CHARACTERISTICS OF WATER AND WATER BODIES IN THE NATURAL ENVIRONMENT

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Contents

Summary

This chapter describes the peculiarities of surface water in different natural environments, i.e. atmosphere, oceans and seas of different types, coastal and estuarine zones, rivers systems of different groups, artificial reservoirs, lake basins and swamps.

1. Atmospheric water

Atmospheric water, transferring from one condition to another, participates in water circulation. Moisture is mainly in its gaseous phase when found in the atmosphere, but also can be present as a liquid or solid. Water vapor is a small but constantly changing component of the atmosphere and it plays an essential role in the environment. The atmospheric content of water vapor is no more than 4%, but this small, constantly renewing amount greatly influences temperature distribution on the Earth and is the only source for fresh water regeneration (through evaporation) and the main source for water resources replenishment (through precipitation). The average atmospheric content of water vapor decreases with altitude and latitude and depends on the season and type of underlying surface. The atmosphere contains about 0.001% of the total natural water resources.

Water vapor enters the atmosphere mainly through evaporation from the surface of the World Ocean. Water also enters the atmosphere as a result of evaporation from the surface of lakes, rivers, ice, snow and soil, and also during evapotranspiration. However, all these others sources make small contributions when compared with evaporation from the ocean surface, which is estimated to be approximately 492 000 km^3/yr. Meridional water vapor transfer is a main peculiarity of water circulation. Water vapor founded in air masses, transports a great amount of heat phase transformations from the warmer regions of the Earth to colder ones. When an air mass containing water vapor cools, the vapor condenses, forming water drops. The movement of humid air from warmer areas of low latitudes to higher latitudes or from lower atmospheric layers to upper ones contributes to the cooling process, vapor condensation and the production of a great amount of latent condensation heat.

Atmospheric water is constantly transferring from one phase to another. Evaporation and condensation, being accompanied by absorption and extraction of a great amount of heat, are the main processes of transference. In turn, this heat plays an important role in total atmosphere circulation. If vapor pressure reaches saturation values, then vapor condensation and the formation of drops takes place on particles that are always to be found in the atmosphere. These particles serve as nuclei for condensation (e.g. particles of sea salt, atmospheric gases, dusts, nuclei of freezing and sublimation, etc.). Phase transformations from water vapor - water - ice occur when the pressure of water vapor exceeds saturation vapor pressure of water and ice at particular temperatures.

Transitions from liquid phase to solid (ice) can promote quick growth of the latter. Snowflakes can also grow quickly until they fall down. Big drops of drizzle and then rain can be initiated by the collision and condensation (coagulation) of cloudy drops through Brownian movement (on a small scale), by air turbulence or gravitational coagulation (the capturing of smaller drops by larger and more rapidly falling drops). Ice crystals grow larger when they come in contact with super-cooled liquid water at sub-zero temperatures. The growth of snow crystals is a major process leading to snow falls in areas with negative temperature, and rain in those places where snowflakes are precipitated at higher altitudes but melt in the lower and warmer layers of the atmosphere. Snowflakes, when falling through a cloud of super-cooled drops (and growing from contact with super-cooled ice) form a small fraction of soft hail or hail.

The lowest values of atmospheric H_2O are observed at a considerable height in the atmosphere and above the Antarctic plateau. The largest values are observed in subtropical and equatorial areas, where it often amounts to more than 3 to 4%.

For assessing the water vapor content in the atmosphere, one must determine relative humidity, absolute humidity, mixture ratio and moisture mass portion.

Relative humidity is a percentage ratio between water vapor partial pressure in the atmosphere and saturated water vapor partial pressure under given temperature and atmospheric pressure. When relative humidity reaches 100%, condensation occurs on condensation nuclei (the small solid particles), leading to cloud formation. Human comfort levels are influenced by relative humidity. On warm days, a feeling of discomfort occurs when there is a high value of relative humidity. It is easier to tolerate higher temperatures at low relative humidity levels. The influence of relative humidity is less obvious at lower temperatures.

Absolute humidity is the mass of water vapor contained in a unit of dry air volume and is expressed in g/m^3.

Mixture ratio reflects the relation between a mass of water vapor contained in a unit of dry air volume, and dry air mass in the same volume, expressed usually in pro mille.

Moisture is removed from the atmosphere by precipitation as rain, snow, hail, dew, rime, etc. Fog is an accumulation of very small water drops and ice crystals, decreasing visibility in and near the surface atmospheric layer.

2. Surface water: oceans, interior seas, coastal zones and estuaries

Solar radiation falling on the ocean surface along with thermodynamic interaction with the atmosphere causes thermohaline changes in the density of surface water. Most area and temporary variations in water density are concentrated in the upper, active ocean layer, the thickness of which is determined by a range of annual oscillations of mass flow, intensity of wind mixing, and also by the character and value of vertical velocity in its lower boundary. In the upper, clearly defined layer, mixing occurs, which creates an essentially homogeneous zone varying from several tens to hundreds of meters in depth. The lower part of this productive layer is marked by the seasonal thermocline, at which density increases due to a lowering of temperature and increase in salinity. An upper quasi-homogeneous layer is generated by the mixing of surface waves, turbulence generated by drift currents and dense convection and cooling at the ocean surface, or increased salinization (e.g. by evaporation). Here even very small but finite density gradients exist, providing significant vertical mass flows at almost neutral stratification due to intense mixing. Near the lower boundary of the upper quasi-homogeneous layer, in the area called the ‘main skip’, the temperature gradient often reaches several degrees per meter and the densest gradients are observed. On average, seasonal changes in water temperature are observed below the skip layer, in the seasonal (or upper) thermocline. That layer where seasonal changes in water temperature are not noted is considered to be the lower boundary of the ocean’s surface water.

Bodies of ocean water that possess more or less similar hydrologic, hydrochemical and biological characteristics and that mix as a whole in the system of total ocean water circulation are considered ‘water masses’. They are formed over a relatively long period in determined climatic conditions. The boundaries of water masses are zones where the gradients of hydrologic and hydrochemical characteristics change sharply. These boundaries between water masses are called frontal zones.

All oceanic water masses are formed near the surface, mainly due to vertical winter circulation, and then are transferred by sea currents to other regions and depths. Mixing and currents cause mainly vertical distribution of oceanographic characteristics and inter-stratifications of ocean water.

Depending on the stability of surface layers and the size of the basin, the zone of wind mixing spreads to a depth of 10-15 m. The smaller the basin size, the smaller the waves—causing wind mixing to occur to shallower depths. The vertical distribution of oceanologic characteristics is distinguished by significant variability. An entire zone may become completely homogeneous after prolonged storms. The effects of external and internal factors play an important role in surface water, and form a vertical gradient of oceanologic characteristics after winds subside.

Convective mixing affects water from the sea’s surface down to significant depths. Usually, the convective zone is formed by vertical winter circulation, although in some cases (in tropical and subtropical areas) it may be created as a result of increased salinization during evaporation. In summer, the zone is often preserved as a cold intermediate layer, which can disappear at the end of the summer. The zone of convective mixing is the most active zone of the ocean. Mixing influences on the ocean regime appear first of all in the distribution of variations in the physical and chemical properties of water, primarily in a vertical direction, but also horizontally. The seas are classified as interior (inland), marginal, or inter-insular according to their geographical position and degree of isolation from the World Ocean. Inland (interior) seas are seas deeply intruding into the land but connecting with oceans or adjoining seas through channels (straits). According to their geographical positions, interior seas can be subdivided into continental and intercontinental types. A continental sea is usually shallow and deeply intruding into the land within a continent (e.g. the Sea of Azov, the Black and the White Seas, and Hudson Bay). An intercontinental or mediterranean sea is a part of the World Ocean, located between continents and connected with the ocean or other seas by straits (e.g. the Mediterranean and Red Seas).

A marginal or adjacent sea is a part of the World Ocean, adjoining the continent and partially separated from it by a peninsula or a group of islands or simply by the uplifting of the ocean bottom. They can be on the continental shelf (a 'shelf sea'), or on the continental slope (e.g. the Barents, the Laptev, the Norwegian, and the Bellingshausen Seas). An inter-insular sea (encircled by islands) is a part of the World Ocean that is surrounded by a more or less dense circle of islands. The straits between these islands prevent a free water exchange with the open ocean. Examples include the Javan, the Bandu, and the Sulu Seas. Completely specific water masses, sometimes markedly different in their physical and chemical properties from water masses of adjoining seas or the ocean, are created in each sea. The main factors are: fresh water balance, water exchange with adjoining seas (affected by the size of straits and current velocity), intensity of convective mixing and to a large extent the depth of the strait connecting this sea with the ocean.

The water of the open part of the World Ocean contains a fairly constant main ion composition and comparatively specialized range of variation in biogenic elements, but sea water composition in marginal and interior seas can differ significantly from that of the World Ocean. This can be explained by the strong influence of surface runoff from the land into the sea. In this case, the amount of surface runoff and limits on water exchange between the sea and the World Ocean are the most significant influences. Inflow of ground and thermal water to the bottom can also significantly change the chemical composition. Some regions of the Red Sea provide the most prominent examples of these processes. Coastal zones, due to the active influence of hydrodynamic factors, are the most dynamic in comparison with other areas of seas and ocean. A very active mixing layer extends to significant depths in these areas. This is an upper part of the continental shelf that undergoes constant influence by waves of different intensity and its lower boundary can be conditionally determined according to limits of maximum appearance of strong storms, repeating from year to year.

Coastal areas, especially those with sandy sea coasts, are distinguished by large size and slow gradual expenditure of wave energy coming from the open ocean. Depending on the prevalent hydrodynamic factors, they can be divided into three zones. The first, the open sea wave deformation zone, is characterized by the influence of different currents that can be connected with waves and are drift constant non-wave currents. As a result, predominance of unidirectional plane water flows, spreading to different depths, is observed. The second zone closer to the shore is the wave zone where the destruction of waves takes place or the processes of wave energy extinction are divided into several stages, with waves being partly destroyed. Here a prevalence of wave oscillator water movements is observed. The high turbulence of water masses and the presence of strong wave currents in divergent directions, usually forming a complex system, are connected with the processes of intensive rearrangement and wave destruction. The third zone, closest to the shore, is the area of wave flow spatter (the beach zone), i.e. the water movement between the breaking zone and the upper swash zone. In the wave swash zone there is a fluctuating plane of turbulent water flow, forming at final wave destruction near the water line. A prevalence of straightforward different direction water is observed here. Naturally different modifications of coastal area structure can be found, and some zones may be absent (e.g. in the case of a very deep abrasive coast with steep bottom slopes).

An estuary is a partially enclosed coastal reservoir, freely connected with the sea (ocean) and within which seas (oceanic) salt water is diluted by fresh water, inflowing from a river. Often, estuaries are situated in tidal river mouths and the more significant an estuary is, the larger the river to which it corresponds. This is a transient zone between a river and the ocean. The hydrodynamic regime of estuaries is unique. Among the many affecting factors one may mention sea waves, tide level fluctuations and the currents they induce, river runoff, dense water stratification, wind currents, inner waves, and Coriolis forces. Estuaries are more productive than oceanic and freshwater environments. In terms of pure productivity, estuaries have no equivalent in ocean ecotopes. At the same time, they can be sources of contaminant accumulation, inflowing in surface runoff from the land.

Estuaries may be divided into three categories: normal, hypersaline (hyperhaline), and closed or saline (lagoons). Among normal estuaries we can distinguish: 1) highly stratified estuaries in large river mouths with salt water thermoclines in their lower part, through the upper boundary of which mixing between salt and fresh water occurs; 2) estuaries that are highly vertically stratified with two-layer circulation; 3) moderately stratified or partly mixed estuaries (here a gradual increase in salinity towards the sea or ocean from surface to bottom is observed); 4) vertically homogeneous estuaries with characteristics that vary in a lengthwise direction; 5) estuaries homogeneous in vertical and lengthwise directions (narrow straits with intensive tidal mixing). Moreover, estuaries are subdivided into three classes: “positive”, where sea water is diluted by fresh water (river runoff with precipitation exceeding water losses to evaporation); “reverse” estuaries with increased salinity, where losses from evaporation exceed discharge and precipitation; and “neutral”, where evaporation is fully compensated but not exceeded by discharge and precipitation.

According to the character of river and seawater mixing, estuaries are usually subdivided into three additional groups: those that are completely mixed and are vertically homogeneous; those that are partially vertically mixed and which are moderately stratified, and those with a salt wedge, which are highly stratified.

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Biographical Sketches

Dolotov Yuri Sergeevich (Dr. Sci) is a corresponding Member of the Russian Academy of Sciences, and chief scientist of the Water Problems Institute of RAS. In 1954 he graduated from the Geographical Faculty of Moscow State University. In 1961 he obtained his PhD Degree, and in 1990 his thesis for a Doctor's degree.
His main fields of professional interest are: study of relief-forming and sedimentary depositional processes in coastal areas of the World Ocean, especially of prolonged relief-change in the coastal zone and sandy coasts; solution of problems related to coastal protection, rational use of coastal territories and conservation of coastal biodiversity and natural resources.
His published works include three monographs:

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Igor S. Zektser received his doctorate in 1975 in hydrogeology from the All Union Research Institute for Hydrogeology and Engineering Geology in the former Soviet Union. For the past 30 years, he has been Head of the Laboratory of Hydrogeology in the Water Problems Institute of the Russian Academy of Sciences.
Dr. Zektser's fields of specialization include: quantitative assessment of groundwater resources; evaluation of the contribution of groundwater to total water resources and water balance; assessment of the interrelation between ground and surface water and groundwater discharge into rivers, lakes, and seas; study of the main regularities of groundwater formation and distribution in various natural as well as

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Dr. Zektser was one of the original authors of the groundwater flow map of central and eastern Europe as well as the world hydrogeological map, and his research has had international recognition. He also served as expert and scientific leader for several projects of the International Hydrological Program, UNESCO, on groundwater resources assessment.