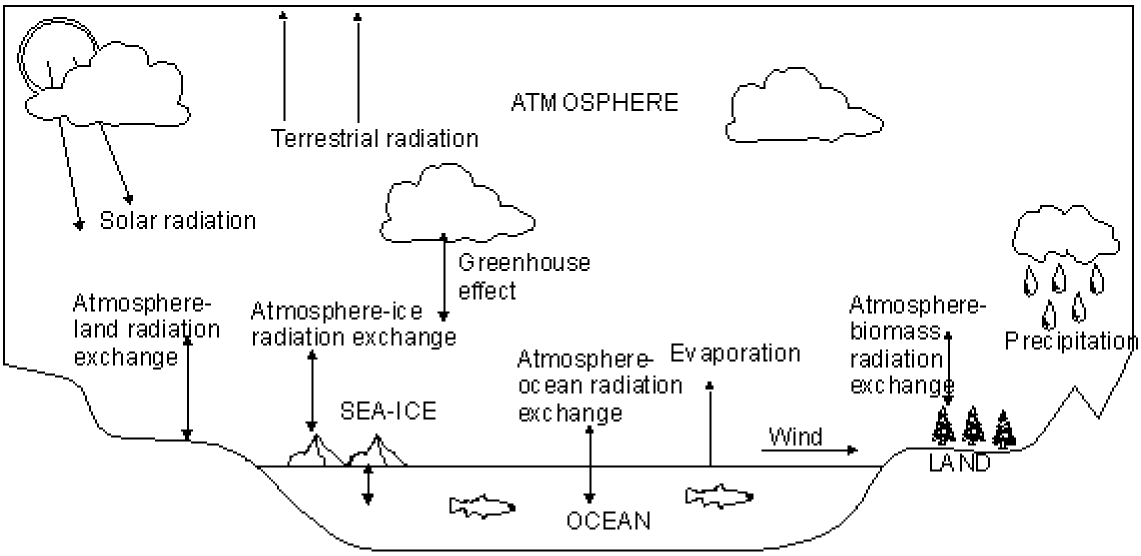
5. The Climate System

Introduction

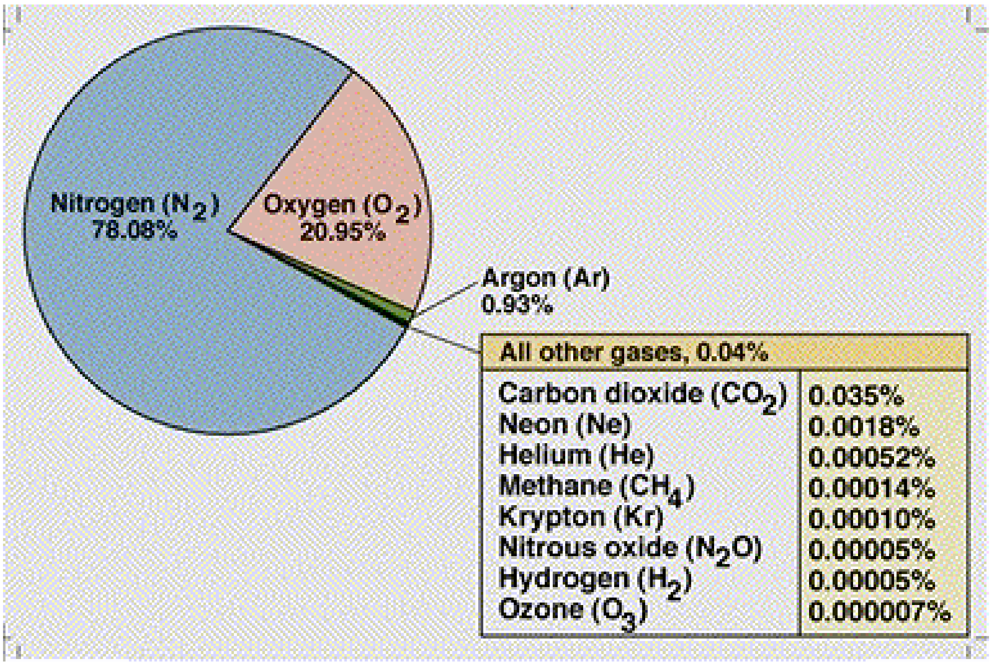
The key to understanding global climate change is to first understand what global climate is, and how it operates. The global climate system is a consequence of, and a link between, the atmosphere, oceans, the ice sheets (cryosphere), living organisms (biosphere) and the soils, sediments and rocks (geosphere).

The Climate System



The Atmosphere

The atmosphere is a mixture of different gases and aerosols (suspended liquid and solid particles) collectively known as air. Although traces of atmospheric gases have been detected well out into space, 99% of the mass of the atmosphere lies below about 25 to 30km altitude, whilst 50% is concentrated in the lowest 5km (less than the height of Mount Everest). This gaseous mixture remains remarkably uniform in composition, and is the result of efficient recycling processes and turbulent mixing in the atmosphere. The two most abundant gases are nitrogen (78% by volume) and oxygen (21% by volume). Despite their relative scarcity, the so-called greenhouse gases play an important role in the regulation of the atmosphere's energy budget. These include carbon dioxide (364ppmv), methane (1720ppbv) and nitrous oxide. In addition, water vapour makes up about 2% of the global atmosphere, and is itself the most important of the natural greenhouse gases.



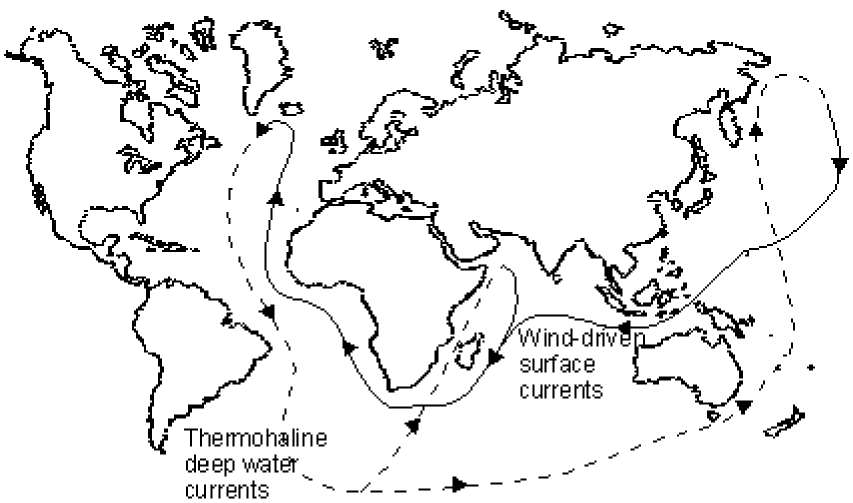
The Energy Budget of the Atmosphere

The Earth receives energy from the Sun in the form of ultra-violet and visible radiation, and emits terrestrial radiation in the form of infra-red energy. These two major energy fluxes must balance, i.e. they must be in equilibrium. The Earth's atmosphere, however, affects the nature of this energy balance. The greenhouse gases allow the short-wave solar radiation to pass through unimpeded, whilst trapping (absorbing) most of the long-wave terrestrial radiation. Consequently, the average global temperature is 15^{o}C, 33^{o}C warmer than the Earth would be without an atmosphere. This process is popularly known as the greenhouse effect. A latitudinal interchange of heat also exists from the tropics to the poles. If this energy transfer did not occur, the equator would be 14°C warmer on average than now, whilst the North Pole would be 25°C colder. Changes to these fluxes of energy determine the state of our climate. Factors which influence these on a global scale may be regarded as causes of global climate change.

The Oceans

The atmosphere does not respond as an isolated system. Transfers of energy take place between the atmosphere and the other parts of the climate system. The most important of these include the world's oceans. Surface ocean currents assist in the latitudinal transfer of heat. Warm water moves poleward whilst cold water returns towards the equator. Energy is also transferred via moisture. Water evaporating from the surface of the oceans stores heat which is subsequently released when the vapour condenses to form clouds and rain. The surface ocean currents form part of a wider global ocean circulation system, with deep water currents also transferring energy across the Earth. This system is called the global thermohaline circulation, so called because it is driven by differences in temperature and salinity (saltiness). [*Greek*: thermo = temperature, haline = salinity.]

Global ocean thermohaline circulation



The significance of the ocean is that it stores a much greater quantity of energy than the atmosphere. The upper ocean in contact with the atmosphere alone stores approximately 30 times as much heat as the atmosphere. Thus for a given change in heat content of the ocean-atmosphere system, the temperature change in the atmosphere will be around 30 times greater than that in the ocean. Small changes to the energy content of the oceans could therefore have considerable effects on global climate. Energy exchanges also occur vertically within the oceans, between the upper layer and deep water. Sea salt remains in the water during the formation of sea ice in the polar regions, with the effect of increased salinity of the ocean. This cold, saline (salty) water is particularly dense and sinks, transporting with it a considerable quantity of energy. A global thermohaline circulation exists, which plays an important role in the regulation of the global climate.

The Cryosphere

The cryosphere consists of those regions of the globe, both land and sea, covered by snow and ice. These include Antarctica, the Arctic Ocean, Greenland, Northern Canada, Northern Siberia and most of the high mountain ranges throughout the world, where sub-zero temperatures persist throughout the year. The cryosphere plays another important role in the regulation of the global climate. Snow and ice, being white, have a high albedo (reflectivity), that is they reflect much of the solar radiation they receive. Without the cryosphere, more energy would be absorbed at the Earth's surface rather than reflected, and consequently the temperature of the atmosphere would be higher.

The Biosphere

The biosphere influences the fluxes of certain greenhouse gases such as carbon dioxide and methane. Plankton in the surface oceans utilise the dissolved carbon dioxide for photosynthesis. This establishes a flux of carbon dioxide, with the oceans effectively "sucking" down the gas from the atmosphere. On death, the plankton sink, transporting the carbon dioxide to the deep ocean. Such primary productivity reduces by at least four-fold the atmospheric concentration of carbon dioxide, significantly weakening the Earth's natural greenhouse effect. The biosphere also influences the amount of aerosols in the atmosphere. Millions of spores, viruses, bacteria, pollen and other minute organic species are transported into the atmosphere by winds, where they scatter incoming solar radiation, and influence the global climate.

The Geosphere

Variations in global climate over hundreds of millions of years are due to changes within the interior of the Earth. Changes in the shape of ocean basins and the size of mountain chains (driven by plate tectonic processes) may influence the energy transfers within and between the other parts of the climate system. On much shorter time scales physical and chemical processes affect certain characteristics of the soil, such as moisture availability and water run-off, and the amounts of greenhouse gases and aerosols in the atmosphere and oceans. Volcanic eruptions replenish the carbon dioxide in the atmosphere, removed by the biosphere, and emit considerable quantities of dust and aerosols.

Conclusion

The overall state of the global climate is determined by the balance of solar (Sun) and terrestrial (Earth) energy flows. How this energy balance is regulated depends upon the flows of energy within the global climate system, made up of its 5 parts: the atmosphere, the oceans, the cryosphere, the biosphere and the geosphere.