BIOLOGICAL AND MICROBIOLOGICAL PROPERTIES OF ATMOSPHERIC WATER

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Summary

Water in the atmosphere is present in all three phases states, i.e. the atmosphere can contain water vapor, liquid water and ice. Water vapor is one of the minor but at the same time, a very important gas found in the atmospheric air, as this constituent generates clouds where the water can change into its liquid and solid states. Depending on latitude, the water vapor content in the atmosphere near the Earth's surface varies from 0.2 to 3% of the volume. It is hard to believe that this small amount (as it seems) is capable of creating heavy rain of enormous power.

The basic biological property of atmospheric water is the same as that of the atmosphere itself. Our planet Earth is an inhabited planet owing to its wonderful atmosphere and the water vapor in it. Life is impossible without water as it is the main constituent of almost all living organisms. It is a well-known fact that an adequate supply of water is vital to life on Earth. The global hydrologic cycle provides the basis for the existence of life on the planet as it supports continuous exchange of water between the oceans, the atmosphere, and the continents. The atmosphere provides the vital link between the oceans and continents. Although the amount of water vapor in the air at any one time is only a minute fraction of the Earth's total water supply, the absolute quantities that are cycled through the atmosphere in a year are immense. According to the latest estimates, this volume reaches 380 000 cubic kilometers—an amount that can cover the Earth's surface by a layer about 100 cm deep. The water evaporated from the oceans comes to the continents as atmospheric precipitation. The biological role of precipitation is obvious, for no plant would be able to survive without vital drops of water falling from the sky, washing its leaves and feeding its roots. There is a strong correlation between precipitation amount and diversity of life at any place on the planet. So, <u>the most important biological role of atmospheric water is to serve as the main link in the global hydrologic cycle and to create atmospheric precipitation</u>.

Another biological role that can be played by atmospheric water is to be a habitat for living organisms. Fresh or salt liquid water is normally a good medium for many organisms to live in. Sizes of aquatic organisms certainly depend on the scale of a water body. So, when considering the atmospheric water we can think of only microorganisms that are able to survive in water droplets in the atmosphere. Cloud particles of liquid water have diameters from a few to tens of micron (fog particles have practically the same sizes). Raindrops differ from cloud particles only in size. A diameter of 200 microns is usually taken as the upper limit for the size of cloud drops. Liquid water droplets and ice crystals are aggregated in the atmosphere into clouds, that are wonderful natural phenomena. Liquid water can exist in the atmosphere only in clouds or in precipitation. Life inside a raindrop must necessarily be very small and very short-lived, and dropping out of the atmosphere must mean the end of aerial life and the start of new terrestrial or aqueous life.

Researchers have studied the composition and size of biological particles found in rain water. Fortunately, no adverse biological particles, like viruses, were found. Particles present included bacteria, microscopic fungi and algae. In the context of this property of atmospheric water, the normal chemical composition of atmospheric water is generally very favorable for life, but recent decades have seen increasing anthropogenic impacts such as acid rains.

One more property of atmospheric water is mentioned—a means of transportation for many microorganisms that are lifted from the surface by wind and can be carried with clouds over a certain distance: sometimes this distance can be considerable. However, oceans still present an impenetrable barrier for direct exchange by seeds and spores; within a continent this mechanism is an important means of dispersal.

It should be noted that biological and microbiological properties of atmospheric water are very rarely discussed in scientific literature, in either meteorology or biology. This chapter is, therefore, mainly the result of the author’s understanding of the matter.

1. Link in the global hydrologic cycle

“Water is life”—this well-known definition reflects the importance of water for the life on our planet. It is essential for our existence, like the very air we breathe. We can survive without food for several weeks; but without water we should die in a few short days. And it is a well-known fact that any breathing is much more difficult in extremely dry air—for breathing every human being needs at least slightly moist air.

It is rather difficult to hypothesize about the composition of the primary atmosphere and dissolved substances in the primary hydrosphere at the very first stage of their formation. It is obvious, however, that both the atmosphere and the hydrosphere quickly assimilated gases released by volcanic eruptions and other tectonic events. Atmosphere saturated with such gases had a regenerating character, as there was no oxygen in it. Carbon dioxide released by eruptions and by degassing processes stimulated the greenhouse effect, thus gradually rising the surface air temperature of the Earth; this had important consequences for its further evolution. During the billions of years since the origin of the Earth, the world's supply of water has remained practically constant. Little has been added or lost since the first clouds formed and the first rains fell.

Water in the atmosphere is mainly water vapor and its condensate (water droplets and ice crystals). A high proportion of this (90%) is in the lower layer of the atmosphere, i.e. in the low troposphere.

Water vapor constitutes only a small fraction of the atmosphere, varying from almost 0 to 4% by volume, but the importance of water in the air is far greater than this small percentage would indicate. Water vapor is one of the most important of all constituents of the atmosphere, as this is the component that creates fog, clouds, rain, hail, snow and other known hydrometeors.

There is no really pure water in Nature. Even one drop of rain contains some salts and gases dissolved in it. Water is a very effective solvent. It dissolves almost all chemicals, except oils, fats, hydrocarbons, quartz, and a few others. This important property facilitates provision of nutrient salts and other dissolved elements to plants in Nature.

A few words about what atmospheric water is: it is mainly water vapor, which is an odorless, colorless gas that mixes freely with the other gases in the atmosphere. Unlike oxygen and nitrogen—the two most abundant components of the atmosphere—water vapor can readily change from one state (solid, liquid, or gas) to another at the temperatures and pressures typically found in the atmosphere and near the surface. This ability permits water to leave the oceans as a gas and to return as a liquid; this is vital to the global hydrological cycle.

Approximately 12 900 km^3 of moisture is contained in the atmosphere. If one can imagine that all this water is condensed and felt onto the surface as precipitation, the layer would be 25 mm thick. This is almost the amount of precipitation that falls during a strong rainstorm in middle latitudes. Fortunately, humanity does not have to face the problem of such a large amount of fresh water, and this happy circumstance is attributable to the Sun.

It is clear that an adequate supply of water is vital to life on Earth. In all, the total water content of the global hydrosphere is roughly about 1.37 billion cubic kilometers (326 million cubic miles). It seems that this huge quantity can be used indefinitely, but one must remember that much of the life on Earth needs to be supplied with fresh water, rather than saline. At the same time, the vast bulk (about 97.5%) is stored in the global oceans, where, of course, it is saline. The fresh water volume (about 2.5%) is estimated to be 35 million cubic kilometers (about 5.6 million cubic meters for each inhabitant of the Earth), but the problem is that the great bulk of this water is not easily accessible for non-marine organisms. Almost 70% of fresh waters is locked up in the ice sheets of polar regions and in mountain glaciers, 30% is in groundwater aquifers, so our rivers and lakes contain only 0.006% of total global storage of fresh water. This would be an insuperable problem if the world did not have the hydrological cycle, and the atmosphere, which is a vital link in the system.

Atmospheric water is always fresh as it is formed by evaporation from water or wetted land surface, as well as being produced by the transpiration of plants. Water vapor is often not considered as part of the hydrosphere. It is normally studied by meteorologists, but, recently, hydrologists have focused more attention on water flows in the atmosphere. These are equivalent to rivers but they are invisible and have no banks.

Weather and climate are mainly responsible for forming and sustaining lakes and rivers, creating deserts, and producing floods and droughts. The giant mechanism of Nature, which produces fresh water, is powered by the Sun. Its movement is known as the hydrological cycle. Figure 1 shows the operation of the cycle—a never-ending movement of water from the Earth's surface to the atmosphere and then back to the Earth as precipitation, then to rivers and lakes and to the sea. Some water can be stored in natural underground reservoirs for long periods. Most of the water vapor carried by the atmosphere is evaporated from the salty seas. The hydrological cycle is Nature's great distillation plant, converting saline sea-water into water vapor and then into fresh water that falls on the land as rain or snow. All the water on Earth (except that bound to minerals) takes part in the hydrological cycle, but at different rates. Thus, complete exchange of waters in the World Ocean proceeds over hundreds of years. The component of the cycle that is important for life, however, is only a minute proportion (470 000 km^3) of the Earth's water (1 360 000 km^3).

Figure 1 shows the importance of the atmospheric link in this water-driving machine. At any given moment, the atmosphere contains a very small portion of the Earth's water. However, the air enveloping the Earth is in such constant motion that over a period of time it transports tremendous volumes of water. Thus, on average in a July week in Arizona (USA), the atmosphere carries 18 000 million cubic meters (15 million acre-feet) of water over that dry State. This is equal to the annual flow of the Colorado River. All the water replenishing our lakes, rivers and wells must pass through the atmosphere. The behavior of the atmosphere, and of water in it, therefore controls the water on which we and all other living beings depend.

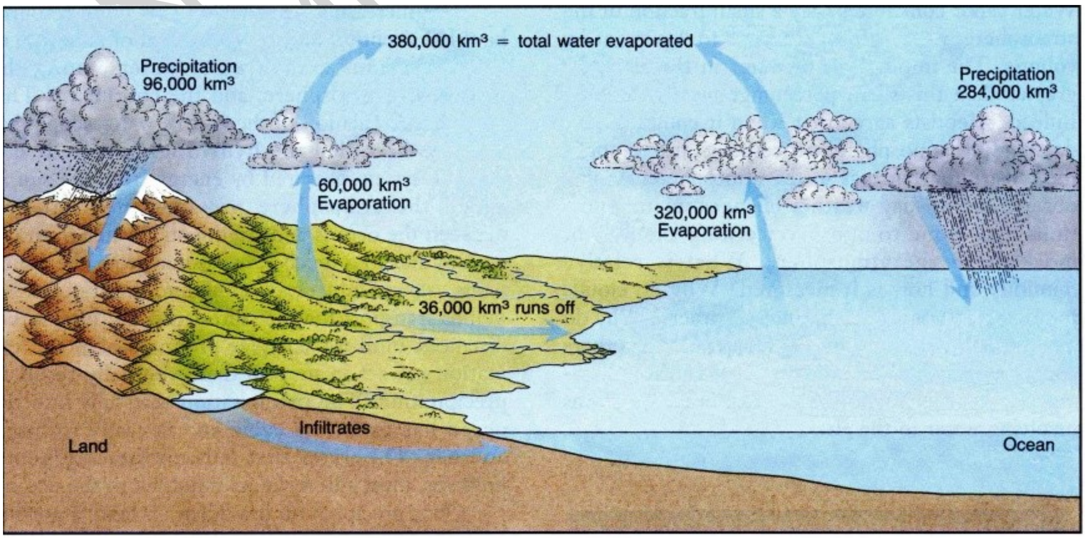

Figure 1. The global hydrological cycle.

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Biographical Sketch

Nina A. Zaitseva, Dr.Sc., was born in August 1940 in Moscow (Soviet Union). In 1962, she graduated from the Lomonosov Moscow State University as a geographer-climatologist. A citizen of Russia, she is now one of the leading Russian scientists in the field of atmospheric physics, radiation processes, and upper-air techniques. For about thirty years she dealt with radiometersonde observations, which were organized on a special radiometersounding network on the USSR territory, weather ships, and in Antarctica. Her PhD (1971) and Dr.Sc. theses were devoted to study of spatial and temporal variability of terrestrial (long-wave) radiation in the free atmosphere based on the radiometersounding method. She was an active participant of a number of large international experiments in the framework of the Global Atmosphere Research Program, and twice participated in Soviet Antarctic Expeditions. During 1976-1984, N.A. Zaitseva was twice elected a member of the IAMAP (International Association of Meteorology and Atmospheric Physics) Radiation Commission. She participated with reports in several quadrennial International Radiation Symposia, and is well experienced in international co-operation. She is the author of over 100 published works and a textbook on aerology. In 1962-1997, she served as junior, then senior scientist and secretary in the Central Aerological Observatory of the Russian Federal Service of Hydrometeorology and Environmental Monitoring. Since 1997, she has been leading scientist of the Department of Earth Sciences in Presidium of Russian Academy of Sciences.