ENVIRONMENTAL STRUCTURE AND FUNCTION: EARTH SYSTEM

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Keywords: astenosphere, atmosphere, circulation, Coriolis effect, environment, heterosphere, air (atmospheric) pressure, weather, troposphere, stratosphere, mesosphere, cyclone, anticyclone, cloudiness, radiation, geosphere, geostrophic wind, gradient wind, greenhouse effect, hydrosphere, homosphere, solar radiation, heat radiation, hydrosphere, freshwater, sea level, groundwater, sea water, snow cover, permafrost, river, lake, glacier, glaciation, ice sheet, lithosphere, geological process, mineral resources, land forms, pedosphere, soil genesis, geography, landscape, variability, water cycle

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Summary

This article considers the structures of the Earth's main envelopes or spheres, and briefly describes their structure and functioning, showing the main features of each. It is shown that, on the basis of their chemical composition and phase and aggregate state, the following most important envelopes can be recognized: the atmosphere, hydrosphere, living matter, soils, cryosphere, the Earth's crust, mantle, astenosphere (aesthenosphere), and core. The Earth's crust and a part of the upper mantle are the "solid" envelope of the Earth (unlike the lower part of the mantle and the astenosphere, which have plasticity), and they are isolated as a lithospheric envelope or the lithosphere. Each of these envelopes has its own structure and properties. Spatially, great parts of these envelopes partially overlap. The Earth's envelopes (or spheres)—the atmosphere, hydrosphere, pedosphere, cryosphere, lithosphere, and living matter—are closely linked one to another by flows of matter and energy which integrate them into specific systems. Two large integrated systems are recognized: the geographical envelope and the biosphere.

1. Introduction

Earth is the only planet in our solar system that supports life as we know it, and its distance from the Sun provides favorable temperatures for life. Planet Earth is a sphere about 25,000 miles (40,000 kilometers) in circumference, the fifth largest in the solar system. About 70 percent of its surface is covered by large bodies of salty water called oceans, which are never still, but flow and change all the time. About 30 percent is dry land. The great land masses, known as continents, are surrounded by the oceans. The formation and evolution of the Earth and its environment have occurred over the long, long course of millennia. The principal components of the planet are:

- The atmosphere: the mass of air surrounding the Earth like a transparent wrapping.
- The lithosphere: the solid outer crust of rocks about 80 km thick, which is the outer solid shell of the planet body. This also includes the pedosphere, where the soils are present and the soil-forming processes occur.
- The hydrosphere: the water portion of Earth as distinguished from the solid part (the lithosphere), and from the gaseous outer envelope (the atmosphere). This part of the environment also includes the cryosphere, which is that part of the

Earth's body that is predominantly frozen and mainly consists of different forms of ice.
- The biosphere: the life zone of the planet which permeates all the above as life is widely spread around the planet. The biosphere includes the lower atmosphere, the whole hydrosphere, the pedosphere, and the outer portion of the lithosphere to a depth of about 2 km; in short, all regions in which living organisms exist.

These structural components are interlinked and unified into a holistic concept of the Earth system. The Earth's living system is discussed in other themes of EOLSS on-line.
In the topic on the atmosphere, stress is placed on the structure, physics, and chemistry of this medium and on its circulation patterns. While the hydrosphere is included here to provide a complete overview of the physical environment as a whole, the subject is considered in far greater detail in other themes. Besides covering the hydrological cycle, the hydrosphere topic includes articles on the oceans, freshwater (surface water and groundwater), and the linkages between surface water and groundwater. The cryosphere topic deals with all forms of ice on Earth. This has an important effect on the global climate, which is also considered in other themes. In the topic on the lithosphere, discussions deal with the genesis of the zone, the geologic processes occurring there, and the mineral resources it contains. Although the pedosphere is the outer layer of the lithosphere, it is discussed here as a separate entity because of the special circumstances of its genesis and its important role in the functioning of many life-supporting systems.

2. Atmosphere

In everyday life and activities, human society interacts closely with the atmosphere through climate and weather, 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 life forms. Without it the Earth would be a lifeless planet.
Weather has a powerful effect on agricultural productivity; it controls human needs in the production and consumption of all forms of energy, and it is critical for aviation safety and the efficiency of ground transportation. Many aspects of human activities are critically affected by sharp changes in weather and the oscillations of climate. History knows many cases when severe winters, or extensive summer droughts afflicting large territories, brought catastrophe to the economies of whole countries.

The atmosphere—an air envelope of our planet—is studied in 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's surface), and investigates the origin and causes of various atmospheric phenomena, partly with the objective of developing forecasting techniques.

2.1. Composition and Structure of the Atmosphere

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 virtually to its upper limit, where it gradually dwindles into outer cosmic space.

Up to about 100 km the atmosphere is fairly homogeneous in its chemical composition. Close to the surface, dry air contains 78.8 percent nitrogen, 20.5 percent oxygen, 0.3 percent argon, 0.3 percent carbon dioxide, with a further 0.1 percent comprising such gases as hydrogen, neon, helium, methane, and crypton. It also contains xenon, ammonia, hydrogen peroxide, iodine, radon, and some others in even smaller amounts.

The mass of 1 liter of atmospheric air at 0 °C and 1013 hPa and the standard gravity acceleration (at 45° latitude) is 1.9 g. The total mass of the atmosphere is about 5.57 10^{15} tonnes.

The atmosphere also contains small amounts of water vapor and of tri-atomic oxygen (ozone, O_3), at about 0–3 percent, and 0.000.001 percent, respectively. In contrast to other atmospheric components, the amounts of water vapor and ozone in the atmosphere vary strongly diurnally, seasonally, and geographically. Despite the relatively small amounts of these gases in the atmosphere as compared with its principal components, their role in atmospheric processes is quite significant. For example, together with carbon dioxide, both water vapor and ozone strongly affect the thermal regime of the atmosphere, particularly at great heights. Ozone absorbs a great deal of the short-wave (damaging) 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 vary widely with time and place. Water droplets, ice crystals, and also dust, soot, and ash (particularly from forest fires), cosmic and volcanic dust, and particles 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 is seldom very high.

Significant pollution of the atmosphere by aerosols results from human industrial and agricultural activities (the so-called anthropogenic aerosols). Most industrial aerosols enter the atmosphere from chemical industries, fuel combustion, automobile exhausts, and other similar sources. They result in noticeable differences in atmospheric composition in certain areas, clearly deviating from the background composition of the atmosphere, so that a specialized monitoring and controlling service is needed.

Molecules of oxygen dissociate into individual atoms above 100–110 km, and carbon dioxide and water vapor also dissociate in the atmosphere at this level, so the molecular mass of air decreases. Above a height of 1,000 km, the lighter gases, such as helium and hydrogen start to dominate in atmospheric composition, and even higher up the terrestrial atmosphere gradually turn into interplanetary gas.

Despite the high variability of atmospheric parameters with altitude, one may envisage the atmosphere as consisting of several layers, the characteristics of each being fairly stable. Such a division enables one to present a generalized structural scheme of the atmosphere.

One may classify the atmosphere into layers in several ways, depending on the particular properties one considers as the basis of such a stratification. These may include its thermal state, dynamics, electrical properties, the content of either its constant or variable components, and so on. We shall consider such a general scheme of the atmospheric structure, based on the vertical temperature profile. Note that the particularities of that profile differ from region to region, and strongly vary with time. Changes in air temperature may be caused by variations in the thermal budget of the atmosphere and of the Earth's surface. They are related to regular oscillations in the amount of solar radiation reaching the atmosphere and the surface (e.g. when day is followed by night, or winter by summer, the so-called daily and seasonal temperature cycles), and also to numerous processes in the atmosphere associated with air movements.

Figure 1 shows the average vertical temperature profile of the atmosphere, depicting five basic layers. The average altitudes at which the temperature profile has sharp salient points are taken for boundaries between them. The principal features of temperature distribution with height remain stable within each of those layers.

In the lower stratosphere, temperature only gradually varies up to about 20 km (the so-called isothermal range); it is not uncommon to find the temperature still slowly decreasing with height there. Above this level, temperature starts steadily to increase, slowly at first, but from around 34 or 36 km up, rise becomes quite rapid. The upper boundary of the stratosphere—the *stratopause*—is stratified at the level of maximum temperature (260–270°K, or about 0°C). The layer above the stratopause, in which the temperature drops off with height again, is called the *mesosphere* (from *meso*, meaning middle), and the temperature at its upper boundary—the *mesopause*—can reach as low as 170–200 K (–80 to –130°C). The layer found above the mesopause is the *thermosphere* (*thermo* means warm), characterized by a rapid temperature increase with height. The corpuscular and X-ray emissions from the Sun are absorbed there, and meteors burn up in the thin air, so that it is the most "protective" layer for the Earth. One should not be confused by the temperature rise within this layer shown in Figure 1,

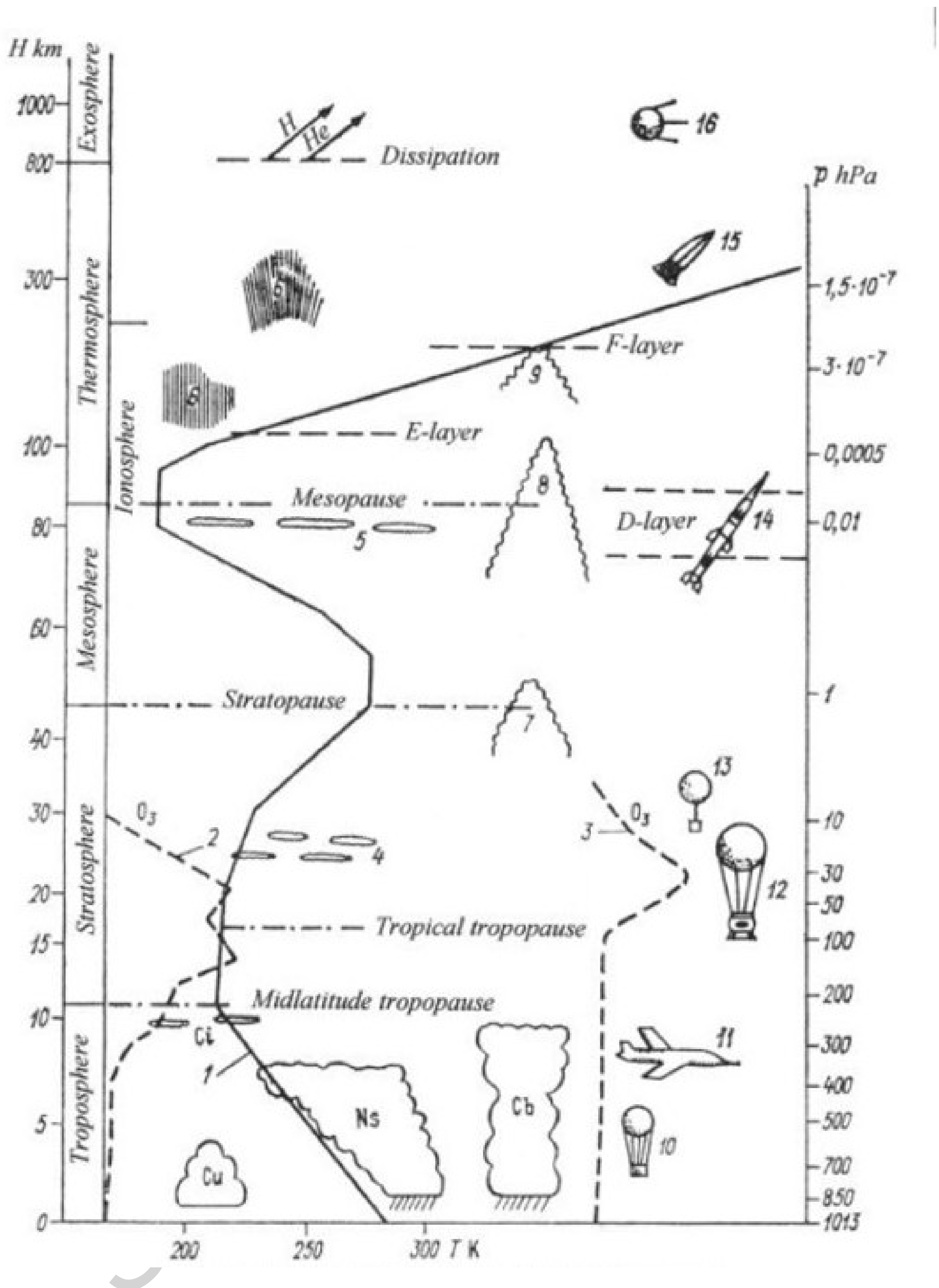

Figure 1. Structure of the atmosphere and methods of investigation
1: temperature profile; 2: ozone vertical distribution in middle and polar latitudes; 3: ozone vertical distribution in tropics; 4: nacreous (pearl) clouds; 5: noctilucent clouds; 6: auroras; 7: reflection of acoustic waves; 8: reflection of medium radio waves; 9: reflection of short radio waves; 10: free-flight manned balloons; 11: aircraft (flying laboratories); 12: stratospheric manned balloons; 13: radiosondes; 14: meteorological rockets; 15: geophysical rockets; 16: satellites.

as this temperature profile only reflects the continuously increasing kinetic energy of the air molecules, which move at nearly cosmic speeds in the extremely rarefied medium at this level.

The lowest atmospheric layer, characterized by a decrease of temperature by about 6 °C per kilometer, is called the *troposphere* (from Greek *tropo* changing). The *stratosphere* (from Greek *strato*, stratified) lies above it, and is generally characterized by increasing temperature with height. The boundary between the troposphere and the stratosphere is called the *tropopause*.

The height at which the boundaries between the layers are found, and also their thickness, show significant variations both in time and space. The tropopause, for example, is found at altitudes from 8 to 17 km (its average height at the equator is 16–18 km, and 8–10 km at the poles), the stratopause from 45 to 55 km, and the mesopause from 80 to 90 km.

Beside the character of the vertical profile of temperature, the atmospheric layers are often identified according to the typical physical properties of air at the altitudes under consideration. Such layers are, in particular, the *ozonosphere*, the *ionosphere*, and the *exosphere*.

- The ozonosphere is that layer, from 10 to 50 km, in which the principal mass of atmospheric ozone is concentrated.
- The ionosphere, above 70 km (i.e. in the thermosphere), contains strongly ionized air.
- The exosphere (*exo* means outer) is the outer range of the sphere, from which the atmospheric gases "escape" into cosmic space. The lower boundary of the exosphere is found at 600–800 km. This layer is sometimes called the "dissipation" layer.

On the basis of its chemical composition, the atmosphere is separated into the *homosphere* and the *heterosphere*. The homosphere is characterized by the constancy of the relative content of its principal gases (nitrogen, oxygen, argon). It reaches from the Earth's surface to the *turbopause* (up to 100–110 km). Above it lies the heterosphere, in which the composition of the atmospheric air noticeably changes: atomic oxygen is first generated in it, with nitrogen following at higher altitudes, then both the carbon dioxide and water vapor vanish, and air ionization becomes stronger. The molecular mass of air drops too.

As for the character of the interaction between the atmosphere and the underlying surface, two principal layers are identified: the *boundary layer* and the *free atmosphere*. Another surface layer is identified within the boundary layer, covering the lowest several tens of meters, that layer being in direct contact with the surface.

Lately the term "near-Earth cosmic space" has come into use in the context of orbital flights of artificial satellites and manned space stations. This "space" starts from 150–200 km up. Note that above 200 km both the temperature and density of air undergo great changes in both space and time: it is as if the atmosphere pulses at those heights, periodically shrinking and expanding.

2.2. Physics of the Atmosphere

Strictly speaking, *physics of the atmosphere* is a branch of meteorology that studies the optical, electrical, acoustical, and thermodynamic properties of the gas mixture present in the atmosphere. The problem is that this gas mixture is not studied in laboratory conditions, where a scientist-physicist can create a state desirable for investigation (prescribed gas composition, temperature, moisture, etc.), but under very complex conditions with unpredictable interactions with other spheres (hydrosphere, cryosphere, pedosphere, and lithosphere). This makes meteorological investigations very difficult. For example, the most reliable measurements are those made *in situ* and with precise instruments. But many layers in the atmosphere (mainly the higher ones) are not accessible for direct measurement, so scientists must use different, remote methods to obtain information on the atmospheric state at one or another region.

Being a gaseous medium, the atmosphere is the most mobile of all the Earth's envelopes. The atmosphere does not "recognize" any political frontiers, and air polluted at one place passes across any borders into other regions. This is why countries have agreed to the establishment of the World Meteorological Organization (WMO), a specialized Agency of the United Nations Organization for co-ordinating, standardizing, and improving meteorological activities throughout the world, and for encouraging the efficient exchange of information between countries in the interest of various human activities. The main body of the WMO is the World Weather Watch (WWW). This is a worldwide, co-ordinated, developing system of meteorological facilities and services provided by different countries—the WMO members—so as to ensure that all countries obtain the meteorological information required both for operational work and for research.

The essential elements of WWW are the Global Observing System (GOS), the Global Data-Processing System (GDPS), and the Global Telecommunication System (GTS). The GOS embraces a huge range of observational stations (meteorological, synoptic, upper-air or aerological, agrometeorological, actinometric, etc.) throughout the world. It is the co-ordinated system of methods, techniques, and facilities for making observations on a worldwide scale. The GDPS consists of meteorological centers with responsibility for the processing, storage, and retrieval of meteorological information. The GTS is the co-ordinated global system of telecommunication facilities and arrangements for the rapid collection, exchange, and distribution of observational data, processed information, and related data. All three operate within the framework of the WWW.

Thus, all the above international bodies perform activities to support scientists dealing with problems of the atmosphere and studying atmospheric physics and chemistry. The final task of meteorology is to provide the people and administrative bodies of every country on the globe with reliable information on the prevailing weather state and with correct weather forecasts (as far as possible).

Like any other gaseous medium, the atmosphere obeys the laws of thermodynamics. These are the laws governing the processes of heat exchange and the conservation of energy. Of particular relevance are the gas laws, which in classical physics are applied to perfect gases: the Boyle-Mariotte Law, Charles-Gay-Lussac Law, Dalton's Law, and the equation of state. The Boyle-Mariotte Law states that the product of pressure p and volume V is constant in an isothermal process, i.e. $pV = F(T)$, where the function F of the temperature T cannot be specified without reference to other laws. The Charles-Gay-Lussac Law states that in a gaseous system at constant pressure, the temperature increase and the relative volume increase stand in approximately the same proportion for perfect gases. Dalton's law states that a mixture of gases have a pressure equal to the sum of the partial pressure that each of the gases of the mixture would have as sole component with the same volume and temperature, provided there is no chemical interaction. And, most importantly, the equation of state relates the temperature, pressure, and volume of a system in thermodynamic equilibrium. In meteorology, it has been found sufficient to use the equation for thermally perfect gases in the form $pV = M (R^*/m) T$. Here p is the pressure, V is the volume, T is the Kelvin temperature, R^* is the universal gas constant, m is the molecular weight of the gas, and M is the mass of the system. For a mixture of several perfect gases, the partial pressures are added up by Dalton's law, and the resulting equation is $pv = RT$, where v is the specific volume and R is the gas constant for the mixture.

As seen in the previous section, the atmosphere contains various gases, some of which are far from ideal, and both p and V change significantly with height. Classical physics usually operates with so-called *adiabatic conditions* when physical processes running in a volume of a gas medium are considered as an adiabatically enclosed system, which is a thermodynamic system across whose boundaries no heat or mass is transported. It is evident that the open atmosphere does not allow occurrences of such conditions in nature, so meteorologists usually deal with diabatic or *non-adiabatic* processes. This makes any experimental investigation of the real atmospheric state, and in particular its physical description, a very complicated task.

The principal characteristics of any physical medium are heat and temperature. The concepts of heat and temperature are sometimes confused. *Heat* is a form of energy, and is defined as the total kinetic energy of all the atoms or molecules that compose a medium or substance. The *temperature* is a measure of the average kinetic energy of the individual atoms or molecules in a substance. When a substance is heated, its atoms move faster and faster, and its temperature rises.

Three mechanisms of heat transfer are recognized: conduction, convection, and radiation. Although they are presented separately, all three processes proceed simultaneously in the atmosphere. In addition, these mechanisms operate to transfer heat between the land–water surface and the atmosphere. Conduction is the transfer of heat through matter by molecular activity. It does not play an important role in atmospheric physics. Convection is the transfer of heat by mass movement within a substance. It can only take place in fluids (liquids and gases), so it is of great importance in atmospheric physics.

As noted, the Sun is the basic source of energy that drives all physical processes on the Earth, and the "weather machine" in particular. The Sun emits all types of electromagnetic radiation, like a "black body" in classical physics. Remember that all types of radiation, whether x-rays, radio, light, or heat waves, travel through the vacuum of space at a constant speed which is close to 300,000 kilometers per second, and only slightly slower through the air. There are three important ranges or divisions of the solar radiation spectrum: *visible light* (0.4–0.7 micrometers), *ultraviolet radiation (rays)* (0.4–0.001 micrometers), and *infrared radiation* (0.7–3.0 is the close solar IR, and 3.0–40 micrometers is the terrestrial LW radiation). The most important radiation laws are the Stefan-Boltzman law and Wien's displacement law. The *Stefan-Boltzman law* mathematically expresses the rate of radiation emission depending on a body temperature per unit area: $E = \sigma T^4$, where σ is the Stefan-Boltzman constant which is equal to 5.67×10^{-8} $W{\cdot}m^{-2}K^{-4}$. *Wien's displacement law* describes the relationship between the temperature T of a radiating body and its wavelength of maximum emission λ_{max}: $\lambda_{max} = C/T$.

When entering the atmosphere, incoming solar radiation is prone to scattering, absorption, and reflection. An important characteristic of the Earth's surface is *albedo*, which is the reflected fraction of the total solar radiation expressed as a percentage. The albedo for the Earth as a whole (planetary albedo) is about 30 percent. The albedo can vary considerably from place to place as well as from time to time, depending on surface properties and the amount of cloud cover. It is a very important characteristic for radiation budget studies.

Water vapor is a very important component of the atmosphere. Although the total amount is not great (see above), its role in atmospheric physics is very significant. The most interesting manifestations of the condensation process are clouds in the atmosphere. A cloud is a visible hydrometeor consisting of an aggregation of minute water and/or ice particles in the atmosphere above the Earth's surface (cloud differs from *fog* only in that the latter is in contact with the surface). Clouds are of great importance for many physical processes occurring in the free atmosphere.

Optics of the atmosphere deals with the laws of light propagation in the atmosphere, and the nature of many interesting optical phenomena such as mirages, rainbows, halos, Sun Dogs, Solar Pillars, the Glory, and the Corona. It embraces the study of such atmospheric processes and properties as the refraction, reflection, diffraction, scattering, and polarization of light. It does not include the study of other kinds of radiation, especially the radiation transformation and transfer in the atmosphere and on the surface. Atmospheric physics also deals with *atmospheric electricity*. The atmosphere has its own electric field which is certainly linked with the general planetary electric field. Disturbances of these fields create electrical phenomena in the atmosphere. These phenomena include not only such striking manifestations as lightning and St. Elmo's fire (visible phenomena), but also less noticeable but important effects such as electric currents and discharges in the atmosphere and atmospheric ionization.

Atmospheric physics is also concerned with atmospheric acoustics: the role of the atmosphere in the propagation of sound.

2.3. Chemistry of the Atmosphere

This comprises the totality of subjects related to chemical composition and chemical reactions in the atmosphere. It embraces studies of the chemical composition of atmospheric air near the Earth's surface and at high levels, aerosols and gas admixtures, air ionization, photochemical reactions in the atmosphere, the chemistry of atmospheric precipitation, chemical exchanges between the air and soils, ocean, and space, and natural and anthropogenic radioactivity as well.

In view of the increasing pollution of the atmosphere over recent decades and such new phenomena as acid rain, understanding of atmospheric chemistry is becoming ever more important for developing adequate measures for protection of the natural world from anthropogenic impact.

2.4. The Atmosphere as a Colloidal Medium

In the physical sense the atmosphere can be considered as a colloid system: an intimate mixture of two substances, one of which—called the *dispersed phase* (or colloid)—is uniformly distributed in a finely divided state through the second substance, called the *dispersion medium*. The dispersion medium may be a gas or liquid (or a solid) and the dispersed phase may also be any of these, with the exception that one does not speak of a colloidal system of one gas in another. A system of liquid or solid particles colloidally dispersed in a gas is called an *aerosol*. A cloud may be considered as a colloidal system in the atmosphere.

2.5. Nature of Atmospheric Circulation

Being a mobile gas medium, the atmosphere is in permanent motion. Different flows of atmospheric air are combined into the very complicated system of atmospheric circulation. The principal manifestation of atmosphere movement is the wind. The largest wind patterns, called macroscale winds, have great geographical extent. These planetary-scale flow patterns extend around the entire globe and can remain essentially unchanged for weeks at a time. A somewhat smaller circulation is termed synoptic scale; it consists mainly of individual traveling cyclones and anticyclones. These weather "producers" are common in the middle latitudes, where they move in a west–east direction in the Northern Hemisphere, and in the opposite direction in the Southern. These rotating systems usually persist for days or occasionally weeks, and have a horizontal dimension of hundreds to thousands of kilometers. Then there are mesoscale winds, which influence smaller areas but usually have more intensive vertical flows. The final category of atmospheric motion is local winds, of which land and sea breezes are perfect examples.

One of the first contributions to the classical model of global atmospheric circulation came from George Hadley in 1735. He pioneered understanding of solar radiation and the non-homogeneity of the Earth's surface albedo as the basic driving forces for atmospheric circulation. He assumed that the large temperature contrast between the poles and the equator would create a thermal circulation similar to that of a sea breeze. Since that time science meteorology has progressed a long way towards understanding the nature of atmospheric circulation, though many features are still not well understood. A great amount of observational data allowed formulation of the concept of general atmospheric circulation: a complete statistical description of atmospheric motion over the Earth.

2.6. Modeling of Atmospheric Circulation

Any model presents either a theoretical or an empirical representation of phenomena. Theoretical models have been developed to study many features of atmospheric circulation, while for different practical uses empirical models are needed.

The most important empirical model of the atmosphere is the so-called *standard atmosphere.* This is a hypothetical vertical distribution of atmospheric temperature, pressure, and density which, by international agreement, is taken to be representative of the atmosphere for purposes of pressure altimeter calibrations, aircraft performance calculations, aircraft and missile design, and ballistic tables, among other purposes. In other words, it is a statistical description of the atmosphere. Such standard atmosphere is adopted by national and international organizations (NASA Standard Atmosphere, WMO Standard Atmosphere, International Civil Aeronautical Organization (ICAO) Standard Atmosphere, etc.).

There is also a theoretical model of the atmosphere. It is developed as a system of mathematical equations or numerical approximations capable of reproducing certain key structures and processes in the atmosphere. Numerical models of the atmosphere general circulation, and ones for certain mesoscale or local patterns, are now widely used as relevant instruments for weather forecasting.

3. Hydrosphere

The hydrosphere is the water portion of the Earth's upper part, as distinguished from its solid part (the lithosphere) and from the gaseous outer envelope (the atmosphere). It includes the waters of oceans, seas, rivers, lakes, swamps, and marshes, as well as soil moisture, underground waters, water in the atmosphere, and water in glaciers, ice, and snow cover, as well as in all living organisms. In this way, it penetrates through all other parts of the geosphere.

In the early stages of its history Earth was devoid of free water. Formation of the hydrosphere was a very gradual process resulting from degassing of the mantle. According to estimates of the hydrologist R. Klige, 4 billion years ago the hydrosphere volume amounted approximately to 20 million km^3, which was 7,000 times smaller than the present volume. The degassing process from the mantle and increment of the hydrosphere volume (approximately 1 km^3 per year) is still taking place today. Water bodies now occupy about 75 percent of the Earth's surface.

Water in the hydrosphere exists in different phase states: liquid, solid, and gaseous. Furthermore, water in the hydrosphere has different isotope and molecular composition.
In addition to its wide occurrence, water has several specific properties that determine its important role on the Earth. One of these properties is its mobility. Unlike mountain rocks, water in its liquid and vaporous state can move quickly. Even ice, in which water exists in its solid phase, has fluidity. Water can evaporate at any temperature. It is a good solvent, owing to which it is able to accumulate and transport huge amounts of dissolved components. The high thermal capacity of water determines the huge heat storage capacity of the oceans, and this in turn has important effects on the climates of

different regions. This plays a very important role in processes of exchange by matter and energy. Phase transitions of water occurring in nature are accompanied by change in its volume. So, for example, when water freezes its volume increases by 11 percent, and this is of great importance for weathering, mountain rock destruction, and soil formation. The presence of water is a necessary condition for existence of all living organisms. It is necessary for maintaining the processes of life, including photosynthesis of organic matter, and for many organisms it is also a medium of life.

Almost all chemical elements are present in natural waters. Numerous investigations have shown that in natural waters bicarbonate, sulfate, and chloride are generally predominant among anions (acid ions), while among the cations calcium, sodium, magnesium, and potassium are the most abundant. The relationship between anions and cations is used as a basis for the most widespread classifications of the chemical composition of natural waters.

Water volumes are distributed in fundamentally different proportions in the different parts of the hydrosphere (see Table 1).

3.1. Atmospheric Waters

Atmospheric waters comprise water vapor and particles of liquid water and ice condensing around very fine inorganic and organic solid particles: aerosols (volcanic dust, smoke, salt particles, etc.) present in the atmosphere. Water particles range in size from 0.0003 to 0.016 cm. Further condensation of water vapor on these particles, as well as their coalescence, leads to growth in the size and weight of the water droplets or ice crystals. The amount of water in the atmosphere depends on geographical location and on the season.

The maximum evaporation (in some oceanic regions) is as high as 2,500 mm of the water layer, while the minimal one (in deserts and some polar regions) is less than 100 mm (even in places where sometimes no rain occurs, there is some evaporation as there may be some other source of moisture supply).

The pressure of water vapor in the atmosphere decreases with height, and so the moisture content in the atmosphere decreases too. Half of the water vapor content is present in the lowest layer of the atmosphere, up to 1.5 km high, and more than 99 percent is in the troposphere.

After evaporation from the surface of the Earth, movement of atmospheric water proceeds mainly as a result of the mass movement of air, as well as of its gravitational fallout from the atmosphere.

Atmospheric water precipitation varies significantly across both space and time. In arid regions, the precipitation is sometimes only a few mm per year. In other regions it can exceed 10,000 mm annually. In one of the rainiest areas of the world, Cherapundji in the foothills of the Himalayas in India, on average more than 11,000 mm of rain fall every year, while the largest recorded total is almost 23,000 mm.

Elements of the hydrosphere	Water volume (thousand $km^{3)}$	% of total volume
World ocean	1 370 000	93.94
Underground waters	60 000	4.11
including those in a zone of active water exchange	4 000	0.27
Glaciers	24 000	1.65
Lakes	278	0.019
Soil moisture	83	0.006
Water vapor in the atmosphere	14	0.001
River waters	1.2	0.00008
Water in living organisms	≈ 8–12	0.0007
Total	**≈ 1 458 400**	**100**

Table 1. Water volumes on the globe

Water evaporated from the land surface or from oceans contains a very small quantity of salts. Thus, for example, general mineralization of condensates of oceanic waters amounts to between 0.1 and 2 mgl^{-1}, and the content of individual ions is as follows (in mgl^{-1}):

Na^{+}:	0.04–0.6
K^{+}:	0.003–0.06
Ca^{2+}:	0.06–0.15
Mg^{2+}:	0.01–0.06
HCO^{3-} + CO^{32-}:	0.09–0.4
SO_4^{2-}:	0.02–0.32
Cl^{-}:	0.05–0.8

Dissolution of solid aerosols present in the atmosphere has an important influence on the composition of atmospheric water, and thus its mineralization increases. So, for example, around coastal zones or in areas with a wide occurrence of solonchaks or salt lakes, fine salt particles are carried up to the atmosphere and the mineralization of atmospheric precipitation drastically increases. Anthropogenic activity also results in significant change of the aerosol composition, and hence, of atmospheric precipitation. Emissions of compounds of sulfur, nitrogen, and chlorine into the atmosphere cause acidification of the atmospheric precipitation in some regions in the world. While in the most regions average pH of atmospheric precipitation is 5.6, in some industrial regions pH can be as low as 2.8. High acidity of atmospheric precipitation can exert a strong negative effect on the biological productivity of water bodies and forests, and on soil fertility.

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