COMPOSITION AND STRUCTURE OF THE ATMOSPHERE

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Summary

Weather influences our everyday lives, i.e. our activities, jobs, health and comfort. And everyone should understand that weather is the state of the atmosphere, one of the most important parts of our physical environment. The Earth's physical environment is traditionally divided into three major parts (spheres): the solid earth or lithosphere; the water portion of the planet, the hydrosphere; and the Earth's gaseous envelope, the atmosphere. And, it is significant that our environment is highly integrated and is not dominated by rock, water, or air alone. They are in continuous interaction as air comes into contact with rock, rock with water, and water with air. Moreover, the biosphere, the totality of life forms on our planet, is associated with each of the three physical domains and is an equally integral part of the Earth. The interplay and interaction among the spheres of the Earth's environment are uncountable.

Acted on by the combined effects of the Earth's motion and energy from the Sun, our planet's formless and invisible envelope of air reacts by producing an infinite variety of weather, which, in turn, creates the global climates. For better understanding of the atmosphere, people created many instruments and methods of sounding the atmosphere from the very surface up to its upper limits. Meteorological elements and units are actually physical ones; like all processes running in the atmosphere they are physical but they take place in a very complicated medium. The composition of atmospheric air is extremely favorable for all life forms, and if nobody still knows how life first appeared on the planet, no one should have any doubts that life exists here only owing to this beautiful "blanket".

The atmosphere extends from the Earth's surface up to thousands of kilometres above the ground. A basic property of the atmosphere is that it consists of several important layers:

troposphere, stratosphere, mesosphere, thermosphere, and exosphere (highest region of the atmosphere). Each has its own character of temperature profile. In addition, the atmosphere includes the ionosphere and ozonesphere.

1. Introduction

In its everyday life and activities human society closely interacts with the atmosphere and climate and weather—phenomena which are intimately related to the state of the atmosphere. Quite minor in its mass, as compared to that of the whole planet (it amounts to only about one millionth of the latter) the atmosphere is an absolutely indispensable environment for all the life forms. Without it the Earth would be a lifeless planet. So, the atmosphere is one of the most important elements of the life support systems—the subjects of the Encyclopedia of Life Support Systems (EOLSS).

Weather has enormous effects on agricultural productivity; it controls human needs in production and consumption of all forms of energy and is vital for aviation safety and efficiency of ground transportation. Many aspects of human activities strongly depend on abrupt changes in weather and on oscillations of climate. History knows many cases when severe winters and extensive summer droughts affecting large territories caused grave ruin to the economies of whole countries.

The atmosphere is an air envelope of our planet, and is the study object of the science of meteorology, which considers atmospheric processes in all their complexity, including the interaction of the atmosphere with the hydrosphere and the lithosphere (the Earth surface). It also investigates the origin and causes of various atmospheric phenomena aiming at developing techniques to predict such phenomena.

Basic physical elements characterizing the state of the atmosphere are atmospheric pressure, air temperature and humidity, cloudiness (its forms, height and amount), wind speed and direction, forms and amount of precipitation (rain, snow, hail, etc.), and some others. Among meteorological observations, some are made by means of measurements, using special instruments (thermometer, barometer, psychrometer, etc.), while others are performed visually and in such cases the skill of observers is of great importance. To monitor weather and atmosphere state over the globe, a special global network of different types of observational stations permanently and regularly operates in all countries throughout the world.

Studies of the atmosphere originated in times immemorial. The first meteorological observations were naturally conducted from the very surface of the planet. However the atmospheric processes in their development, and the weather phenomena precipitated by them all depend on interaction between atmospheric layers at various heights, so it becomes very important to be able to assess the state of the atmosphere throughout its whole vertical extent.

Studies of the atmosphere at various altitudes started simultaneously with the appearance of the first flying vehicles. Following the rapid technological progress in the twentieth century, meteorology went through a very quick developmental stage, so that it now includes a number of disciplines in their own right; the scope of the physical processes and phenomena in the atmosphere and the various techniques used to study them is very wide indeed. They include the physics of the atmosphere, synoptic meteorology, dynamic meteorology and climatology and some others, such as the main branches of contemporary meteorology.

The available techniques for studying the state of the atmosphere have made it possible to determine its chemical composition and structure from the surface of the Earth up to, practically, its upper limit, where it gradually dwindles into outer cosmic space.

Up to about 100 km the atmosphere is rather homogeneous in its chemical composition. Close to the surface, dry air contains 78.08% nitrogen, 20.95% oxygen, 0.93% argon, 0.03% carbon dioxide, and a remaining 0.01% such gases as hydrogen, neon, helium, methane, and crypton. It also contains xenon, ammonia, hydrogen peroxide, iodine, radon, and some others in even lesser amounts.

The mass of 1 liter of atmospheric air at 0 °C and 1013 hPa and the standard gravity acceleration (at 45 deg latitude) is 1.29 g. The total mass of the atmosphere is about 5.157 10^{15} *t*.

Atmosphere also contains small amounts of water vapor and of tri-atomic oxygen—ozone, O^3 (at about 0 - 3, and 0.000 001%, respectively). In contrast to other atmospheric components the amounts of water vapor and ozone in the atmosphere strongly vary diurnally, seasonally and geographically. Despite the relatively small amounts of these gases in the atmosphere, as compared to its principal components, their role in atmospheric processes is very significant. For example, together with carbon dioxide, both water vapor and O^3 strongly affect the thermal regime of the atmosphere, particularly at large heights. Ozone absorbs a major part of the incoming ultra-violet radiation. Water vapor is critical to the formation of clouds and precipitation.

The atmosphere always contains certain amounts of fine solid and liquid particles—the so-called atmospheric aerosols. Their concentration and other characteristics strongly vary with time and place. Water droplets, ice crystals, and also dust, soot, and ash from forest and other fires, soil, cosmic and volcanic dust, and particles lifted (raised) by wind from the surface, such as plant pollen, are among the natural aerosols. As a rule these are not toxic, and their concentration rarely becomes high.

Significant pollution of the atmosphere by aerosols results from human industrial and agricultural activities (the so-called anthropogenic aerosols). Most of the industrial aerosol enters the atmosphere from chemical industries, fuel combustion, automobile exhausts. These cause notable deviations from the norm of atmospheric composition, so that a specialized monitoring and control service is needed.

Molecules of oxygen dissociate above 100 to 110 km, and carbon dioxide and water vapor vanish from the atmosphere there too, so the molecular mass of air decreases. Above heights of 1000 km the lighter gases, such as helium and hydrogen start to dominate in the atmospheric composition, and even higher up the terrestrial atmosphere gradually turns into interplanetary gas.

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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 throughout the territory of USSR, on weather ships, and in Antarctica. Her PhD (1971) and DSc. (2004) 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, Nina 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 very experienced in international co-operation. She is the author of over 100 published works, including a textbook on aerology and an English-Russian Dictionary of Meteorology (co-author).

From 1962 to 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.