 mln sq.km) and by swamps and wetlands (about 3 mln sq.km).

The surface of the planet occupied by the hydrosphere is subject to significant seasonal variations. The above value of the total area of the hydrosphere on the Earth's surface is its lower limit. The maximum extent of the hydrosphere exceeds 443 mln sq.km; this is observed during periods of maximum snow storage during cold seasons which occur at different times in the northern and southern hemispheres.

The hydrosphere is characterized by a very high water exchange rate due to the water cycle which combines all parts of the hydrosphere.

The World Ocean is the main contributor to the water cycle. Most of the water evaporated from its surface falls (after condensation) back onto the ocean surface as atmospheric precipitation, thus terminating this minor water cycle. Some moisture is transported to land by air fluxes and this contributes to a complex water exchange between other components of the hydrosphere (subsurface water and soil moisture, rivers, swamps and lakes). Finally, the water transported from the ocean to land discharges back to the World Ocean again, thus terminating the major water cycle. This is the most important natural mechanism providing land with constantly renewed fresh water.

The origin of the hydrosphere is associated with two processes. Firstly, the inner heating of the primary matter of the planet (the pro-Earth), caused a heat front to move from the core. This melted the ice particles of the cometary matter and forced the produced water out to the surface. In the second stage an intensified heat flux caused melting of the primary matter and released chemically confined water and gases during water degassing. Continuous degassing produced certain conditions for permanent recharge of the hydrosphere by a new supply of water, though this process was not uniform. According to current understanding, the major portion of the hydrosphere was formed during the ancient stage of the Earth's evolution.

The hydrosphere is closely related to the other spheres of the Earth, i.e. the lithosphere, atmosphere and biosphere. The relation between the hydrosphere and the Earth s crust is accomplished by subsurface waters. Atmospheric water (water vapor) relates the hydrosphere to the atmosphere. Relations between hydrosphere and biosphere are more complicated. These relations are maintained by water that contributes to biological processes, to formation of organic matter resulting in oxygen discharge, that is essential for the activity of living organisms and human activity and, finally, to transpiration recharging atmosphere with water. Water storage in different components of the hydrosphere is summarized in Table 1, which was prepared by the author on the basis of the latest publications on the subject.

Components of the hydrosphere	Water volume, **10^3 cu. km**	**% of the volume**
World ocean	1,370,000	93.7
Subsurface water (1)	60,000	4.10
Zone of intensive water exchange (included in 1)	4,000	0.27
Snow and ice storage	30,000	2.05
Minor components:		
Lakes	280∗	0.02
Soil moisture	85	0.006
Swamps	11	0.001
Atmospheric moisture	14	0.001
Rivers	2	0.0001
Total	**1,460,392**	**100**

∗ Including about 5,000 cu .km of water in reservoirs.

Table 1. Volume of water in the components of the hydrosphere

As evident from Table 1, the whole volume of the hydrosphere slightly exceeds 1.45 bln. cu. km. The accuracy of this assessment of the hydrosphere is considered to be within 3% of its volume.

2. Components of the hydrosphere

2.1. Oceans and seas

Oceans and seas form the major portion of the hydrosphere. They contain $1.37 \cdot x\ 10^9$ cu.km of water or about 94% of the total volume of the hydrosphere. Oceans and seas accumulate much heat thus regulating the temperature regime on the surface of the planet producing conditions required for life on Earth. In most parts of the ocean (52.6%) water depths attain 400m to 6000m. More than 38% of the ocean area has depths from 200m to 400m. Areas with depths more than 6000m and less than 200m are small (1.2% and 7.5%, respectively). The Mariana Trench in the Pacific Ocean is the deepest place in the World Ocean (11 022m). The major portion of the World Ocean is in the southern hemisphere, where it occupies 81% of the Earth's area; the water area in the northern hemisphere occupies only 61%. The generalized profile of the World Ocean bottom and a hypsographic curve (after K.S. Losev, 1989) are given in Figure 1.

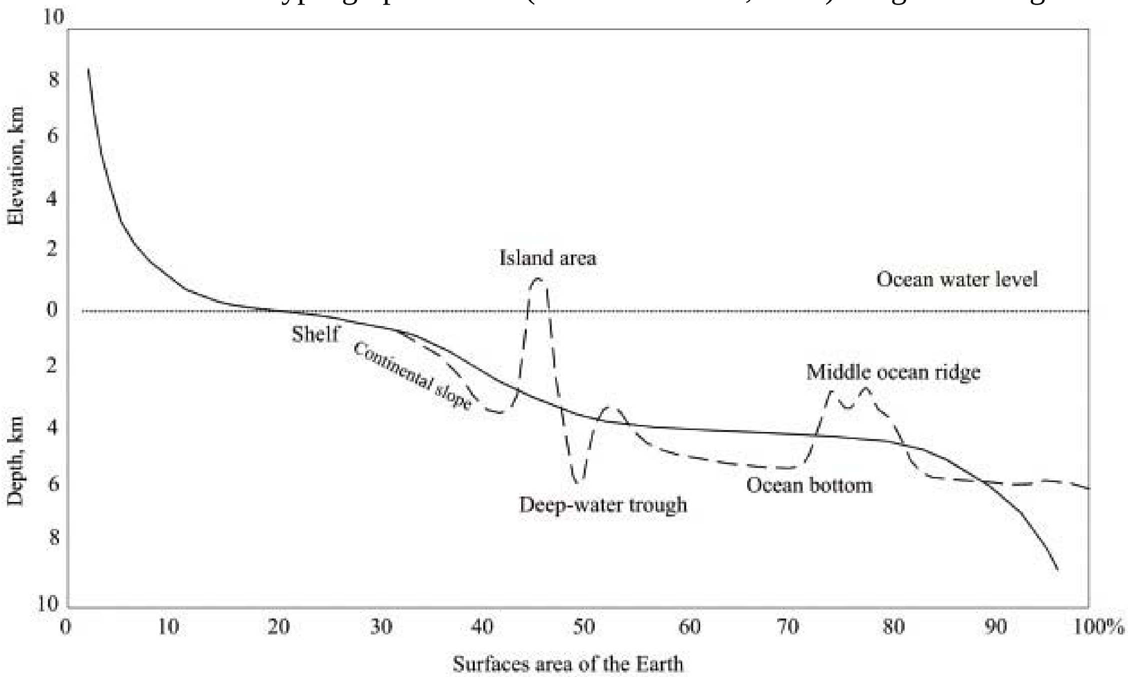

Figure 1. Hypsographic curve and the generalized profile of the World Ocean bottom

Sea water is a compound salt solution; its mean salinity is 35‰. In the Arctic Ocean mean water salinity is lower (31‰); in the Red Sea it is higher and attains 42‰. Oceanic water is saturated with different gasses absorbed from the atmosphere and from the oceanic bottom deposits. Carbon dioxide prevails in the dissolved gases; its volume is $11.8 \cdot x\ 10^5$ cu.km which is almost 100 times greater than that in the atmosphere of the Earth. As for oxygen, the amount dissolved in the ocean is about 100 times less than that in the atmosphere ($1.4 \cdot x\ 10^4$cu.km only). The nitrogen content in the World Ocean is 1.8 cu.km. The volumes of hydrogen sulfide, argon and methane are much less.

The water of oceans and seas has a weak reflecting capacity; it absorbs the solar energy intensively and serves as a kind of a "heating machine" for the planet. Water heating mainly occurs in the equatorial belt from 15° SL to 30° NL. In higher latitudes in the two hemispheres the ocean gives back its heat transported by the sea currents flowing around each continent. The mean temperature of the ocean surface is 17.8 °C which is about 3.6 °C higher than the mean air temperature on the surface of the planet.

Water mixing caused by external forces (wind effects, change in atmospheric pressure and tidal effects) occurs in the top water layer to 150-200 m. Below this layer there is the so-called "leap-layer"; the water temperature suddenly falls by several degrees. Then, a gradual decrease of water temperature is observed to a depth of 1500 m; in deeper layers the water temperature is almost constant and ranges from 3 °C to 1°C.

This water stratification helps to create stability in the oceanic system, but atmospheric forces, (wind, differences in atmospheric pressure), uneven heating of the water surface, differences in salinity and temperature , gravitational forces of the Moon and Sun, as well as other events cause and support active motion of the water masses in the World Ocean. Surface currents which form a system of gigantic cyclical water movement arhave been well studied; they move clockwise in the northern hemisphere and counter-clockwise in the southern hemisphere. There are some minor water circulations between these currents, which move in opposite directions. Mean surface water current velocity is from 0.1 to 0.2 m/s, but in some places it attains 1 m/s; the highest velocities of 3 m/s are observed in the warm Gulf Stream drift.

In addition to surface currents, subsurface currents have been discovered which move in opposite directions. Deep currents in the ocean have also been discovered but knowledge about these currents is inadequate. The available assessments show that huge water volumes are transported by these currents every year (inner water exchange). Water mass transportation is most intensive in the Indian and Atlantic Oceans, and the least intensive water transportation occurs in the Arctic Ocean. Volumes of water masses transported by currents in oceans and intensity of water mass exchange (after M.I.Lvovich,1974) are given in Table 2.

Ocean	**Area, mln. sq. km**	**Volume, mln. cu. km**	**Annual discharge of the transported water masses, mln. cu km**	**Water exchange intensity (number of years)**
Pacific	180	725	6.56	110
Atlantic	93	338	7,30	46
Indian	75	290	7,40	39
Arctic	13	17	0,44	38
World Ocean	363	1370	21,70	63

Source: M.I.Lvovich, 1974 /

Table 2. Volume of water masses transported by currents in oceans and intensity of water mass exchange

The water transported by sea currents is three orders of magnitude more than all the rivers of the world, and the resultant water exchange is 50 times more intensive than the water exchange caused by precipitation onto the ocean surface and evaporation. Therefore, the inner water exchange in the ocean is more intensive than the outer one involving fresh water circulation.

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Biographical Sketch

Valery Vuglinsky was born in March 1939, in Moscow, Russia.

Education:

1966 Graduated from Department of Geography, St. Petersburg State University,

1972 Ph.D. State Hydrological Institute,

1990 Sc.D. Moscow State University named after Lomonosov,

1994 Professor, St. Petersburg State University

Positions held:

Deputy Director for science (1982 - present), State Hydrological Institute,

Professor and Head (1989 - present), Department of Hydrology, St. Petersburg University.

International experience:

Member (1993 – present) International Informatization Academy,

Member (1982 – present), Working Group on Hydrology RA-VI (Europe), World Meteorological Organization,

Member (1993 – present), International BALTEX Science Steering Group.

Lecturing activities:
Courses in St. Petersburg University:
River runoff and water balance,

Hydrology of lakes and reservoirs,

Water resources inventory, etc.

Research activities:
Water resources and water balance,

Hydrology of lakes and reservoirs,

Water resources inventory;
Hydroecology

Books:

“Water Balance of River Basins”, 1982, Co-author: V.Babkin, Leningrad, Hydrometeoizdat, (in Russian);
“Manual on hydrological computations for reservoirs under project”, 1983, Editor and co-author; Leningrad, Hydrometeoizdat, (in Russian);

”Water Resources and Water Balance of the USSR Large Reservoirs” 1991, Leningrad, Hydrometeoizdat,(in Russian);

“Methodology for distinguishing between man’s influence and climatic effects on the hydrological cycle”, 1989, co-author, Technical Documents in Hydrology, UNESCO;
“Casebook of Operational Hydrological Networks in RA-VI (Europe)”,1995, WMO;

“Basis of Geoecology”, 1994, Co-author, St. Petersburg University (in Russian).

Publications:
More than 100 publications in numerous journals (in the USSR, in Russia, USA, etc.) and in the proceedings of different international and national conferences.