# ENVIRONMENTAL STRUCTURE AND FUNCTION: CLIMATE SYSTEM

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## Contents



## Summary

The Global Climate System and factors of climate variability are described. The main processes in the Global Climate System are considered. Climate over the Globe as it is seen today on observational data is presented. Climate changes in the last century and the most significant patterns of climatic trends are presented. Climate modeling and possibilities of the models to reproduce the Contemporary Climate and current climate changes are analysed. And at last an answer to question: what do climate models tell us about our future is offered.

## 1. Introduction

Our "blue planet" that we call "home of people" is a very special and unique place. It is the only planet in our solar system and possibly in the galaxy where life is known definitely to exist. All life concentrates within a thin blanket of air, water, and soil. This spherical shell of life is known as the biosphere. The biosphere can be in three environs: the atmosphere (air), the hydrosphere (water), and the lithosphere (land surface: rock and soil). It is the unique attributes of the Earth's atmosphere that allow it to be a habitable place for humans, animals, and plants.

The **atmosphere** is a mixture of gases and particles that surround our planet. When seen from space, the atmosphere appears as a thin seam of dark blue light on a curved horizon. The atmosphere serves several purposes: it provides us with the air we breathe; its gases retain the heat that warms the Earth; and its protective layer of ozone shields us from damaging rays emitted by the sun. The atmosphere also acts as a reservoir or storehouse for natural substances as well as emissions derived from human activities. Within the storehouse, physical and chemical actions and reactions take place. Physical processes and the characteristics of physical condition of atmosphere determine the weather and climate.

The terms "atmosphere", "weather" and "climate" frequently are used in daily life in a broad sense. For example, it is possible to speak about "friendly climate" or about "tense atmosphere". People sometimes use the terms “weather” and “climate” interchangeably, but they are not the same.

In science these terms have a narrower precise sense. **Weather** is defined as the physical state of the atmosphere at a specified point of the Globe and at a specified moment of time. Concerned variables include temperature and pressure, wind velocity, humidity, precipitation, sunshine and cloudiness, phenomena such as fog, frost, hail storms, and other characteristics. **Climate** in the narrow, but widely used sense is the synthesis of day-to-day weather variations. It is represented by the whole variety of weather conditions for a specified area and a specified interval of time. The statistical description in terms of the mean, variability and extreme of relevant quantities or phenomena frequency over a period of time is used to characterize climate. (All these statistical values are called as "climatic variables".) The standard period for assessing of the current or Contemporary Climate is three decades, as defined by WMO.

The properties that characterize the climate are thermal (temperatures of the surface air, water, land, and ice), kinetic (wind and ocean currents, together with associated vertical motions and the motions of air masses, aqueous humidity, cloudiness and cloud water content, groundwater, lake lands, and water content of snow on land and sea ice), and static (pressure and density of the atmosphere and ocean, composition of the dry air, salinity of the oceans, and the geometric boundaries and physical constants of the system). These properties are interconnected by the various physical processes such as precipitation, evaporation, infrared radiation, convection, advection, and turbulence.

***Modeling the Global Climate and Future Projections.*** One of the most effective ways of estimating our future climate is to use powerful computer simulations of past and present climates.

Scientists have been able to make some projections about how greenhouse gas concentrations may change over the next hundred years, based on a range of scenarios. The most extreme scenario is based on an assumption that high economic growth will continue, and that humans will continue to use coal, oil, and gas globally for their energy needs. This scenario suggests that concentrations of carbon dioxide could reach more than three times pre-industrial levels by 2100. Even the most hopeful scenario based on low growth in global population and intensive conversion to renewable energies suggests that carbon dioxide concentrations would be about 75 percent higher than pre-industrial levels by 2100, and would continue to rise thereafter. Stabilizing global emissions at 1990 levels now would have the same effect, because of the long life of these gases in the atmosphere.

The international research community have employed the most advanced climate models to determine what these projected increases in greenhouse gas concentration could mean. Their research suggests that average global surface temperature may increase on average by almost a half degree each decade during the next century. To provide an idea of what that means, global warming over the next century may be as great as the change in temperature between the peak of the last ice age, some 25,000 years ago, and today.

Stabilizing greenhouse gases is only a part of the solution, though. Scientific projections also indicate that, even if the concentrations of greenhouse gases were stabilized by 2100, air temperature could continue to increase. As well, sea levels, which are expected to rise anywhere from 15 to 95 cm by 2100, could continue to rise at a similar rate in future centuries. This would be the case even after concentrations of greenhouse gases had been stabilized, and even after global mean temperatures had stabilized. This is because of the long time it takes oceans to heat up before they fully respond to increased air temperatures.

***Potential Impacts of Climate Change***. In general, all available models agree that warming will be greater in Arctic regions than in equatorial regions, and that continents will warm more than oceans. Beyond this, however, scientists are not able to predict the exact consequences of continued increases in greenhouse gas concentrations or its impact on specific regions.

Around the world, climate change is projected to:

- threaten the world's boreal forests with an increased fire risk because of the drying climate;
- cause water needs to outstrip supply;
- cause severe water loss due to changes in evaporation and precipitation patterns;
- cause flood damage to low-lying countries and island states, including loss of coastal land to rising sea levels;
- encourage the movement of tropical diseases such as malaria northward, where populations have little or no immunity; and
- affect international trade patterns.

The remainder of this paper introduces the problem of **Environmental Structure and Climatic System** in more detail.

***What role does the greenhouse effect play in climate?***
***How does the water cycle affect the climate?***
***What role do oceans play in influencing climate?***
***How do the volcanoes affect the climate variability?***

We describe components of the Global Climate System and factors of climate variability (see *Climate and the global climate system*, in EOLSS On-Line) and we answer the questions: Can we change the climate? Why are greenhouse gas amounts increasing?

We represent a general picture of the climate over the Globe as it is seen today on observational data (see *Climate now*). We discuss scales and major forms of climate variability including short-term climate oscillations, such as ENSO, QBO, Blocking etc. (see *Weather systems and weather forecasting*). As well, we consider how climate has changed in the last century and present the most significant patterns of climatic trends in surface temperature and precipitation, upper air temperature, atmospheric circulation etc. (see *Observed climate change in the twentieth century*, in EOLSS On-Line).

Then, we describe the basic aspects of climate modeling and possibilities of the models to reproduce the Contemporary Climate and current climate changes (see *Global climate models*) and, also, what do climate models tell us about our future (see *Climate projections and future climate*, in EOLSS On-Line).

We conclude with a reflection: Where do we go from here? And we describe the most important international actions and programs dealing with a problem of the Climate and Climate Change (see *International activity concerning climate*).

## 2. Processes in the Global Climate System.

In a simplistic sense, the Earth's climate system is like a giant heat engine. Incoming short wave energy from the sun is the fuel that drives the system. This energy heats the Earth's atmosphere, surface and oceans, and provides the thermal energy that produces the hydrological cycle of evaporation, condensation, precipitation and water flow. It also is the indirect source of the kinetic energy inherent in the atmospheric motion, ocean currents and storms. However, like an internal combustion engine, the climate system also needs a mechanism for dispensing heat back to space in order to avoid overheating. That mechanism is provided by the radiation of long-wave "heat energy" from the earth's surface and atmosphere back to space. As long as the incoming solar energy and the net outgoing heat radiation are in balance, the Earth's climate system neither heats up nor cools down. It is in "equilibrium", and its average surface temperature will remain relatively constant.

The above energy flow within the planet's climate system involves a large number of individual physical and chemical processes, many of which interact in complex ways. These processes not only take place within the atmosphere, but also involve each of the other components of the climate system, such as the oceans, the cryosphere (snow and ice) and the geo-biosphere (terrestrial ecosystems, soils, fresh water). Some of these processes have been studied for many decades and are well understood. However, others still defy adequate description. Some take place at the microphysical level, and on time scales of seconds, while others can be hemispheric in scale and take place over years, decades or even longer time scales. Yet all may be important in understanding how the climate system behaves and, perhaps more significantly, how it responds to any imbalances in the net energy flow into and out of the system that may occur.

To better understand these processes and how they interact, scientists use a combination of empirical information collected under controlled experiments or through observation of the natural climate system and theoretical models that attempt to describe these processes in terms of mathematics and physics. Progress in understanding thus becomes an iterative process of modeling theories developed on the basis of observations, then testing and refining these models against further observations. Such models range from very simple algorithms that describe relationships between two climate system variables to very complex biogeochemical and coupled climate models that attempt to portray a realistic simulation of how the entire real climate system works in space and time. All are important in advancing the scientific understanding of the climate system. This process of identifying and modeling such processes are described in more detail in the following sections.

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**Biographical Sketch**

**Georgii V. Gruza** was born in 19 August 1931 in Tashkent, USSR (now Uzbekistan). In 1949 he entered and in 1954 he graduated from the Tashkent State University, Physics & Mathematics Faculty. Post graduate studies he passed from 1954 to 1957. Next Education steps: 1961 - PhD, TSU & Uzbek Academy of Science, 1968 - Doctor of Science, Geophysics, 1976 - Full Professor of Meteorology. His working positions were: 1957-1959 - Scientist-member of the Soviet Antarctic Expedition (Mirny), 1959-1970 - Head of Numerical Weather Forecast Dept., Central Asian Research Hydrometeorological Institute (Tashkent) 1970-1975 - Head of Data Processing and Methods Developing Dept., at the Research Institute of Hydrometeorological Information - World Data Center (RIHI-WDC), Obninsk, Kaluga Region), 1975-1982 - Deputy Director (Science Branch) of RIHI-WDC, 1983 up to present - Head of Climate Monitoring and Probabilistic Forecasting Dept. in the Institute of Global Climate and Ecology, Moscow. Areas of his research activities: investigations of the global atmospheric circulation, development of statistical methods for medium and long-range weather forecasting, analysis, detection and forecast of climate change and computer processing of large hydrometeorological data sets. He was the author and co-authors of numerous scientific papers and reports, which he presented at international and national scientific meetings during his scientific career. During several periods he served as an expert, rapporteur or a member of various international boards and meetings, for example, he was a member of WMO Working Group on Climate Change Detection and chair of RA-V1 (Europe) Working Group on Climate-Related Matters, also he was one of lead authors of the Second and the Third IPCC Assessment Reports. Among his awards: - Diploma of senior researcher in geophysics (1966), Multanovskiy Award (highest for forecast investigation in the Hydrometeorological Service of Russia) (1976), title of Honoured Meteorologist of Russian Federation (1999).