ANTHROPOGENIC CLIMATE INFLUENCES

Boroneant C.E.
National Institute of Meteorology and Hydrology, Bucharest, Romania

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Contents

Summary

Humans have always interacted with their environment and exploited its natural resources. Domesticating animals, overgrazing, cutting down forests, constructing huge urban complexes, and developing a large variety of industrial, agricultural, and forestry practices—people have altered the environment.

Since preindustrial times, and mostly during the later half of the twentieth century, the concentrations of several greenhouse gases and atmospheric aerosols have been reported to increase. The observed global warming has been often attributed to these changes. A crucial question in the global-warming debate concerns the extent to which

this recent climate change is caused by anthropogenic forcing and the extent to which it is a manifestation of natural climate variability. Therefore, it is important for us to distinguish between these two aspects of climate variability.

The structure of this paper is as follows. The Introduction (Section 1) presents a summary of the principal human activities that can influence the climate. Section 2 shortly describes the climate and the climate system, the main internal processes and interactions between its components, and the role of human activities in the climate system. First, the driving forces of the climate are discussed and then the greenhouse concept is briefly explained to better understand the difference between the natural and the anthropogenically enhanced greenhouse effect. The greenhouse gases and atmospheric aerosols, their natural and anthropogenic sources and sinks, the time evolution of their concentrations and their individual role and contribution to the enhanced greenhouse effect is discussed in Section 3. Human activities such as deforestation, desertification, and urbanization resulting in landscape changes that influence the climate are discussed in Section 4. Evidences of anthropogenic climate influences are further summarized in Conclusions.

1. Introduction

The scientific community has made considerable progress in attempting to distinguish between natural and anthropogenic influences on climate. Although there are still limitations and uncertainties in the quantification of human-induced climate-change signal, evidence suggests that there is a discernible human influence on global climate.

Activity	**Climatic effect**	**Scale and importance of the effect**
Release of carbon dioxide by burning fossil fuels.	Increases the atmospheric absorption and emission of terrestrial infrared radiation (greenhouse effect), resulting in warming of lower atmosphere and cooling of the stratosphere.	Global: potentially a major influence on climate and biological activity.
Release of methane chlorofluorometha ne, nitrous oxide, carbon tetrachloride, carbon disulphide, etc.	Similar climatic effect as that of carbon dioxide since these too are infrared-absorbing and fairly chemically stable trace gases.	Global: potentially significant influence on climate.
Release of particles (aerosols)	These sunlight scattering and absorbing particles (especially	Largely regional, since aerosols have an average lifetime of

Activity	**Climatic effect**	**Scale and importance of the effect**
from industrial and agricultural practices. Sulphur dioxide is of primary concern since it photochemically converts to sulphuric acid particles.	soot) could decrease albedo over land, causing a warming and could (especially sulphate) increase albedo over water causing a cooling; they also change the stability of lower atmosphere: net climatic effects are still uncertain, although net cooling effect seems more likely.	only a few days, but similar regional effects in different parts of the world could have non-negligible net global effects: stability increase may suppress convective rainfall, but particles could affect cloud properties with more far-reaching effects.
Release of aerosols that act as condensation and freezing nuclei. Again, released soot or sulphur dioxide by industrial activities is of primary concern.	Influences the growth of cloud droplets and ice crystals: may affect the amount of precipitation or albedo of clouds in either direction.	Local (at most) and regional influences on the quantity and quality of precipitation, but unknown and potentially important change of Earth's heat balance if cloud albedo is altered. Some calculations suggest SO_2 released between 1950 and 1980 opposed much of the Northern Hemispheric warming trend that otherwise would have been experienced from rapid building of greenhouse gases during those decades.
Release of heat (thermal pollution).	Warms the surface layers directly.	Locally important now; could become significant regionally; could modify circulation.
Upward transport of chlorofluorometha nes and nitrous oxide into the stratosphere.	The photochemical reaction of their dissociation products probably reduces stratospheric ozone.	Global but uncertain influence of ozone depletion on climate: less total stratospheric ozone allows more solar radiation to reach the surface but this influence is compensated by reducing the greenhouse effect as well. However, if ozone concentration decreases at high altitudes, but increases comparably at lower altitudes, this would lead to potentially large surface warming which

Activity	**Climatic effect**	**Scale and importance of the effect**
		could cause significant biological effects due to the increased exposure to ultraviolet radiation if the total column amount of ozone decreases.
Release of trace gases (e.g. nitrogen oxides, carbon monoxide, or methane) that increase tropospheric ozone by photochemical reactions.	Large atmospheric heating occurs from tropospheric ozone, which enhances both solar and greenhouse heating of lower atmosphere.	Local to regional at present, but could become a significant global climatic warming if large-scale fossil fuel use leads to combustion products that significantly increase tropospheric ozone. Contact with ozone also harms some plants and people.
Patterns of land use, e.g., urbanization, agriculture, overgrazing, deforestation, etc.	Changes surface albedo, evapotranspiration, and runoff and produces aerosols.	Largely regional: net global climatic importance is still uncertain.
Release of radioactive Krypton-85 from nuclear reactors and fuel reprocessing plants.	Increases the conductivity of lower atmosphere with possible implications for Earth's electric field and precipitation from convective clouds.	Global: importance of influence is highly uncertain.
Large-scale nuclear war.	Could lead to very large injections of soot and dust causing transient surface cooling lasting from weeks to months, depending on the nature of the exchange and on how many fires were started.	Could be global, but initially in midlatitudes of the northern hemisphere. Darkness from dust and smoke could disrupt photosynthesis for weeks with severe effects on both natural and agricultural ecosystems of both combatant and non-combatant nations. Transient freezing outbreaks could eliminate some warm season crops in midlatitudes or weakening of monsoon rainfall

Activity	**Climatic effect**	**Scale and importance of the effect**
		could be devastating to any vegetation in tropics or subtropics. Details are still uncertain.

Table 1. Summary of principal human activities that can influence climate (Modified after Schneider S.S. and R. Londer (1984). *The Coevolution of Climate and Life*, 563 pp. San Francisco: Sierra Club Books.)

Human population increases on Earth and, consequently, the potential for human impact on weather and climate becomes increasingly likely. People began altering the environment by domesticating animals, cutting down forests, planting crops, and constructing huge urban complexes. Human activities have resulted in the release of substantial quantities of gases and aerosol particles that have changed the composition and structure of the atmosphere. Emission of gases, smoke, and residuals from the industrial complexes, from urban centers, and from agricultural practices such as burning of trees, deforestation, and intense use of fertilizers have lead to pollution of the atmosphere and waters. Deforestation and overgrazing have caused soil erosion and have produced substantial changes in the surface albedo altering the radiation and moisture balances near the surface and finally leading to desertification. When the physical and chemical modifications of the environment due to human activities become large enough, significant global changes are expected to appear. A comprehensive but not exhaustive list of human activities that may cause climatic effects at various spatial scales is presented in Table 1.

2. The Climate and Climate System

The components of the climate system are the atmosphere, the oceans and hydrology (including rivers, lakes, and surface and subsurface water), the sea ice, snow cover, land ice (including the semipermanent ice sheets and glaciers), and the land and its features (including the vegetation, albedo, biomass, and ecosystems). A schematic description of the components of Earth's climate system, together with the main processes and interactions, is presented in Figure 1. Changes in any of the components of the climate system cause the climate to vary or to change.

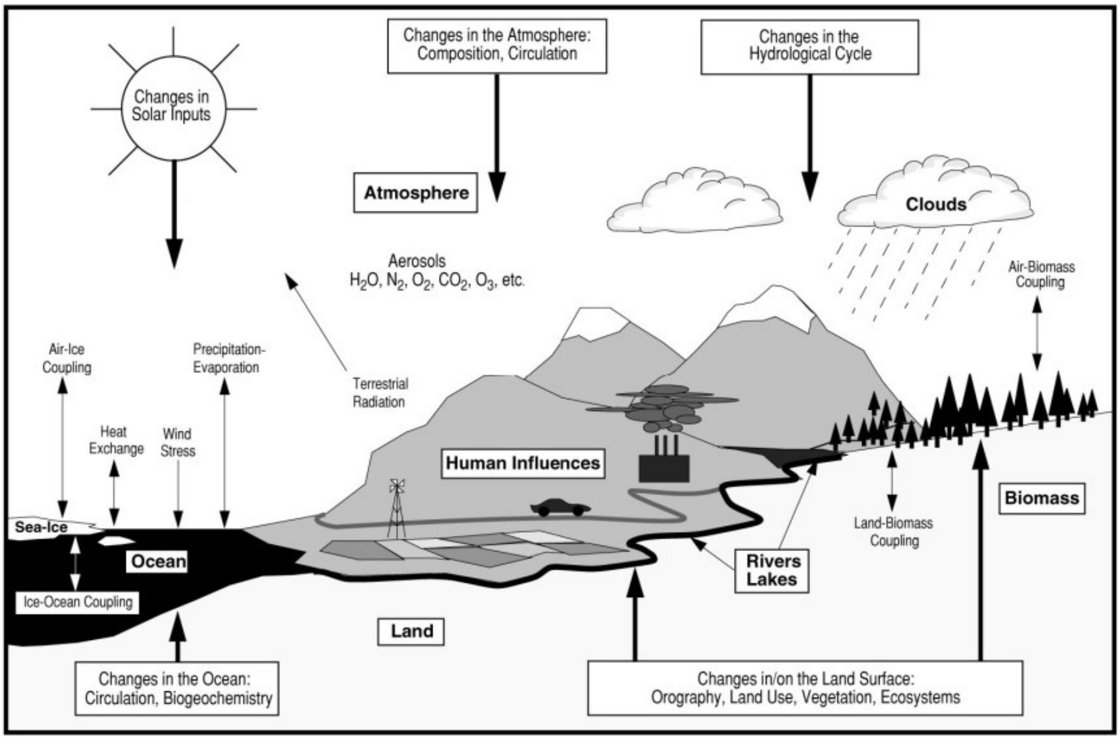

Figure 1. Schematic illustration of the climate system, its processes and interactions (thin arrows) and some characteristics that may change (bold arrows)

Climate is usually defined as a synthesis of weather at a particular region or, more rigorously, climate represents the mean and other statistical quantities that measure the variability of weather conditions in a region over a specified interval of time (usually several decades). The climatic elements include temperature, precipitation, humidity, sunshine, wind velocity, atmospheric phenomena such as storms, frost, and fog, and other properties of weather.

The driving energy for the climate system comes from the Sun. Earth intercepts short-wave solar radiation, about one third of it being reflected and the rest being absorbed by the different components of the climate system such as atmosphere, ocean, ice, land, and biota. The energy absorbed from solar radiation is balanced by the outgoing long-wave radiation from Earth and the atmosphere. Changes in the balance between incoming solar radiation and outgoing infrared radiation cause the radiative forcing on climate. The most obvious of these are the changes in the incident radiation energy from the Sun or the changes in atmospheric composition due to natural events such as volcanic eruptions. Other external forcing may occur as a result of human activities.

2.1. The Driving Forces of Climate

The Sun radiates energy corresponding roughly to a black body radiator with a temperature of about 6000 K. Much of this energy is in the visible part of the spectrum, although some extends into the infrared and some extends into the ultraviolet.

The globally averaged solar radiation incident at the top of the atmosphere is 342 W m^{-}

[2]. About 30% of this energy is reflected back to space, being unavailable to participate in the physical and chemical processes that occur in the climate system. This reflected fraction is called planetary albedo.

As Figure 2 shows, of the 100% of incoming solar radiation, 3% is absorbed by the ozone and molecular oxygen in the stratosphere. The 17% solar absorption in the troposphere is due primarily to water vapor (13%) and clouds (3%), while carbon dioxide, ozone, and oxygen together contribute to the remaining 1%.

Of the 50% of solar radiation absorbed at Earth's surface, 21% is emitted as long-wave radiation into the atmosphere, and 29% is transferred upward into the atmosphere by turbulent and convective processes in the form of sensible heat (5%) and latent heat (24%).

In the long-wave spectrum, only 10% of the 110% energy emitted by the ground passes directly into space without absorption or reemission by the atmosphere. The troposphere receives 149% from radiative and nonradiative sources: 103% from long-wave energy absorption, 17% from short-wave solar absorption, 5% from sensible heat transfer from the ground, and 24% from latent heat release. The troposphere re-emits 89% back to the ground and 60% upward to the stratosphere and space (Figure 2), producing the greenhouse effect.

The energy balance of Earth can be altered if some radiative properties of the atmospheric gas components are changed.

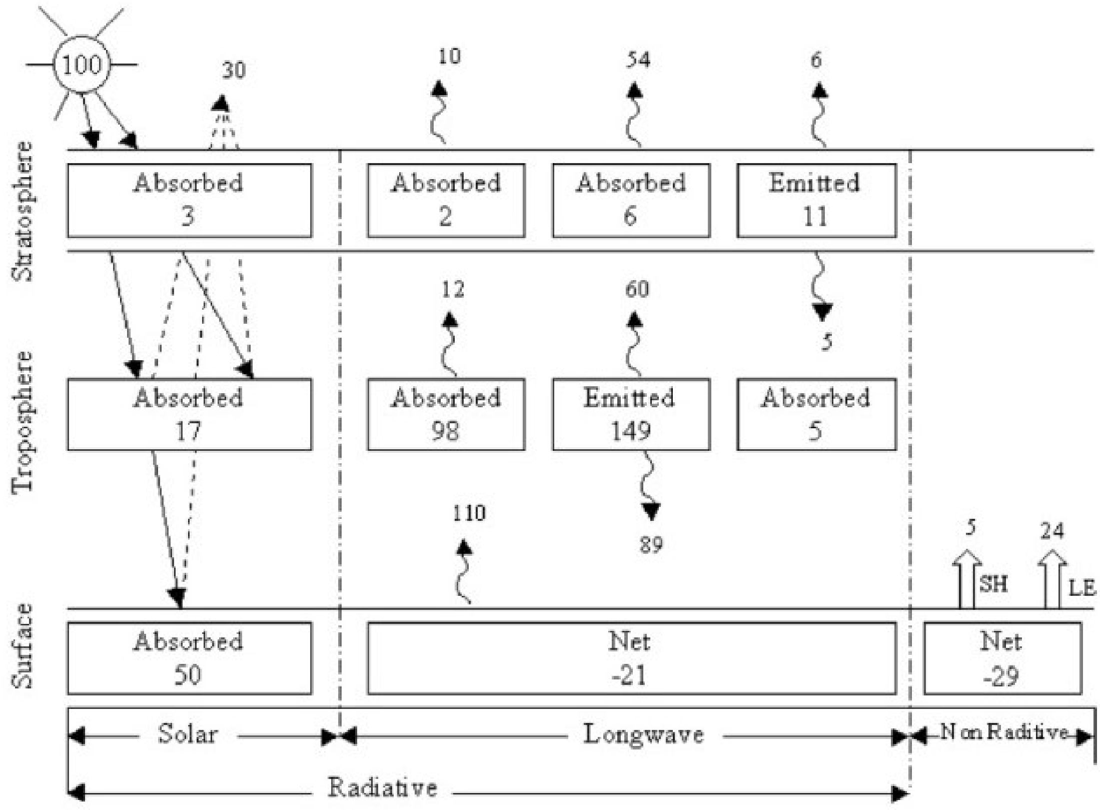

Figure 2. Radiative and nonradiative energy flow diagram for Earth and its atmosphere Units are percentages of the global-mean insolation (100 units = 342 W m^{-2}).

2.2. The Greenhouse Effect

The greenhouse effect is a natural property of Earth's atmosphere that keeps Earth warmer than it would be without an atmosphere. What is referred today as the "greenhouse effect" is actually the anthropogenically enhanced greenhouse effect, which produces an extra warming of the surface and the lower troposphere, leading to other disturbances in the climate system.

The greenhouse concept is not new. It was first introduced in a scientific publication by Fourier in 1827. A simplified explanation of the greenhouse effect consists of the following: the short-wave solar radiation can pass through the clear atmosphere relatively unimpeded while the long-wave terrestrial radiation emitted by Earth's surface is partially absorbed and re-emitted out to space by a number of trace gases in the cooler atmosphere above (Figure 3). This process adds to the net energy input to the lower atmosphere and the underlying surface increasing in such a way their temperature. Because there is an analogy between the effect of a glass acting in a greenhouse and the effect of these trace gases acting in the atmosphere, their effect was called greenhouse effect.

In mathematical terms, the greenhouse effect may be defined by the difference between the surface temperature, T_s, and the effective radiative temperature, T_r:

$$\Delta T = T_s - T_r \qquad (1)$$

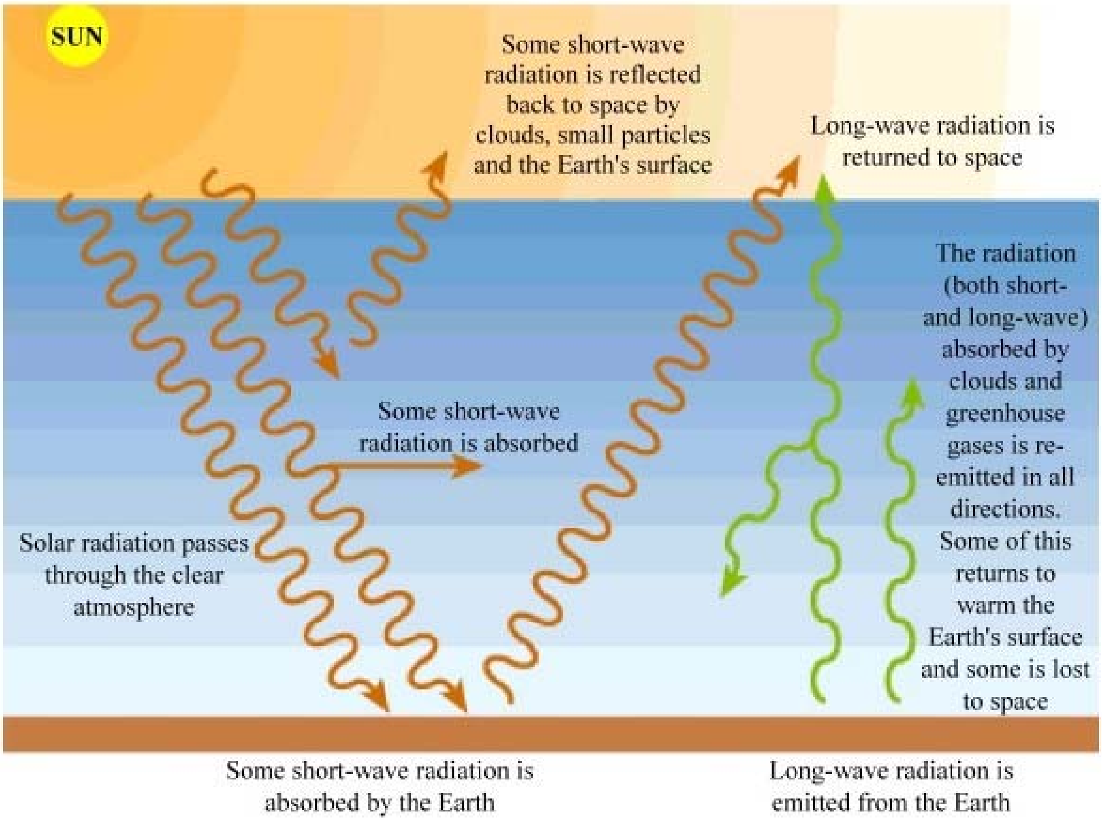

Figure 3. A simplified diagram illustrating the greenhouse effect

The effective radiative temperature, T_r, can be calculated from the Stefan-Boltzmann law relating the flux of radiant energy to temperature:

$$T_r = \left[\frac{F^{\uparrow}}{\sigma}\right]^{\frac{1}{4}} \qquad (2)$$

where $F^{\uparrow}$ is the outgoing thermal emission flux at the top of the atmosphere which is equal to the total solar energy absorbed in the Earth–atmosphere system, and σ is the Stefan-Boltzmann constant.

In the absence of the atmosphere, $T_r = T_s$ and $\Delta T = 0$. If the atmosphere of the planet contains gases that absorb thermal radiation, then the surface temperature will be greater than the effective temperature. The globally averaged thermal emission of the planet is characterized by the equilibrium temperature, T_e, which is determined from the balance averaged over the planet between the absorbed solar energy and the outgoing thermal emission:

$$T_e = [S(1 - \alpha)/4\sigma]^{1/4} \qquad (3)$$

where S is the solar constant for the planet, α is its total albedo, and $\Delta T = T_s - T_e$ is the greenhouse increment. If the following values are introduced in Eq. 3, $S = 1370$ W m^{-2},

$\alpha = 0.3$, and $\sigma = 5.670 \times 10^{-8}$ W m^{-2} K^{-4}, then the average surface temperature of the Earth would be 283 K (i.e., 15 °C) while in the absence of the atmosphere it would have been 255 K (i.e., –18 °C). Therefore, for Earth, the greenhouse increment due to the present atmosphere and its natural greenhouse effect is about $\Delta T = 33$ K.

The main contributors to the greenhouse effect in the atmosphere are water vapors (the main contributor gas which varies naturally in space and time due Earth's hydrological cycle), carbon dioxide, methane, nitrous oxide, ozone, and other minor constituents such as chlorofluorcarbons which are exclusively of anthropogenic origin. It was estimated that water vapors and clouds provide about 80% of the current greenhouse effect.

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Biographical Sketch

Dr. Constanta Emilia Boroneant is Senior Research Scientist in the Dynamic Climatology Group at the National Institute of Meteorology and Hydrology, Bucharest, Romania. She received her bachelor's degree in physics with high honors, MS in meteorology and atmospheric physics, and PhD, magna cum laude, in geoscience with the thesis, "Natural climate variability and anthropogenic climate influences in the Atlantic–European region," all from the University of Bucharest, Romania.

She has taken part as head or member of a team in several projects and themes included in the National Climate Research Plan or in international projects carried out at the National Institute of Meteorology and Hydrology, Bucharest. Her areas of interest and expertise include climate changes in Romania, actual dimensions of global change, natural and anthropogenic impact issues, effects of greenhouse gases and aerosols on climate, impact and vulnerability assessment, strategies for adaptation and prevention, climate monitoring–homogenization, and quality control of climatological data from the national meteorological network.